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Posterior pericardiotomy for the prevention of atrial fibrillation after cardiac surgery: a systematic review and meta-analysis of 25 randomised controlled trials

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KEYWORDS

- atrial fibrillation
- CABG
- cardiac surgery
- posterior pericardiotomy

Abstract

Background: Atrial fibrillation (AF) associated with postoperative pericardial effusion is the most commonly reported adverse event after cardiac surgery.

Aims: We aimed to determine the role of posterior pericardiotomy in preventing postoperative AF (POAF).

Methods: We searched PubMed, Scopus, Web of Science, Ovid, and EBSCO from inception until 30 June 2022. We included randomised clinical trials (RCTs) that compared posterior pericardiotomy (PP) versus control (no PP) in patients undergoing cardiac surgery. The primary endpoint was the incidence of POAF after cardiac surgery. The secondary endpoints were supraventricular arrhythmias, early/late pericardial effusion, pericardial tamponade, pleural effusion, length of hospital/intensive care unit stay, intra-aortic balloon pump use, revision surgery for bleeding, and mortality.

Results: Twenty-five RCTs comprising 4,467 patients were included in this systematic review and meta-analysis. The overall incidence rate of POAF was 11.7% in the PP group compared with 23.67% in the no PP or control group, with a significant decrease in the risk of POAF following PP (odds ratio [OR] 0.49, 95% confidence interval [CI]: 0.38-0.61). Compared with the control group, the risk of supraventricular tachycardia (OR 0.66, 95% CI: 0.43-0.89), early pericardial effusion (OR 0.32, 95% CI: 0.22-0.46), late pericardial effusion (OR 0.15, 95% CI: 0.09-0.25), and pericardiac tamponade (OR 0.18, 95% CI: 0.10-0.33) were lower in the PP group.

Conclusions: PP is an effective intervention for reducing the risk of POAF after cardiac surgery. Also, PP is economically efficient in terms of decreasing the length of hospital stay.

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Abbreviations

AF	atrial fibrillation
CABG	coronary artery bypass grafting
CPB	cardiopulmonary bypass
GRADE	Grading of Recommendations Assessment, Development and Evaluation
IABP	intra-aortic balloon pump
ICU	intensive care unit
NA	not assigned
OR	odds ratio
PPE	postoperative pericardial effusion
POAF	postoperative atrial fibrillation
PP	posterior pericardiotomy
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	randomised controlled trial
SVT	supraventricular tachycardia
TSA	trial sequential analysis

Introduction

Following cardiac surgery, atrial fibrillation (AF) is the most commonly reported arrhythmia. The incidence of AF after cardiac surgery affects between 10% and 65% of patients and is more prominent on the second or third postoperative day[1]. Postoperative AF (POAF) has increased morbidity rates, haemodynamic instability, prolonged hospital stays, and healthcare costs[1,2].

The pathophysiology behind AF post-cardiac surgery is multifaceted, and multiple aetiologies have been identified. These include catecholamine surge, atrial stretch, metabolic abnormalities, electrolyte imbalance, inflammatory response, and postoperative pericardial effusion (PPE)[2,3].

Prophylactic beta blockers have been shown to control the catecholamine surge in the perioperative period, demonstrating a significant decrease in the rate of postoperative AF[1,4]. Another proposed aetiology is the presence of PPE. Earlier reports have shown a high incidence of PPE following cardiac surgery in up to 64% of patients[5], with a decreasing rate over time that went as low as 1.5%[6].

As PPE has been shown to be associated with an increased incidence of postoperative AF, the drainage of pericardial blood or effusion will consequently decrease the incidence of the associated AF. In a retrospective study by Kuvin et al[7], 49% of pericardial effusions were posterior and 46% were diffuse. Thus, multiple studies have proposed a method for decreasing the incidence of PPE by making an incision in the posterior pericardium and opening it to the left pleura. This eases the drainage of pericardial fluid and prevents the occurrence of PPE, thus lowering the incidence of AF[2,8,9].

Multiple randomised controlled trials have tested the efficacy of performing a posterior pericardiotomy (PP) after cardiac surgery as a prophylactic measure to prevent postoperative AF (POAF). There are conflicting results on the ability of PP to reduce the incidence of AF after coronary artery bypass graft (CABG): several studies have found that PP did not reduce the incidence of AF after CABG[2,10,11], whereas other studies and three meta-analyses have shown that PP significantly reduced the incidence of AF after CABG[8,12,13]. However, the most recent meta-analysis had only three high-quality trials and many uncontrolled confounders that may have affected their results[13].

So, in our study, we are trying to resolve this controversy by including more high-quality trials and stratifications of as many confounding variables as possible in order to evaluate the role of posterior pericardiotomy in preventing postoperative AF.

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Methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guidelines when performing this systematic review and meta-analysis[14]. The methods were carried out in accordance with the Cochrane Handbook of Systematic Reviews and Meta-analysis of Interventions (version 5.1.0).

ELIGIBILITY CRITERIA

Randomised controlled trials (RCTs) of patients undergoing cardiac surgery who were randomly assigned to PP (intervention group) compared to conventional procedures (no PP: control group) were selected for this systematic review and meta-analysis. Definitions of PP and non-PP procedures are illustrated in **Supplementary Table 1** and **Supplementary Table 2**. We excluded non-English, observational and animal studies, as well as conference abstracts.

PRIMARY AND SECONDARY OUTCOMES

The primary outcome of interest was the incidence of atrial fibrillation, while the secondary outcomes of interest were pleural effusion, length of hospital stay, early pericardial effusion, late pericardial effusion, pericardial tamponade, length of intensive care unit (ICU) stay, pulmonary complications, revision surgery for bleeding, intra-aortic balloon pump (IABP) use, and postoperative mortality. These outcomes were defined according to the study authors' definitions.

LITERATURE SEARCH

We performed a comprehensive literature search on PubMed, Scopus, Web of Science, Ovid, and EBSCO from inception until 30 June 2022, using the following search terms: ["pericardiotomy" OR "posterior left pericardiotomy" OR "post pericardiotomy" OR "pericardial fenestration"] AND ["CABG" OR "coronary artery bypass grafting" OR "heart surgery" OR "cardiothoracic surgery" OR "cardiac surgery" OR "extracorporeal circulation" OR "CAB"] AND ["atrial fibrillation"]. The detailed search terms used for each database are illustrated in **Supplementary Appendix 1**. All duplicates were removed with EndNote (Clarivate). Manual backward and forward citation analyses were done for all the references of the included studies.

The literature search results were screened in two steps: the titles and abstracts of all articles were screened for eligibility and a subsequent full-text screening was performed for the eligible studies.

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DATA EXTRACTION

Data were extracted to a specified data extraction sheet. The extracted data included (1) the characteristics of the included studies, (2) characteristics of the included studies' population, (3) risk of bias domains, and (4) outcome measures: incidence of atrial fibrillation, supraventricular tachycardia (SVT), pleural effusion, length of hospital stay, early pericardial effusion, late pericardial effusion, pericardial tamponade, length of intensive care unit (ICU) stay, pulmonary complications, revision surgery for bleeding, IABP use and postoperative mortality in patients who had undergone PP versus no PP.

SYNTHESIS OF RESULTS

In the case of studies reporting data with multiple timepoints, we considered the most consistent follow-up time for our analysis. For outcomes with dichotomous data, the frequency of events and the total number of patients in each group were pooled as odds ratios (OR) between the two groups (PP vs no PP) in the DerSimonian-Laird random-effects model. For outcomes with continuous data, mean differences (MD) and 95% confidence intervals (CI) were pooled in the DerSimonian-Laird random-effects model. All statistical analyses were done by Stata MP Version 17 for Windows (StataCorp).

ASSESSMENT OF HETEROGENEITY

The chi-square test (Cochran's Q test) was used to assess statistical heterogeneity among studies. Then, the I^2 value was calculated using the chi-square statistic, Cochran Q, according to the equation:

$$I^2 = \frac{Q - df}{Q} \times 100\%$$

A p-value of chi-square of less than 0.1 was considered a significant heterogeneity. High heterogeneity was defined as an I^2 value ≥50%. When there was significant heterogeneity, a sensitivity analysis using the leave-one-out model was performed to resolve this; moreover, for every outcome in the meta-analysis, we ran sensitivity analyses in multiple scenarios, excluding one study in each scenario to ensure the overall effect size was not dependent on any single study. We also used the Galbraith plot to detect for any heterogeneity across studies.

QUALITY ASSESSMENT

Two authors independently assessed the quality of included clinical trials according to the Cochrane risk of bias 2 (ROB-2) tool for RCTs that involves the following five domains: randomisation process (selection bias), deviation from intended interventions (performance bias), outcome measurement (detection bias), missing outcome data (attrition bias), selection of reported results (reporting bias) and other potential sources of bias[15,16]. The authors' decisions were classified as "low risk of bias", "high risk of bias" or "some concerns". Any conflicts between the two authors were resolved through discussion with a third author. To explore the publication bias across studies, funnel plots were considered to present the relationship between effect size and standard error. Egger's regression test was used to assess evidence of publication bias.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) scale was used to evaluate the strength and level of evidence for recommendations and was stratified as follows: high quality, which indicates no further research is needed and unlikely to change the confidence of the effects estimations; moderate quality, which indicates that further studies may affect the confidence of the effects estimation; low quality, which indicates further research is likely to have an crucial impact on the confidence of the effects estimation and may change the estimation; and very low quality, which indicates that we cannot be certain about this estimation.

Due to the cumulative pooling of trials in a chronological order, there is an increased risk of a type 1 error. Given the limited amount of data, we used trial sequential analysis (TSA) to determine whether the pooled evidence was conclusive and reliable. When the cumulative z-line on the curve crosses the boundary of sequence monitoring, the level of confidence for the intervention is conclusive and sufficient, indicating that no further studies are required. On the other hand, if the z-line on the curve does not cross any boundaries, the level of confidence is insufficient to draw a conclusion, and further studies are still needed. In this meta-analysis, we used an alpha error of 0.05, a beta error of 80% power, and a reduction in the risk ratio (RR) of POAF of 20%. We calculated the proportion of events from the control group in the current meta-analysis to obtain the sample size required for TSA.

Results

A total of 540 unique citations were revealed through the literature search. After title and abstract screening, only 50 studies were deemed eligible, and following further assessment, 25 studies were included in this systematic review and meta-analysis. The PRISMA flowchart for study selection is shown in **Figure 1**.

CHARACTERISTICS OF INCLUDED STUDIES

Our study included 25 trials of 4,467 patients comparing PP with the control group (no PP)[2,10,11,17-38]. Twenty-two studies of 4,300 patients assessed our primary outcome, POAF. Twenty studies assessed early pericardial effusion, 20 assessed pericardial tamponade, 16 assessed pleural effusion, and 11 assessed pulmonary complications. These studies were conducted in nine countries, mostly in Turkey (11 studies) and Egypt (5 studies). Baseline characteristics and a summary of the included studies are shown in **Table 1** and **Table 2**.

RISK OF BIAS ASSESSMENTS

A summary and graph of the risk of bias in our included studies are shown in **Figure 2**. Most studies showed an overall unclear risk of bias; however, eight studies showed a low risk. The authors' judgments were made according to the Cochrane risk of bias assessment tool[39].

POSTOPERATIVE ATRIAL FIBRILLATION (POAF)

POAF was reported in 22 studies included in our analysis. Our study's cumulative incidence of POAF was 11.7% in the PP

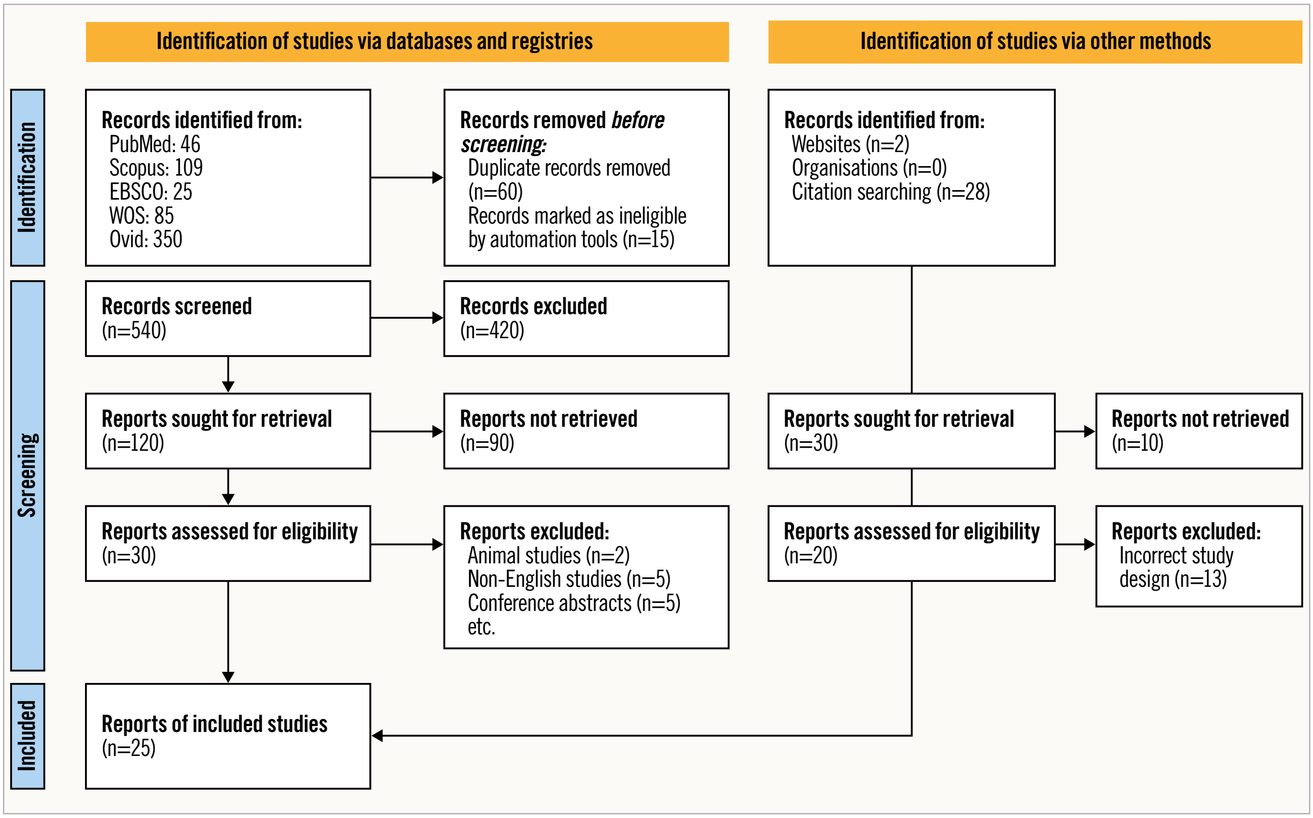

Figure 1. *PRISMA flowchart for studies included in the systematic review and meta-analysis.*

group and 23.67% in the control group. The pooled OR and 95% CI for POAF were 0.49, 95% CI: 0.38-0.61 (p<0.001) favouring PP for the decrease in POAF as shown in **Figure 3**. Pooled studies were heterogeneous (I^2=38.74%; p=0.04). Leave-one-out sensitivity analysis showed that no single study had a disproportional effect on the pooled OR, which varied between 0.46 (95% CI: 0.37-057), after excluding Bakhshandeh et al, and 0.52 (95% CI: 0.42-0.65), after excluding Kaygin et al, as shown in **Figure 4**.

We tested the source of heterogeneity via a sensitivity analysis. First, we excluded studies with the smallest sample sizes[10,31]. Then we used the random-effects model, which provided similar results to the overall results (OR 0.47, 95% CI: 0.37-0.60; p<0.001) with significant heterogeneity (I^2=42.46%; p=0.02), as shown in **Supplementary Figure 1**.

We further analysed 16 studies in which the included patients did not take preoperative oral beta blockers. Still, significant heterogeneity was observed (I^2=34.70%; p=0.14). The pooled analysis of these 16 studies using the random-effects model showed that the PP group had a lower incidence of POAF compared to the control group (OR 0.47, 95% CI: 0.35-0.62; p<0.001), as shown in **Supplementary Figure 2**.

We also examined the clinical heterogeneity according to geographical area, as about 41% of the included studies that mentioned POAF were conducted in Turkey. When we pooled and analysed studies based on geography, studies in Egypt and Turkey showed clinical significance (OR 0.45, 95% CI: 0.30-0.67; and OR 0.33, 95% CI: 0.24-0.46), respectively. The pooled studies were homogenous for Egypt and Turkey (I^2=0.00%; p<0.001 and I^2=12.03%; p<0.001), respectively, as shown in **Supplementary Figure 3**.

We performed a subgroup analysis based on the type of surgery, as about 72.7% of the included studies assessing POAF had patients who had undergone CABG. Seventeen studies were pooled in the CABG group and only 7 studies included mixed surgeries, of which the pooled analysis showed that in both subgroups, CABG only or mixed surgeries, the PP group had a lower incidence of POAF compared to the control group (OR 0.41, 95% CI: 0.31-0.54; p<0.001; and OR 0.66, 95% CI: 0.50-0.87; p<0.001), respectively, as shown in **Supplementary Figure 4**.

We also tested heterogeneity using the Galbraith plot, and four studies appeared outside the 95% CI of the regression, indicating their heterogeneity from other trials **(Figure 5)**. Moreover, the use of a trial sequential analysis (TSA) for 22 RCTs revealed that the evidence for using PP to decrease the postoperative AF was sufficient and conclusive, and no other trials are needed **(Figure 6)**.

We conducted a trial sequential analysis (TSA) for 22 RCTs, as shown in **Figure 6**; the cumulative Z-curve crossed both the conventional boundary for the benefit and the trial sequential monitoring boundary for the benefit and entered the area of benefit

Table 1. Main characteristics of randomised controlled trials included in the review.

Author, year	Region	Study design	Surgery type	Sample size (PP/control)	Age		Male		Cross-clamp time (min)		CPB time (min)	
					PP	control	PP	control	PP	control	PP	control
Abd El-Wahab et al, 2022	Egypt	RCT	CABG	100 (50/50)	58.34±8.73	53.80±8.56	66.0%	80.0%	20.5±54.5	16.5±59.2	28.6±88.6	22.9±86.9
Ahmad et al, 2011	Pakistan	RCT	CABG	100 (50/50)	54.3±8.4	54.3 ±8.8	72.0%	68.0%	37.08±5.8	37.76±6.3	56.50±5.08	54.97±4.13
Amr et al, 2012	Egypt	RCT	CABG	64 (32/32)	62.3±4.5	63.2±3.5	63.0%	59.4%	54.2	53.4	62.5	64.1
Arbatli, 2003	Turkey	RCT	CABG	113 (54/59)	62 ± 8	60 ± 9	83.0%	74.6%	58±17	60±19	117±32	112 ± 35
Asimakopoulos et al, 1997	UK	RCT	CABG	100 (50/50)	61±9	61±2			35±2	33±8	66±17	112±35
Bakhshandeh et al, 2009	Iran	RCT	CABG alone or combined with valve repair or replacement	410 (205/205)	67.3±8.2	68.2±9	38.0%	42.0%	NA	NA	NA	NA
Benyameen et al, 2021	Egypt	RCT	Valve replacement, CABG. Both	98 (48/50)	48.10±14.34	53.10±14.82	54.2%	56.0%	85.59±29.76	84.06±24.20	115.35±25.52	113.70±16.90
Cakalagaoglu et al, 2012	Turkey	RCT	Valve replacement, CABG. Both	100 (50/50)	63.20±7.67	58.82±12.69	80.0%	86.0%	55.08±18.88	53.22±30.09	91.68±21.69	88.04±37.54
Ebaid et al, 2021	Egypt	RCT	Valvular or CABG	400 (200/200)	43.4±6.5	44.5±9.6	66.0%	60.0%	50±19.4	51.4±20.6	72.4±20.9	73.5±22.7
Ekim et al, 2006	Turkey	RCT	CABG	100 (50/50)	59.1±8.9	60.1±3.2	66.0%	64.0%	63±19	62±12	89±21	87±26
Erdil et al, 2005	Turkey	RCT	Heart valve operation with mechanical prosthesis	100 (50/50)	40.9±13.9	43.2±15.4	46.0%	32.0%	86.3±39.8	85.8±36.6	113.9±51.4	115.3±44.4
Ezelsoy et al, 2019	Turkey	RCT	CABG	220 (110/110)	67.51±7.35	66.84±6.92	64.5%	61.8%	53.15±17.23	55.31±09.11	86.48±21.89	89.32±19.15
Farsak et al, 2002	Turkey	RCT	CABG	150 (75/75)	64.2±8.9	62.8±5.4	36.0%	32.0%	35±11	40±9.3	57.5±6.1	61.4±8.7
Fawzy et al, 2015	Egypt	RCT	CABG	200 (100/100)	54.3±8.6	56±9.7	64.0%	68.0%	54.5±20.5	59.2±16.5	88.6±28.6	86.9±22.9
Gaudino et al, 2021	USA	RCT	Primary, elective interventions on the coronary arteries, the aortic valve, or the ascending aorta, or a combination of these	212/208	61.0 (52.0-69.0)	62.0 (55.0-70.0)	162 (76%)	156 (75%)	81·0 (64·0-101·0)	78·5 (61·0-100·0)	104·0 (84·5-126·5)	100·0 (82·0-121·0)
Haddadzadeh et al, 2015	Iran	RCT	CABG	105/102	61/07±10/4	61/4±11/6	72 (68.6%)	70 (68.6%)	NA	NA	NA	NA
Kaleda et al, 2017	Russian Federation	RCT	Primary isolated aortic valve replacement	49/51	56.6±9.9	55.4±10.5	28 (57.0%)	33 (65.0%)	45±13	46±12	64±16	64±20
Kaya et al, 2014	Turkey	RCT	CABG	30/33	56.9±10.13	58.91±10.90	23 (76.7%)	29 (87.9%)	43.47±15.67	45.79±21.19	79.6±26.08	86.24±27.33
Kaya et al, 2015	Turkey	RCT	CABG	72/70	55.86±9.32	57.85±9.35	58 (80.6)	60 (85.7)	44.81±13.09	43.83±13.34	80.31±22.72	78.17±20.32
Kaya et al, 2016	Turkey	RCT	CABG	103/107	58.39±9.24	57.46±9.13	80 (77.7%)	84 (78.5%)	45.47±19.05	42.89±14.91	81.6±26.53	77.02±22.83
Kaygin et al, 2011	Turkey	RCT	CABG	213/212	58.8±11.3	59.0 ±11.3	107 (50.2%)	105 (49.5%)	>50 min =115 (27%)	>50 min =110 (25.9%)	>80 min=101 (23.8%)	>80 min=99 (23.2%)
Kongmalai et al, 2014	Thailand	RCT	CABG	10//10	64.9±13.11	59.2±4.69	5 (50.0%)	5 (50.0%)	84.4±37.7	106.8±39.4	127.5±48.9	152.3±45.1
Kuralay et al, 1999	Turkey	RCT	CABG	100/100	57±12	61±8	77 (77.0%)	73 (77.0%)	36±12	43±9	48±5 (perfusion time)	51±4 (perfusion time)
Sadeghpour et al, 2011	Iran	RCT	CABG	40/40	60.68±8.49	60.3±12.6	31(77.5%)	32 (80.0%)	48.6±24.9	NA	NA	NA
Zhao et al, 2014	People's Republic of China	RCT	Cardiac surgeries (CABG, valve replacement or ventricular aneurysm)	228/230	54±16	56±18	138 (60.5%)	125 (54.3%)	67±29	62±23	110±46	103±51

CABG: coronary artery bypass graft; CPB: cardiopulmonary bypass; NA: not applicable; RCT: randomised controlled trial

Table 2. Summary of randomised controlled trials included in the review.

Study ID	Follow-up	POAF		Early pericardial effusion		Late pericardial effusion		Pulmonary complications		Pericardiac tamponade		ICU stay (days)		Hospitalisation time (days)		IABP usage		Mortality		Revision of bleeding		Pleural effusion	
		PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP	PP	non-PP
Abd El-Wahab et al, 2022	One week	6	12	6	18	NA	NA	NA	NA	0	2	NA	NA	6.1 ±1.25	6.3±1.83	1	0	0	0	1	2	15	10
Ahmad et al, 2011	Up to 2 weeks	2	12	3	18	NA	NA	2	1	NA	NA	NA	NA	5.32±0.95	5.38±0.9	NA	NA	0	0	2	2	11	9
Amr et al, 2012	Up to 30 days	6	13	7	17	10	30	2	2	0	1	1.3 ±0.7	1.2 ±0.5	7.9±4.7	8.5 ±5.1	NA	NA	NA	NA	1	2	NA	NA
Arbatli 2003	Up to 30 days	7	12	14	28	NA	NA	NA	NA	NA	NA	3 ±2	3 ±3	14±8	13 ±5	1	0	NA	NA	NA	NA	7	3
Asimakopoulos et al, 1997	One week	12	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	NA	NA
Bakhshandeh et al, 2009	Up to 30 days	53	59	18	194	26	194	4	3	0	2	1.3±0.7	1.2 ±0.5	5.9±4.7	5.5±5.1	NA	NA	7	11	11	8	NA	NA
Benyameen et al, 2020	Up to 30 days	8	22	12	32	10	28	NA	NA	0	6	NA	NA	10.5±2.27	12.4±3.08	NA	NA	NA	NA	NA	NA	4	0
Cakalagaoglu et al, 2012	Up to 30 days	NA	NA	50	50	NA	NA	14	13	0	6	2.88 ±1.38	2.76 ±1.90	9.58 ±2.60	9.68 ±3.36	NA	NA	0	0	1	1	NA	NA
Ebaid et al, 2021	Up to 15 days	6	12	6	46	6	40	40	26	0	46	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	34	26
Ekim et al, 2006	One week	5	15	6	12	0	3	2	3	0	1	NA	NA	NA	NA	NA	NA	0	0	1	1	12	9
Erdil et al, 2005	Up to 30 days	NA	NA	4	19	0	9	1	2	0	5	NA	NA	7.7 ±3.7	6.9 ±1.5	NA	NA	0	0	2	3	9	7
Ezelsoy et al, 2019	Up to 30 days	5	16	0	2	NA	NA	NA	NA	0	4	1.19±0.6	1.77±0.69	7.3±1.65	7.8±2.15	NA	NA	0	0	3	2	7	3
Farsak et al, 2002	Up to 30 days	7	24	8	32	0	7	3	2	0	0	NA	NA	7±3.7	8±1.5	1	1	1	0	NA	NA	19	13
Fawzy et al, 2015	Up to 30 days	13	30	15	50	NA	NA	NA	NA	0	3	NA	NA	8±2.5	9±2.9	1	1	NA	NA	NA	NA	NA	NA
Gaudino et al, 2021	Up to 30 days	37	66	26	45	NA	NA	NA	NA	1	1	NA	NA	5.7±1.49	5.7±1.49	5	2	2	1	NA	NA	63	67
Haddadzadeh et al, 2015	One week	5	6	11	14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kaleda et al, 2017	Up to 30 days	8	7	5	6	NA	NA	NA	NA	NA	NA	2.6±1.6	2.3±1.0	12.4±4.3	11.9±4.1	NA	NA	0	0	1	4	NA	NA
Kaya et al, 2014	Up to 30 days	6	11	0	4	NA	NA	4	12	0	4	NA	NA	6.63±2.71	11.56±10.64	NA	NA	0	2	0	2	NA	NA
Kaya et al, 2015	Up to 30 days	6	20	34	55	NA	NA	NA	NA	1	1	1.07±0.31	1.38±1.09	6.29±1.87	7.7±4.18	NA	NA	NA	NA	2	3	3	5
Kaya et al, 2016	Up to 30 days	15	30	36	57	NA	NA	NA	NA	0	4	NA	NA	6.11 2.31	7.33 4.05	0	1	0	1	1	2	6	9
Kaygin et al, 2011	Up to 30 days	14	62	10	46	2	32	41	38	0	7	NA	NA	NA	NA	24	25	3	4	13	15	59	32
Kongmalai et al, 2014	Up to 30 days	4	4	7	6	NA	NA	NA	NA	0	0	4+2	2.2+1.62	16.40+6.08	13.60+8.29	0	0	0	0	NA	NA	10	5
Kuralay et al, 1999	Up to 30 days	6	34	1	54	0	21	3	2	0	10	NA	NA	7±2.5	8±2.9	NA	NA	NA	NA	NA	NA	35	29
Sadeghpour 2011	One week	NA	NA	2	23	1	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zhao et al, 2014	One week	20	35	4	27	NA	NA	NA	NA	3	13	2.54±1.92	2.21±1.54	NA	NA	22	19	0	0	NA	NA	42	24

IABP: intra-aortic balloon pump; ICU: intensive care unit; NA: not applicable; POAF: postoperative atrial fibrillation; PP: posterior pericardiotomy

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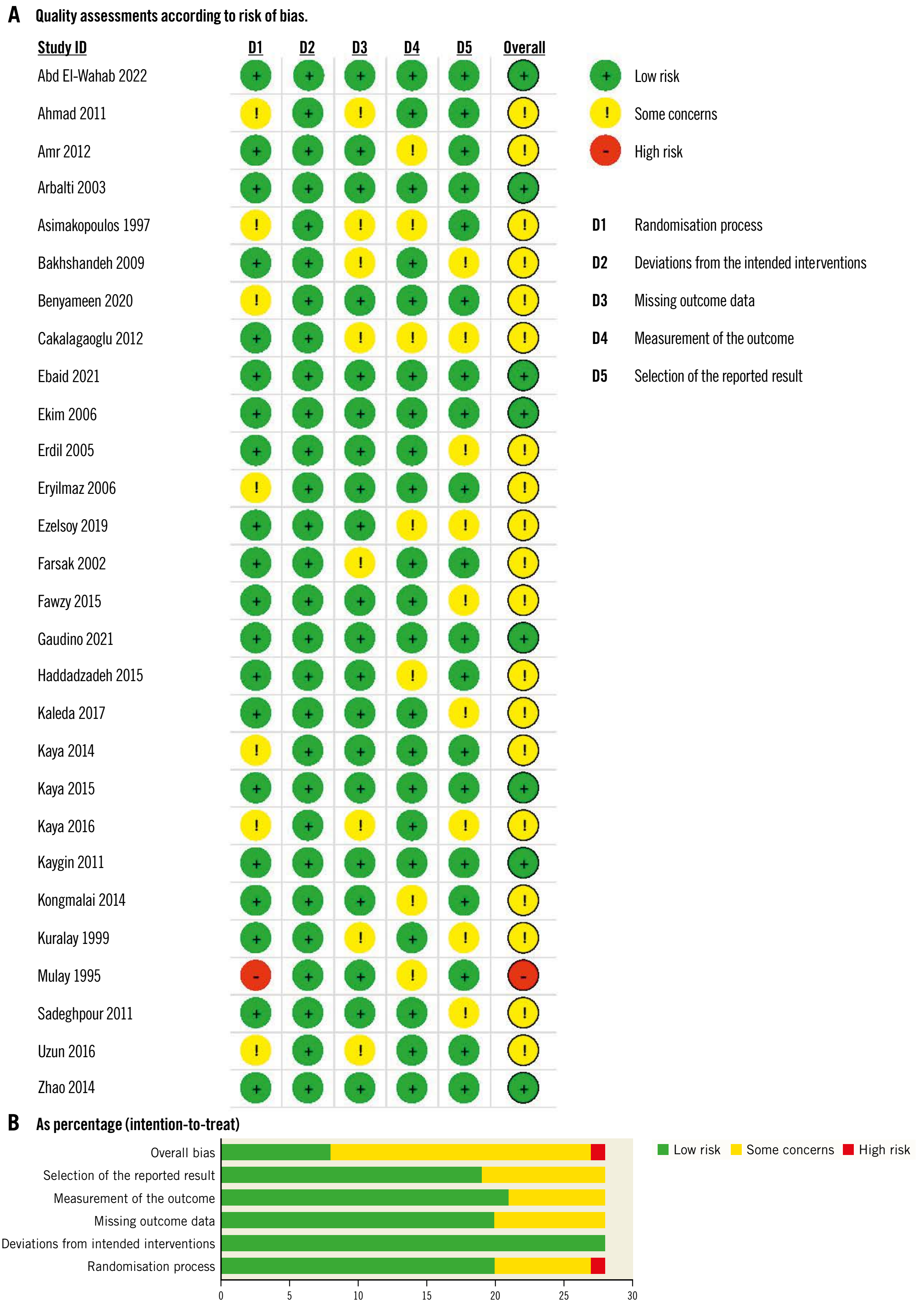

Figure 2. *Quality-assessments. A) Quality assessment according to risk of bias for each study. B) Quality assessment according to risk of bias as percentage (intention to treat).*

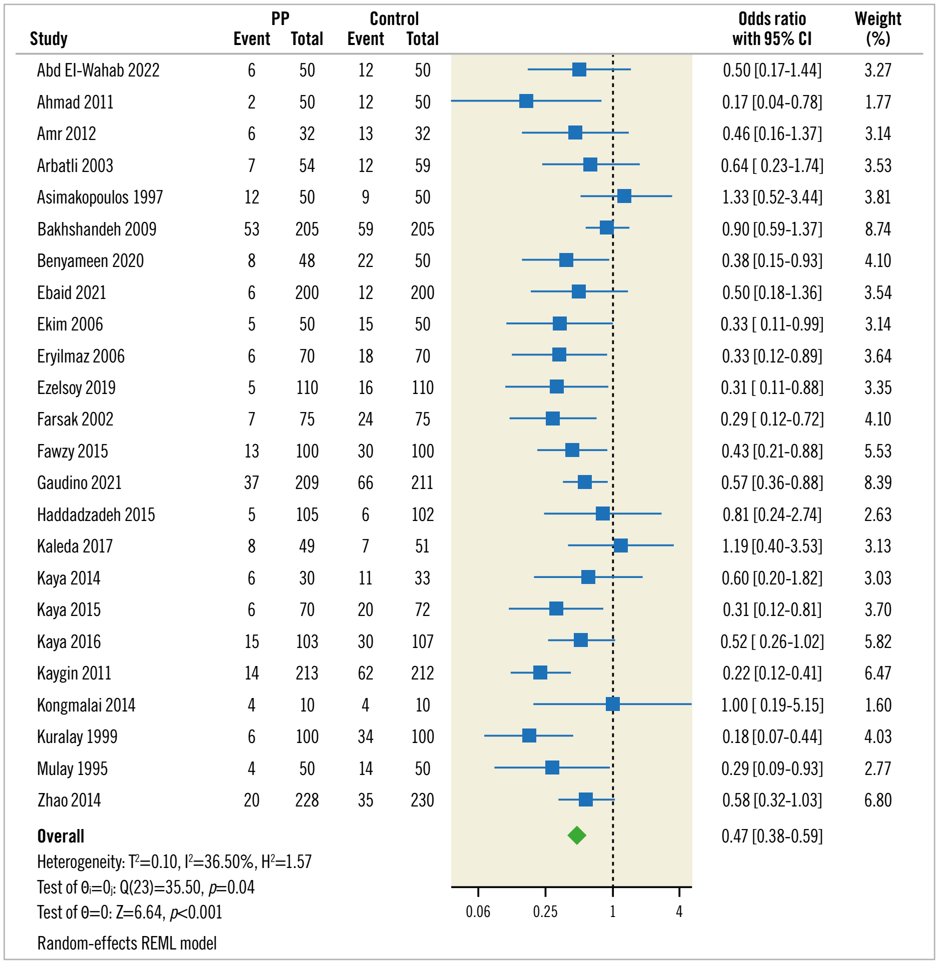

Figure 3. *Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model. AF: atrial fibrillation; CI: confidence interval; PP: posterior pericardiotomy RCT: randomised controlled trials ; REML: restricted maximum likelihood*

suggesting that our evidence of the use of PP decreasing postoperative AF was sufficient, conclusive, and no other trials are needed.

SECONDARY OUTCOMES

Compared to the control group, the PP group had significantly ($p<0.0001$) reduced SVT (OR 0.66, 95% CI: 0.43-0.89), early pericardial effusion (OR 0.32, 95% CI: 0.22-0.46), late pericardial effusion (OR 0.15, 95% CI: 0.09-0.25), pericardiac tamponade (OR 0.18, 95% CI: 0.1-0.33), and hospital stay (MD −0.48, 95% CI: −0.84 to −0.13) **(Supplementary Figure 5-Supplementary Figure 9)**. The pooled studies assessing SVT and late pericardial effusion were slightly heterogeneous (I^2=14.55%; p=0.49 and I^2=38.23%; p<0.16). Studies assessing early pericardial effusion and hospital stay were heterogeneous (I^2=72.54%; p<0.0001 and I^2=67.74%; p<0.0001). The leave-one-out sensitivity analysis for early pericardial effusion showed that no single study had a disproportional effect on the overall OR, which ranged from 0.30 (95% CI: 0.21-0.43), after excluding Cakalagaoglu et al, to 0.36 (95% CI: 0.25-0.5), after excluding Bakhshandeh et al, as shown in **Supplementary Figure 10**. In the leave-one-out sensitivity analysis for hospital stay, the MD ranged from −0.54 (95% CI: −0.90 to −0.18), with Bakhshandeh et al[21] excluded, to −0.39 (95% CI: −0.72 to −0.07) with Benyameen et al[22] excluded **(Supplementary Figure 11)**.

Our analysis did not detect any significant differences between the PP and control groups regarding pulmonary complications (OR 1.14, 95% CI: 0.85-1.52), need for IABP (OR 1.12, 95% CI: 0.75-1.66), revision surgery for bleeding (OR 0.86, 95% CI: 0.56-1.34), mortality (OR 0.79, 95% CI: 0.43-1.45), or ICU stay (MD 0.02, 95% CI: −0.24 to 0.29) **(Supplementary Figure 12-Supplementary Figure 16)**. The pooled studies assessing pulmonary complications, need for IABP, revision surgery for bleeding, and mortality were homogenous with the following values respectively: (I^2=0%; p=0.84, I^2=0%; p=0.98, I^2=0%; p=0.99, and I^2=0%; p=1). Regarding ICU stay, the studies assessing this outcome were heterogeneous (I^2=86.7%; p=0.54). Heterogeneity was best removed by sensitivity analysis and the exclusion of Ezelsoy et al and Kongmalai et al[11,26] (I^2=42.3%; p=0.11) **(Supplementary Figure 17)**.

Pleural effusion was also shown to be significantly higher in the PP group (OR 1.34, 95% CI: 1.12-1.61; p<0.0001) as shown in

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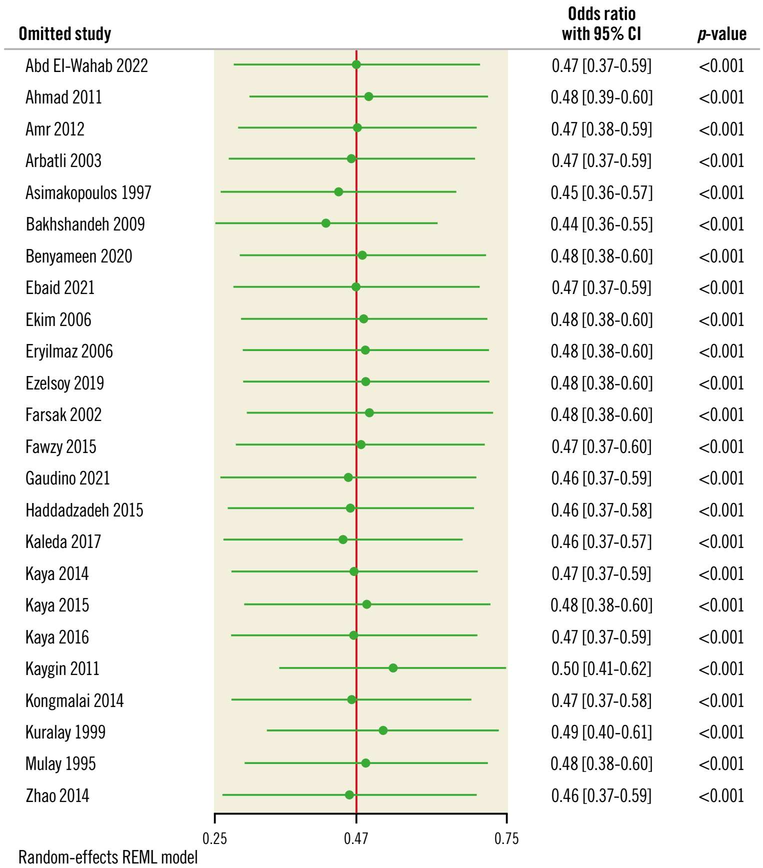

Figure 4. *Leave-one-out analysis of AF. AF: atrial fibrillation; CI: confidence interval; REML: restricted maximum likelihood*

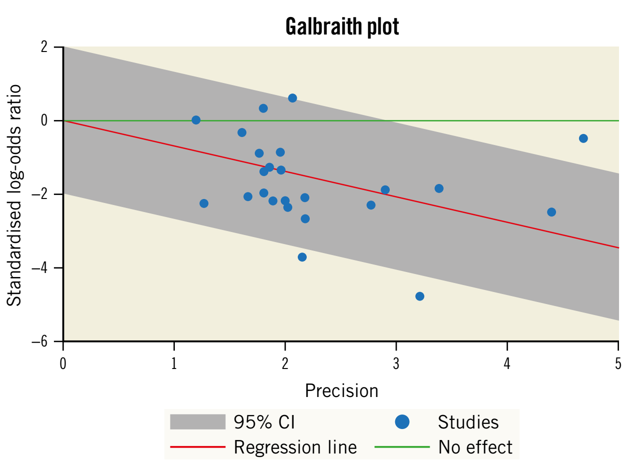

Figure 5. *Galbraith plot indicating the heterogeneity across studies assessing POAF. CI: confidence interval; POAF: postoperative atrial fibrillation*

Supplementary Figure 18. The pooled studies were homogenous (I^2=0%; p=0.68).

PUBLICATION BIAS FOR STUDIES ASSESSING POAF

We used the funnel plot to detect a possible publication bias, and, by inspection, we found slight asymmetry indicating the possibility of publication bias, as shown in **Figure 7A**. We used the trim and fill method to find out which studies needed to improve stability; we found one study that needed to achieve stability, as shown in **Figure 7B**. Our finding may be explained by insufficient literature and clinical heterogeneity.

GRADE ASSESSMENT

The GRADE rating results are shown in **Supplementary Table 3**. According to the GRADE system, the strength of evidence was high for atrial fibrillation, incidence of SVT, early pericardial effusion, late pericardial effusion, pericardial tamponade, and plural effusion; moderate for ICU and hospital stays; low for pulmonary complications, postoperative revision for bleeding and IABP usage; and very low for mortality.

Discussion

Our meta-analysis included 25 trials of 4,467 patients comparing PP with no PP (the control group). We found that the PP group was superior to the control group regarding the following outcomes: POAF, SVT, early and pericardial effusion, pericardiac tamponade, and hospital stay. However, there were no significant differences between the two groups for pulmonary complications, revision surgery for bleeding, mortality, or ICU stay. We also found that pleural effusion was higher in the PP group.

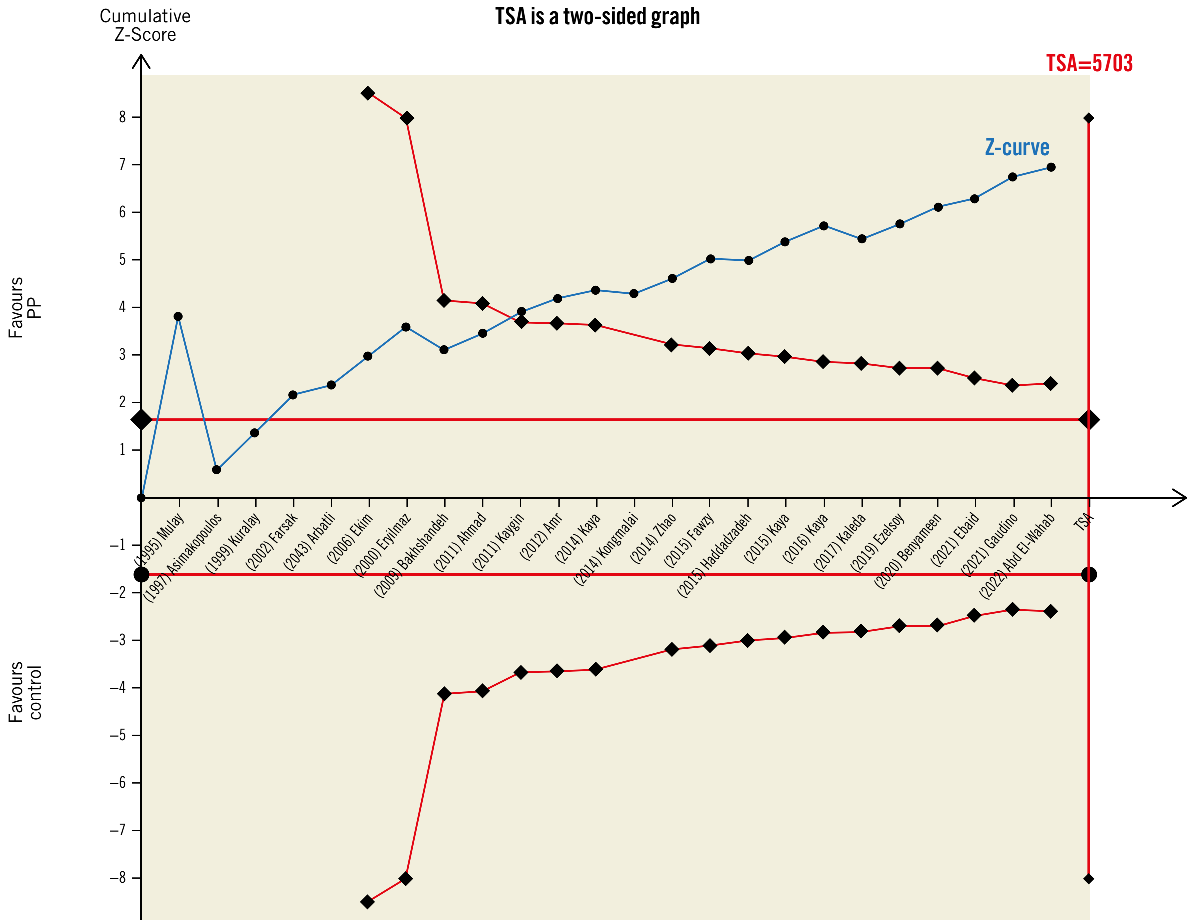

Figure 6. *A trial sequential analysis (TSA) for 22 RCTs illustrating that the cumulative Z-curve crossed both the conventional boundary for benefit and the trial sequential monitoring boundary for benefit and entered the area of benefit, establishing sufficient and conclusive evidence and suggesting further trials are not needed. A diversity-adjusted required information size of 5,703 patients was calculated using an alpha error of 0.05, a beta error of 0.20 (power 80%), an anticipated RR reduction of 20% in AF, and a control event proportion of 23.8%, as calculated from the control group in this meta-analysis. AF: atrial fibrillation; PP: postoperative pericardiotomy; RCT: randomised controlled trial; RR: risk ratio*

Atrial fibrillation is the most frequent postoperative arrhythmia, occurring in up to 20-30% of cases across the studies. Most cases of atrial fibrillation occur within the first few days after surgery and its causes are not clearly understood. Age, atrial dilatation, perioperative ischaemia, electrolyte imbalance, volume overload, right coronary artery involvement, thyroid problems, left ventricular aneurysm, extra valve operations, low cardiac output, kidney injury, respiratory complications, and pericardial effusion are some of the possible precipitating factors for AF[40].

The placement of a chest drain underneath the sternum allows for easy drainage of the anterior area around the heart after CABG. However, the posterior space is a closed region behind the heart and cannot be drained similarly because of its proximity to the grafts and the heart itself. In this way, even a minimal amount of pericardial effusion accumulating in the posterior pericardium can cause localised tamponade of the left atrium and ventricle, which, in turn, can cause POAF. Numerous studies have shown that allowing the pericardial effusion to drain freely into the left pleural space reduces the prevalence of pericardial effusion and POAF, hence preventing arrhythmias and tamponade[23,25].

Our systematic review and meta-analysis of 22 studies assessing POAF found that PP helped prevent POAF in patients after CABG. Although some randomised controlled trials have revealed contradictory results[17,25,38], the present study's findings are consistent with earlier meta-analyses[4,8,12]. The present study used TSA for power analysis, ensuring adequate and convincing evidence. The evidence for POAF prevention was strong. These results suggest that PP may reduce the occurrence of AF following CABG. However, we cannot exclude the possibility of bias in the included studies, as the pooled studies in our analysis were heterogeneous. This could be explained by clinical heterogeneity, and different CABG approaches and pre- and postoperative medications should be considered. Although the incidence of POAF after PP was decreased, this effect seemed to be found only in the studies conducted in Egypt and Turkey, which opens the door for upcoming

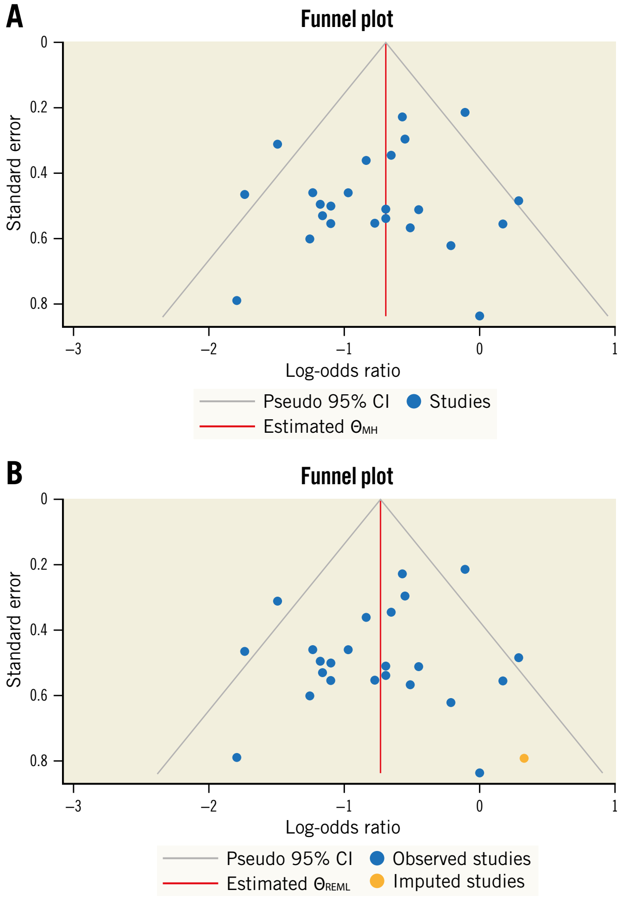

Figure 7. *Funnel plots for publication bias. A) Funnel plot for possible publication bias regarding POAF. B) Funnel plot for possible publication bias using the trim and fill method regarding POAF. CI: confidence interval; Θ_{MH}: Cochran–Mantel–Haenszel test; Θ_{REML}: restricted maximum likelihood; POAF: postoperative atrial fibrillation*

research studies assessing the effect of PP on POAF in Western and Asian countries.

Our findings suggest that PP can dramatically decrease pericardial effusion in patients after CABG, with both early and late pericardial effusion being much less common in the PP group compared to the control group. Similar results were observed by Xiong et al, whereas Cakalagaoglu et al and Ekim et al found no difference; this discrepancy may be due to the smaller sample sizes employed by these researchers[13,23,36].

The current meta-analysis revealed that PP effectively decreases postoperative pericardiac tamponade compared to the control. Consequently, the PP group had a greater increase in pleural effusion, suggesting that fluid can be readily evacuated into the left thoracic cavity via the PP process, which greatly lowered the risk of pericardial tamponade. On the other hand, the accumulation of pericardial fluid in the pleura triggered an inflammatory response in some patients, requiring chest tube reinsertion. The reinsertion, in most cases, took place after the removal of the initial pleural tube[17,19,23,27]. Notably, there was no discernible difference in the occurrence of pulmonary complications between the PP group and the control group. Therefore, the results of the current study suggest that PP is a viable option for chest drainage that can lessen the likelihood of cardiac tamponade without raising the probability of pulmonary complications. Our results were consistent with previous studies[20,27]. Furthermore, we found that PP patients had a shorter average ICU stay after surgery than those in the control group. Preventing AF after CABG surgery with PP may be a safe and cost-effective way to lower patients' medical bills and conserve hospital resources due to the inverse relationship between the length of time spent in the intensive care unit and overall hospitalisation costs[27].

In addition, we found that PP did not reduce the need for intra-aortic balloon pump support, a second operation due to bleeding, or death in the postoperative period. In alignment with our results, the prior meta-analyses did not identify any distinctions between the PP and control groups regarding these outcomes. Our study included 25 studies, of which 22 studies, comprising 4,300 patients, compared POAF in PP and control groups. To detect the heterogeneity and outliers in our study, we applied the random-effects model, leave-one-out sensitivity analysis and the Galbraith plot. We also used TSA to prove that our evidence was sufficient and that no further trials would be needed.

Limitations

This meta-analysis has several limitations. First, although our findings align with those of previous systematic reviews, there was not adequate control for the impact of preoperative medications on the postoperative recurrence of AF in the trials included. Second, the included studies were moderately heterogeneous, which led to unreliable analytic results. This heterogeneity was due to discrepancies in patient characteristics and the definition of postoperative AF. We tried to resolve these issues by stratifying the studied population according to preoperative beta blocker intake, type of CABG surgery, and geographical area, as shown in **Supplementary Figure 2-Supplementary Figure 4**, respectively. Third, the quality of the included studies was variable, as shown in **Figure 2**, but we applied the GRADE system to enhance the certainty of evidence pooled from our studies. Other limitations we faced were heterogeneity in follow-up, outcome assessment, and definition of outcomes assessed across the trials and the varying numbers of surgical interventions performed.

We recommend further studies to resolve heterogeneity by stratifying patients according to their preoperative preparation and medication, and the type of CABG operation – on-pump or off-pump; Haddadzadeh et al showed that PP did not affect postoperative AF incidence in patients undergoing off-pump CABG[10]. Concurrently, Panesar et al, in their meta-analysis, declared that the off-pump technique is associated with a lower incidence of POAF[41].

Conclusions

In conclusion, this systematic review and meta-analysis found that PP effectively reduced the risk of new-onset POAF, pericardial effusion, pericardial tamponade, bleeding problems, and length of hospital stay following CABG. We found no statistically significant differences between the PP and control groups regarding pulmonary complications, IABP use, mortality, or length of time spent in the intensive care unit. Given these results, it seems reasonable to conclude that PP is a straightforward surgical procedure with minimal risk that should be considered in future practice.

Impact on daily practice

Atrial fibrillation is the most frequent postoperative arrhythmia, occurring in up to 20-30% of cases across studies. Most cases of atrial fibrillation occur within the first few days after surgery. Numerous studies have shown that allowing the pericardial effusion to drain freely into the left pleural space reduces the prevalence of pericardial effusion and AF. Our systematic review and meta-analysis of 25 studies found that PP helped prevent AF in patients after cardiac surgery. We used TSA for power analysis, ensuring adequate and convincing data that the evidence for POAF prevention was strong. We also used the GRADE system to detect the power of each outcome, and we concluded that the evidence of POAF prevention was high.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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Supplementary data

Supplementary Appendix 1. Search terms according to databases.

Supplementary Table 1. Posterior pericardiotomy operation definitions used in the randomised controlled trials included in the present meta-analysis.

Supplementary Table 2. Conventional procedures (no PP) definitions used in the randomised controlled trials included in the present meta-analysis.

Supplementary Table 3. GRADE evidence profile.

Supplementary Figure 1. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model after removal of studies with the smallest sample size.

Supplementary Figure 2. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model in studies without preoperative oral β-blockers.

Supplementary Figure 3. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model regarding geographical areas.

Supplementary Figure 4. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model regarding type of surgery.

Supplementary Figure 5. Pooled estimates from RCTs evaluating the effect of PP on the incidence of SVT after cardiac surgery with a random-effects model.

Supplementary Figure 6. Pooled estimates from RCTs evaluating the effect of PP on the incidence of early pericardial effusion after cardiac surgery with a random-effects model.

Supplementary Figure 7. Pooled estimates from RCTs evaluating the effect of PP on the incidence of late pericardial effusion after cardiac surgery with a random-effects model.

Supplementary Figure 8. Pooled estimates from RCTs evaluating the effect of PP on the incidence of pericardiac tamponade after cardiac surgery with a random-effects model.

Supplementary Figure 9. Pooled estimates from RCTs evaluating the effect of PP on hospital stay after cardiac surgery with a random-effects model.

Supplementary Figure 10. Leave-one-out analysis of early pericardial effusion.

Supplementary Figure 11. Leave-one-out analysis of hospital stay.

Supplementary Figure 12. Pooled estimates from RCTs evaluating the effect of PP on pulmonary complications after cardiac surgery with a random-effects model.

Supplementary Figure 13. Pooled estimates from RCTs evaluating the effect of PP on need for IABP after cardiac surgery with a random-effects model.

Supplementary Figure 14. Pooled estimates from RCTs evaluating the effect of PP on the incidence of revision surgery for bleeding after cardiac surgery with a random-effects model.

Supplementary Figure 15. Pooled estimates from RCTs evaluating the effect of PP on mortality after cardiac surgery with a random-effects model.

Supplementary Figure 16. Pooled estimates from RCTs evaluating the effect of PP on ICU stay after cardiac surgery with a random-effects model.

Supplementary Figure 17. Sensitivity analysis from RCTs evaluating the effect of PP on ICU stay after cardiac surgery with a random-effects model.

Supplementary Figure 18. Pooled estimates from RCTs evaluating the effect of PP on pleural effusion after cardiac surgery with a random-effects model.

The supplementary data are published online at: https://eurointervention.pcronline.com/doi/10.4244/EIJ-D-22-00948

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Supplementary data

Supplementary Appendix 1. Search terms according to databases.

Database	Search Strategy
PubMed	("posterior pericardiotomy*[Title/Abstract]" OR "pericardial fenestration*[Title/Abstract]" OR "pericardialwindow*[Title/Abstract]") AND ("Coronary Artery Bypass"[Mesh]) OR ("Artery Bypass, Coronary*[Title/Abstract]" OR "Artery Bypasses, Coronary*[Title/Abstract]" OR "Bypasses, Coronary Artery*[Title/Abstract]" OR "Coronary Artery Bypasses*[Title/Abstract]" OR "Coronary Artery Bypass Surgery*[Title/Abstract]" OR "Bypass, Coronary Artery*[Title/Abstract]" OR "Aortocoronary Bypass*[Title/Abstract]" OR "Aortocoronary Bypasses*[Title/Abstract]" OR "Bypass, Aortocoronary*[Title/Abstract]" OR "Bypasses, Aortocoronary*[Title/Abstract]" OR "Bypass Surgery, Coronary Artery*[Title/Abstract]" OR "Coronary Artery Bypass Grafting*[Title/Abstract]") OR ("CAB*[Title/Abstract]" OR "CABG*[Title/Abstract]") OR("Cardiac Surgical Procedures"[Mesh]) OR ("Procedure, Cardiac Surgical*[Title/Abstract]" OR "Procedures, Cardiac Surgical*[Title/Abstract]" OR "Surgical Procedure, Cardiac*[Title/Abstract]" OR "Surgical Procedures, Cardiac*[Title/Abstract]" OR "Surgical Procedures, Heart*[Title/Abstract]" OR "Cardiac Surgical Procedure*[Title/Abstract]" OR "Heart Surgical Procedures*[Title/Abstract]" OR "Procedure, Heart Surgical*[Title/Abstract]" OR "Procedures, Heart Surgical*[Title/Abstract]" OR "Surgical Procedure, Heart*[Title/Abstract]" OR "Heart Surgical Procedure*[Title/Abstract]") OR "cardiothoracic surgery*[Title/Abstract]" OR "cardiac surgery*[Title/Abstract]" OR "heartsurgery*[Title/Abstract]") OR ("Cardiopulmonary Bypass"[Mesh]) OR ("Heart-Lung Bypass*[Title/Abstract]" OR "Bypass, Heart-Lung*[Title/Abstract]" OR "Bypasses, Heart-Lung*[Title/Abstract]" OR "Heart Lung Bypass*[Title/Abstract]" OR "Heart-Lung Bypasses*[Title/Abstract]" OR "Bypass, Cardiopulmonary*[Title/Abstract]" OR "Bypasses, Cardiopulmonary*[Title/Abstract]" OR "Cardiopulmonary Bypasses*[Title/Abstract]") OR ("CPB*[Title/Abstract]")
EBSCO	('coronary artery bypass graft' OR 'coronary artery bypass' OR 'CAB' OR 'heart surgery' OR 'cardiac surgery' OR 'cardiac surgical procedures' OR 'cardiothoracic surgery' OR 'cardiopulmonary bypass' OR 'CBP) AND ('posterior pericardiotomy' OR 'pericardial fenestration' OR 'pericardialwindow')
Scopus	(“Pericardiotomy” OR “Posterior left pericardiotomy” OR “postpericardiotomy” OR “pericardial fenestration”) AND (“CABG” OR “coronary artery bypass grafting” OR “heart surgery” OR “cardiothoracic surgery” OR “cardiac surgery” OR “extracorporeal circulation” OR “CAB”) AND (“atrial fibrillation”)
Web of Science	(“Pericardiotomy” OR “Posterior left pericardiotomy” OR “postpericardiotomy” OR “pericardial fenestration”) AND (“CABG” OR “coronary artery bypass grafting” OR “heart surgery” OR “cardiothoracic surgery” OR “cardiac surgery” OR “extracorporeal circulation” OR “CAB”) AND (“atrial fibrillation”)
Ovid	(“Pericardiotomy” OR “Posterior left pericardiotomy” OR “postpericardiotomy” OR “pericardial fenestration”) AND (“CABG” OR “coronary artery bypass grafting” OR “heart

	surgery" OR "cardiothoracic surgery" OR "cardiac surgery" OR "extracorporeal circulation" OR "CAB") AND ("atrial fibrillation")

Supplementary Table 1. Posterior pericardiotomy operation definitions used in the randomised controlled trials included in the present meta-analysis.

Author, year	Description of posterior pericardiotomy
Abd El-Wahab et al. 2022	Proximal anastomoses were established a longitudinal incision, 4cm long and 2cm in width, was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm.
Arbalti 2003	a longitudinal incision, 4-cm long and 2-cm width, was made parallel and posterior to the left phrenic nerve,extending from the left inferior pulmonary vein to the diaphragm
Ahmad et al. 2011	Longitudinal incision was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm using diathermy
Amr et al. 2012	Longitudinal incision in the pericardium was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm
Asimakopoulos et al. 1997	a 4 cm posterior pericardial incision below the left inferior pulmonary vein parallel and posterior to the phrenic nerve
Bakhshandeh et al. 2009	a 4-cm longitudinal incision was made parallel and posterior to the left phrenic nerve, extending from the left pulmonary vein to the diaphragm
Benyameen et al. 2021	A longitudinal 4-cm incision parallel and posterior to the left phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Cakalagaoglu et al. 2012	A pericardial fenestration window was opened, similarly to the surgical technique described by Erdil et al [2005]. The fenestration site was away from the phrenic nerve. The pericardial tissue was clamped and retracted upwards to allow fenestration via the use of a low-power electrocauterization instrument
Ebaid et al. 2021	a 4 cm longitudinal incision parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm
Ekim et al. 2006	A 4-cm longitudinal incision was made parallel and 1.5 cm posterior to the phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm
Erdil et al. 2005	Longitudinal incision was made parallel and 15mm posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm
Ezelsoy et al. 2019	The posterior pericardial window procedure was performed before removal of the aortic cross-clamp. In our study, a pericardial fenestration was performed far away from the phrenic nerve.
Farsak et al. 2002	4-cm longitudinal incision was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm.
Fawzy et al. 2015	a longitudinal incision, 4-cm long and 2-cm width, was made parallel and posterior to the left phrenic nerve,extending from the left inferior pulmonary vein to the diaphragm
Gaudino et al. 2021	a 4–5 cm vertical incision posterior to the phrenic nerve and extending from the left inferior pulmonary vein to the diaphragm
Haddadzadeh et al. 2015	longitudinal incision with a length of 4 cm was performed parallel and posterior to the left phrenic nerve from the left pulmonary vein to diaphragm

Kaleda et al. 2017	A longitudinal incision was made parallel and posterior to the phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm
Kaya et al. 2014	a 4-cm longitudinal incision was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm
Kaya et al. 2015	a 4-cm vertical incision was performed parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm after the under cardiopulmonary bypass and proximal anastomoses were established
Kaya et al. 2016	a 4-cm longitudinal incision was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm, as described by Mulay et al.
Kaygin et al. 2011	A 4-cm circular incision was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm as described by Mulay and colleagues (Mulay et al. 1995)
Kongmalai et al. 2014	a 4-cm circular incision was made in parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm as described by Mulay et al 1995
Kuralay et al. 1999	Longitudinal incision was made parallel and posterior to the left phrenic nerve, extending from the left inferior pulmonary vein to the diaphragm Mulay and coworkers.
Sadeghpour et al. 2011	a 4 to 6 cm incision along the posterior length of left pherenic nerve and initiated near the origin of left inferior pulmonary vein and extended to diaphragm.
Zhao et al. 2014	First, the phrenic nerve was identified and an inverse-T incision (2.5 cm long in both dimensions) was created. Gauze was used to shield the moving (inflating) lung and, before incision, surgeons identified the phrenic nerve to avoid damaging it. The incision was made into the pleural cavity by non-continuous electrocautery, parallel and posterior to the phrenic nerve and extending from the left inferior pulmonary vein to the diaphragm, as described by Mulay and coworkers.

Supplementary Table 2. Conventional procedures (no PP) definitions used in the randomised controlled trials included in the present meta-analysis.

Author, year	Description of Conventional procedures
Abd El-Wahab et al. 2022	No posterior drainage.
Ahmad et al. 2011	No posterior drainage.
Arbalti 2003	No posterior drainage.
Amr et al. 2012	No posterior drainage.
Asimakopoulos et al. 1997	No posterior drainage.
Bakhshandeh et al. 2009	No posterior drainage.
Benyameen et al. 2021	insertion of two retrosternal drains in the anterior mediastinum
Cakalagaoglu et al. 2012	Two chest tubes were placed in the anterior mediastinum.
Ebaid et al. 2021	No posterior pericardiotomy, but the left pleura was opened.
Ekim et al. 2006	No posterior drainage.
Erdil et al. 2005	No posterior pericardiotomy, only an anterior mediastinal tube.
Ezelsoy et al. 2019	No posterior pericardiotomy, only two chest tubes at the end of surgery one in the left pleural cavity and the other in the anterior mediastinum.
Farsak et al. 2002	No posterior pericardiotomy, only two chest tubes at the end of surgery one in the left pleural cavity and the other in anterior mediastinum.
Fawzy et al. 2015	No posterior drainage.
Gaudino et al. 2021	No posterior drainage.
Haddadzadeh et al. 2015	No posterior drainage.
Kaleda et al. 2017	No posterior drainage.
Kaya et al. 2014	No posterior drainage.
Kaya et al. 2015	No posterior drainage.
Kaya et al. 2016	No posterior pericardiotomy, only straight tube was placed in the anterior mediastinum and an angled tube was placed into the left hemithorax.
Kaygin et al. 2011	No posterior pericardiotomy, only Two chest tubes (left pleural cavity and anterior mediastinum) were inserted into the pericardium.
Kongmalai et al. 2014	No posterior drainage.
Kuralay et al. 1999	No posterior pericardiotomy, only Two chest tubes (one in the left pleural cavity and the other in anterior mediastinum) were inserted, and the pericardium was left open anteriorly in both groups.
Sadeghpour et al. 2011	No posterior drainage.
Zhao et al. 2014	No posterior drainage.

Supplementary Table 3. GRADE evidence profile.

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Posterior pericardiotomy	Standard care	Relative (95% CI)	Absolute (95% CI)		
Atrial fibrillation assessed with continuous electrocardiogram monitoring												
22	randomized trials	not serious	not serious	not serious	not serious	strong association	251/2141 (11.7%)	511/2159 (23.7%)	**OR 0.49** (0.38 to 0.61)	**105 fewer per 1,000** (from 131 fewer to 78 fewer)	⨁⨁⨁⨁ High	CRITICAL
Incidence of SVT assessed with continuous electrocardiogram monitoring												
8	randomized trials	not serious	not serious	not serious	not serious	none	73/784 (9.3%)	115/786 (14.6%)	**OR 0.66** (0.43 to 0.89)	**45 fewer per 1,000** (from 78 fewer to 14 fewer)	⨁⨁⨁⨁ High	CRITICAL
Early pericardial effusion assessed with dimensional echocardiogram												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Posterior pericardiotomy	Standard care	Relative (95% CI)	Absolute (95% CI)		
20	randomized trials	not serious	serious[a]	not serious	not serious	strong association	218/1918 (11.4%)	723/1927 (37.5%)	**OR 0.32** (0.22 to 0.46)	**214 fewer per 1,000** (from 259 fewer to 159 fewer)	⊕⊕⊕⊕ High	CRITICAL
Late pericardial effusion assessed with dimensional echocardiogram												
10	randomized trials	not serious	not serious	not serious	not serious	strong association	55/1013 (5.4%)	384/1014 (37.9%)	**OR 0.15** (0.09 to 0.25)	**295 fewer per 1,000** (from 327 fewer to 246 fewer)	⊕⊕⊕⊕ High	CRITICAL
Pericardial tamponade assessed with dimensional echocardiogram												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Posterior pericardiotomy**	**Standard care**	**Relative (95% CI)**	**Absolute (95% CI)**		
20	randomized trials	not serious	not serious	not serious	not serious	strong association	5/1982 (0.3%)	116/1998 (5.8%)	**OR 0.18** (0.10 to 0.33)	**47 fewer per 1,000** (from 52 fewer to 38 fewer)	⊕⊕⊕⊕ High	CRITICAL
Plural effusion assessed with two dimensional echocardiogram												
16	randomized trials	not serious	not serious	not serious	not serious	none	336/1620 (20.7%)	251/1636 (15.3%)	**OR 1.34** (1.12 to 1.61)	**42 more per 1,000** (from 15 more to 72 more)	⊕⊕⊕⊕ High	CRITICAL
Pulmonary Complications assessed with postoperative chest-x rays												
11	randomized trials	serious[b]	not serious	serious[c]	not serious	none	116/1055 (11.0%)	104/1057 (9.8%)	**OR 1.14** (0.85 to 1.52)	**12 more per 1,000** (from 14 fewer to 44 more)	⊕⊕◯◯ Low	IMPORTANT

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Posterior pericardiotomy	Standard care	Relative (95% CI)	Absolute (95% CI)		
Postoperative revision for bleeding assessed with two dimensional echocardiogram and postoperative drainage												
15	randomized trials	serious[d]	not serious	serious[e]	not serious	none	40/1312 (3.0%)	94/1322 (7.1%)	**OR 0.86** (0.56 to 1.34)	**9 fewer per 1,000** (from 30 fewer to 22 more)	⊕⊕◯◯ Low	IMPORTANT
IABP usage assessed with two dimensional echocardiogram												
10	randomized trials	serious[f]	not serious	serious[g]	not serious	none	56/1092 (5.1%)	50/1104 (4.5%)	**OR 1.12** (0.75 to 1.66)	**5 more per 1,000** (from 11 fewer to 28 more)	⊕⊕◯◯ Low	IMPORTANT
Mortality assessed with postoperative vital signs monitoring												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Posterior pericardiotomy	Standard care	Relative (95% CI)	Absolute (95% CI)		
16	randomized trials	serious[h]	not serious	serious[i]	serious[j]	none	14/1532 (0.9%)	20/1544 (1.3%)	**OR 0.79** (0.43 to 1.45)	**3 fewer per 1,000** (from 7 fewer to 6 more)	⨁◯◯◯ Very low	IMPORTANT
ICU stay measured with: Vital signs monitoring; better indicated lower values												
9	randomized trials	not serious	serious[a]	not serious	not serious	none	808	819	-	SMD **0.02 SD higher** (0.24 lower to 0.29 higher)	⨁⨁⨁◯ Moderate	IMPORTANT
Hospital stay measured with: observational; better indicated lower values												
18	randomized trials	not serious	serious[a]	not serious	not serious	none	1395	1415	-	SMD **48 SD lower** (0.84 lower to 0.13 lower)	⨁⨁⨁◯ Moderate	IMPORTANT

CI: confidence interval; **OR:** odds ratio; **SMD:** standardized mean difference; SD: Standard error.

a. Heterogeneity, I2 > 50%

b. Tracheal intubation, pulmonary congestion, and so on can lead to pulmonary infections.

c. Failure to directly link pp with pulmonary infections.

d. Levels of expression varies

e. Bleeding is not directly related to PP

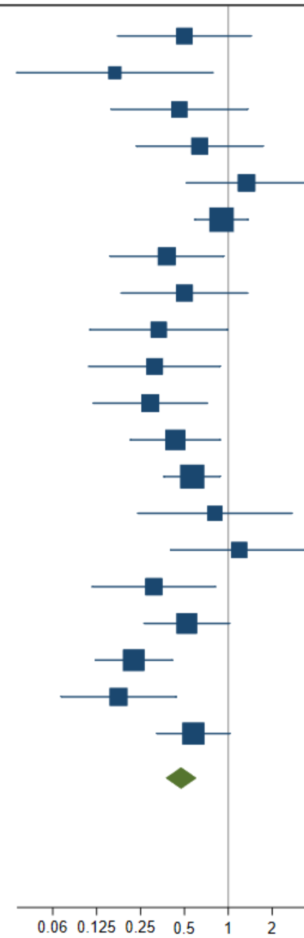
f. There were many reasons for IABP usage

g. The use of IABP is not directly linked to PP

h. There were many causes for death

i. Death was not directly linked to PP

j. 95% CI is wide



Study	PP Event	PP Total	Control Event	Control Total	Odds Ratio with 95% CI	Weight (%)
Abd El-Wahab 2022	6	50	12	50	0.50 [0.17, 1.44]	3.76
Ahmad 2011	2	50	12	50	0.17 [0.04, 0.78]	2.07
Amr 2012	6	32	13	32	0.46 [0.16, 1.37]	3.62
Arbatli 2003	7	54	12	59	0.64 [0.23, 1.74]	4.05
Asimakopouls 1997	12	50	9	50	1.33 [0.52, 3.44]	4.36
Bakhshandeh 2009	53	205	59	205	0.90 [0.59, 1.37]	9.41
Benyameen 2020	8	48	22	50	0.38 [0.15, 0.93]	4.67
Ebaid 2021	6	200	12	200	0.50 [0.18, 1.36]	4.06
Ekim 2006	5	50	15	50	0.33 [0.11, 0.99]	3.62
Ezelsoy 2019	5	110	16	110	0.31 [0.11, 0.88]	3.85
Farsak 2002	7	75	24	75	0.29 [0.12, 0.72]	4.67
Fawzy 2015	13	100	30	100	0.43 [0.21, 0.88]	6.19
Gaudino 2021	37	209	66	211	0.57 [0.36, 0.88]	9.07
Haddadzadeh 2015	5	105	6	102	0.81 [0.24, 2.74]	3.05
Kaleda 2017	8	49	7	51	1.19 [0.40, 3.53]	3.61
Kaya 2015	6	70	20	72	0.31 [0.12, 0.81]	4.23
Kaya2016	15	103	30	107	0.52 [0.26, 1.02]	6.48
Kaygin2011	14	213	62	212	0.22 [0.12, 0.41]	7.15
Kuralay1999	6	100	34	100	0.18 [0.07, 0.44]	4.60
Zhao2014	20	228	35	230	0.58 [0.32, 1.03]	7.49
Overall					0.47 [0.37, 0.60]	

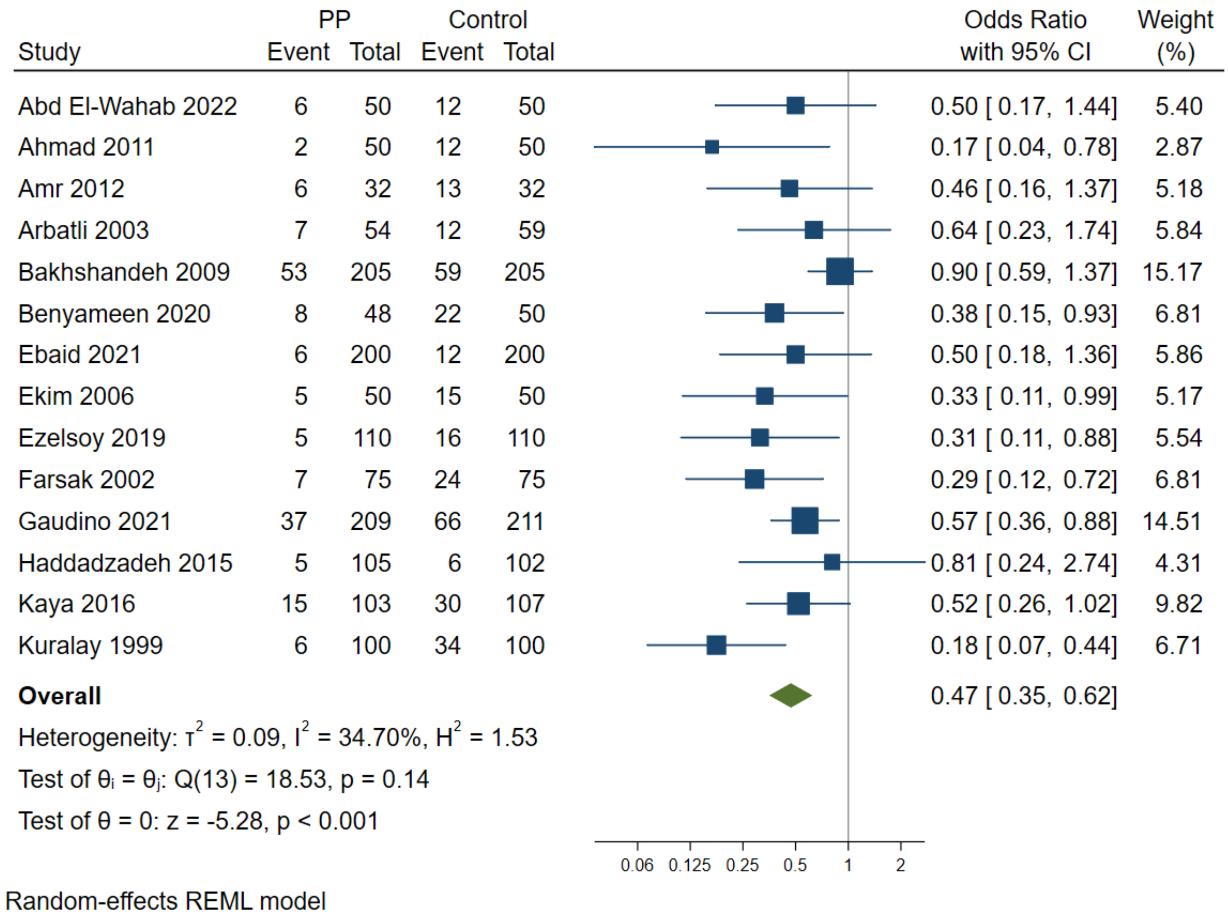
Heterogeneity: $\tau^2 = 0.12$, $I^2 = 42.46\%$, $H^2 = 1.74$

Test of $\theta_i = \theta_j$: $Q(19) = 33.17$, $p = 0.02$

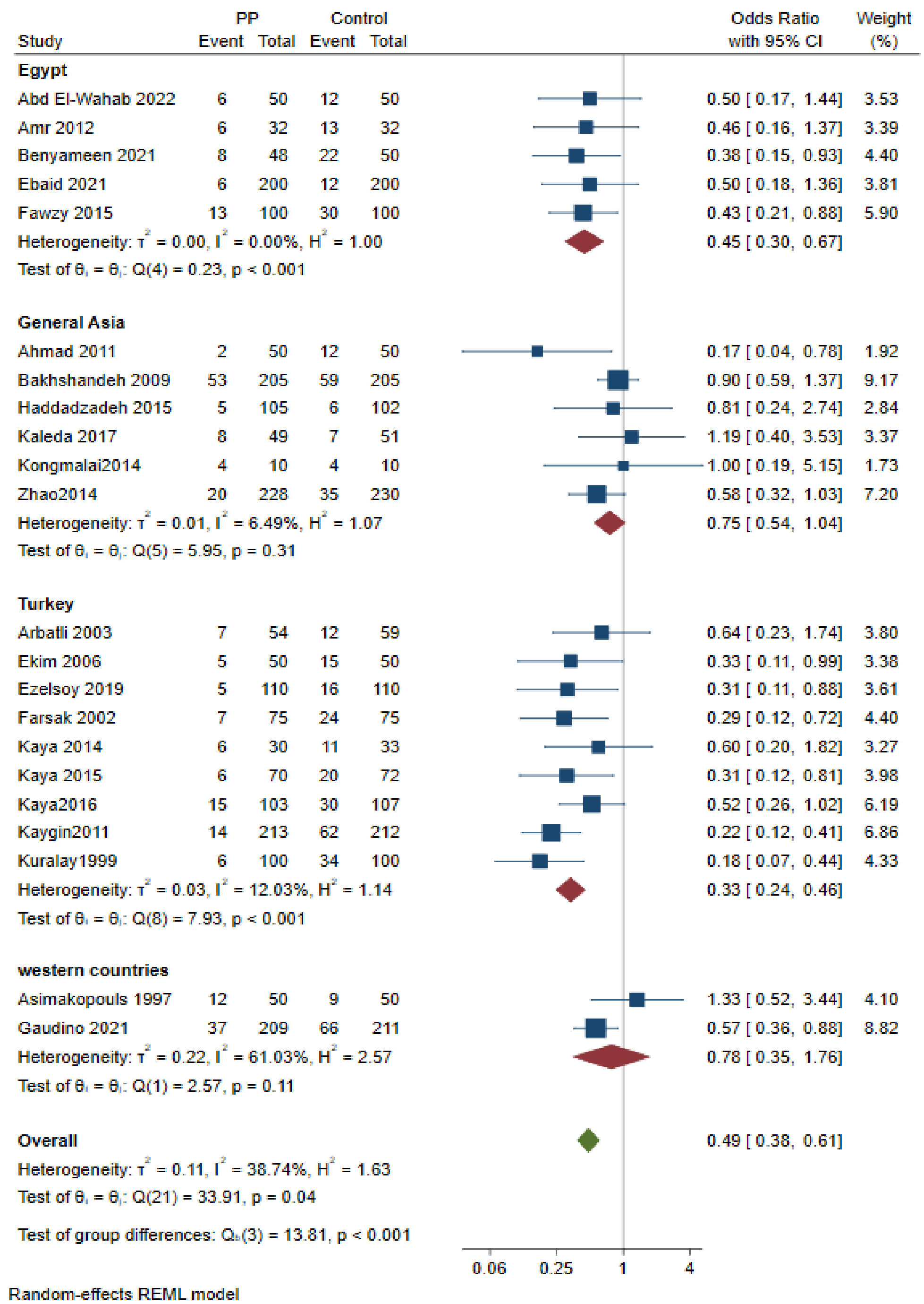
Test of $\theta = 0$: $z = -6.02$, $p < 0.001$

Random-effects REML model

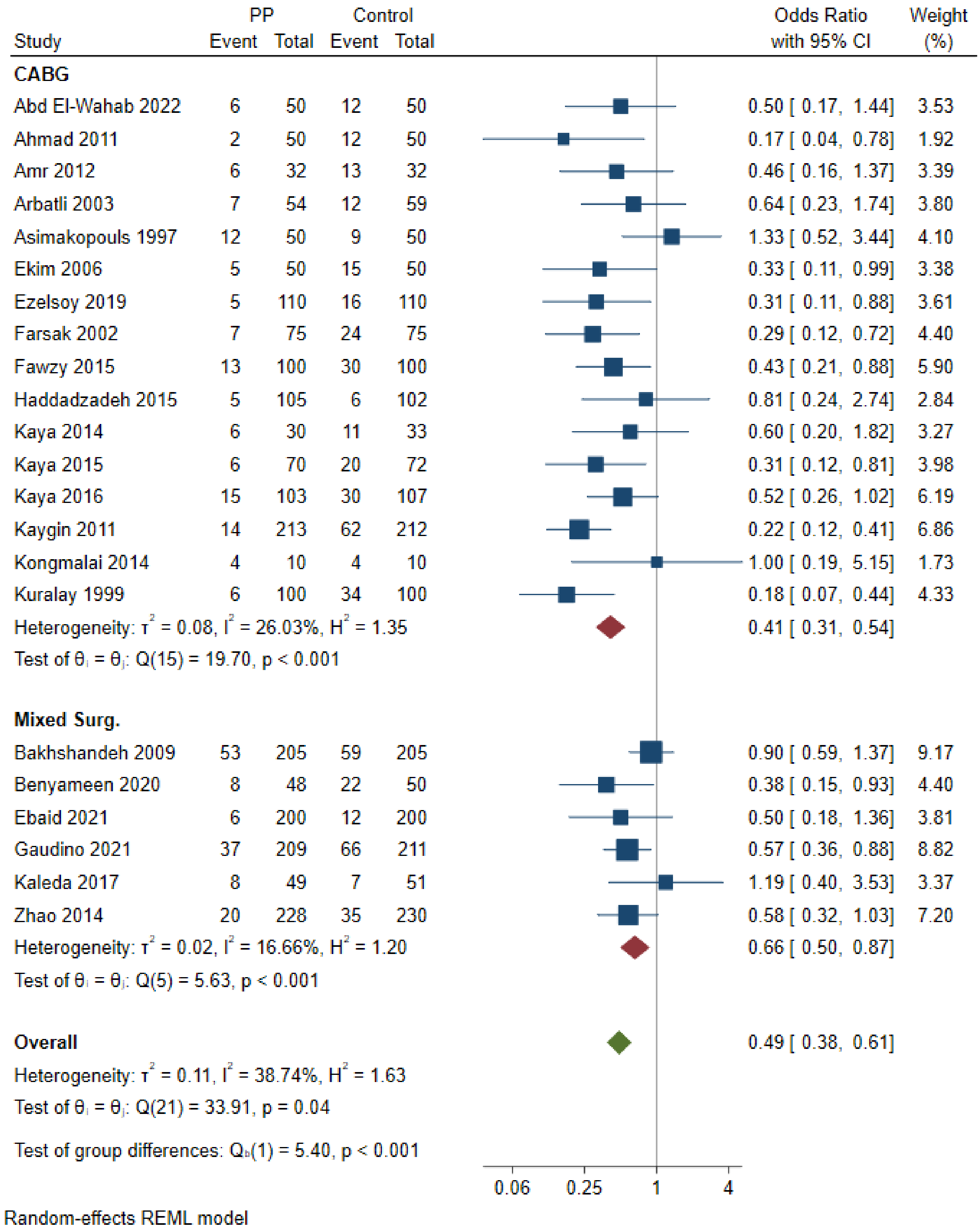
Supplementary Figure 1. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model after removal of studies with the smallest sample size.



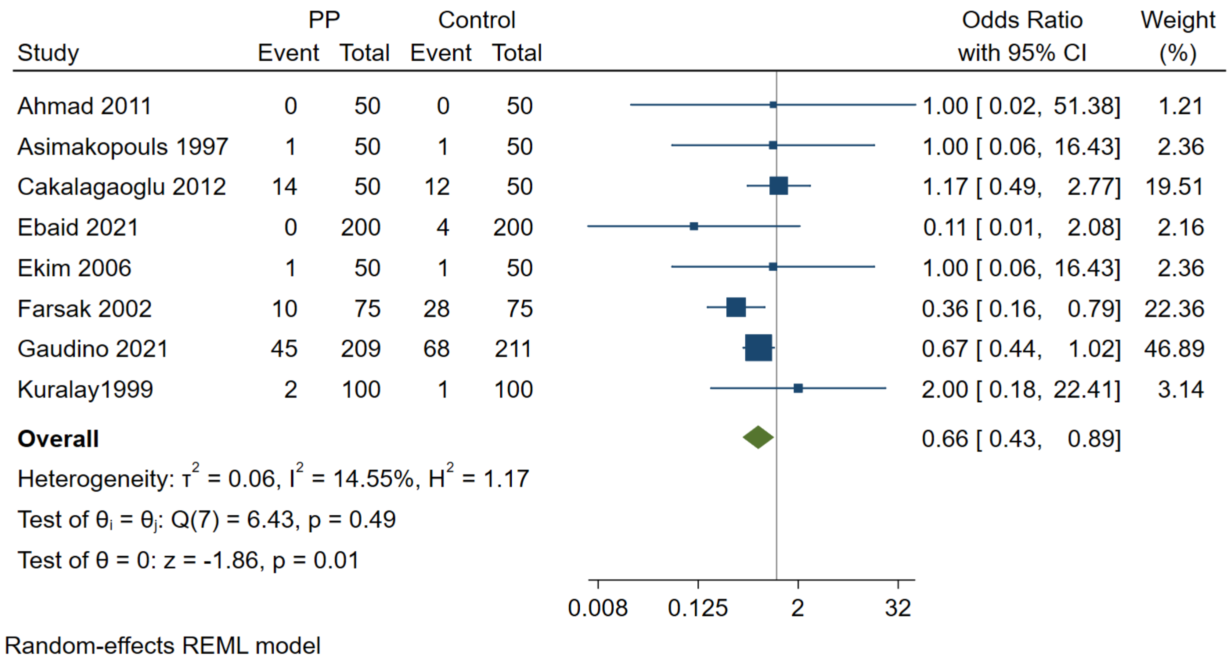
Supplementary Figure 2. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model in studies without preoperative oral β-blockers.



Supplementary Figure 3. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model regarding geographical areas.

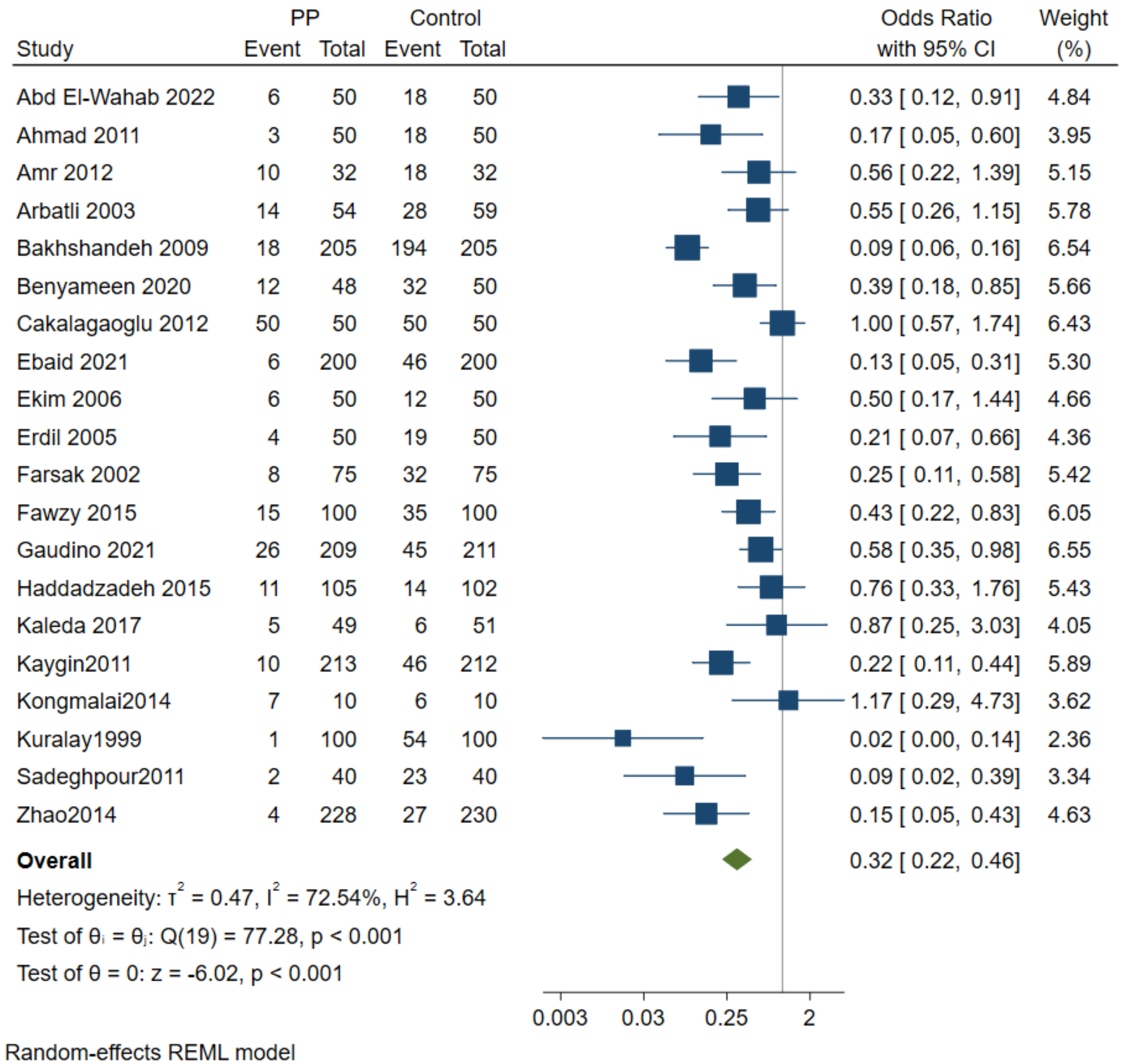


Supplementary Figure 4. Pooled estimates from RCTs evaluating the effect of PP on the incidence of AF after cardiac surgery with a random-effects model regarding type of surgery.



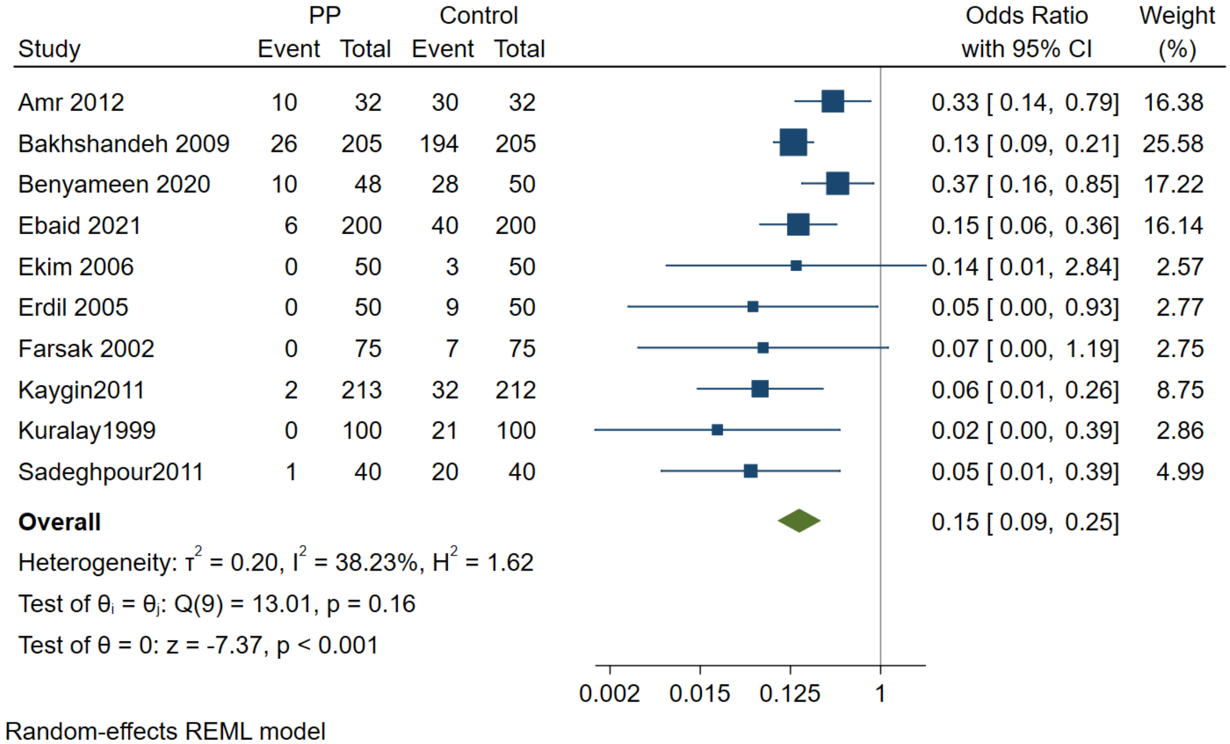
Supplementary Figure 5. Pooled estimates from RCTs evaluating the effect of PP on the incidence of SVT after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



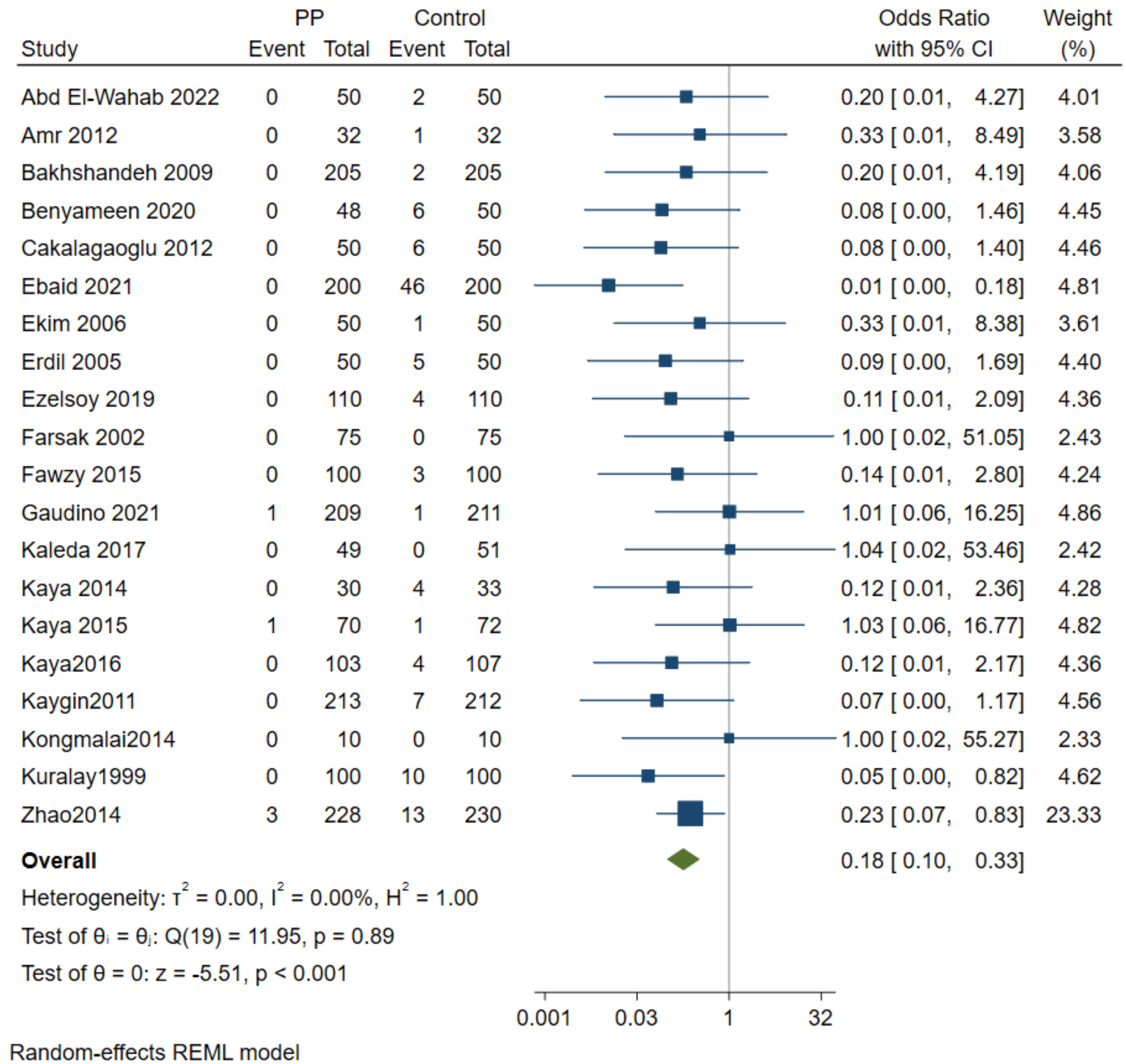
Supplementary Figure 6. Pooled estimates from RCTs evaluating the effect of PP on the incidence of early pericardial effusion after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



Supplementary Figure 7. Pooled estimates from RCTs evaluating the effect of PP on the incidence of late pericardial effusion after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



Supplementary Figure 8. Pooled estimates from RCTs evaluating the effect of PP on the incidence of pericardiac tamponade after cardiac surgery with a random-effects model.

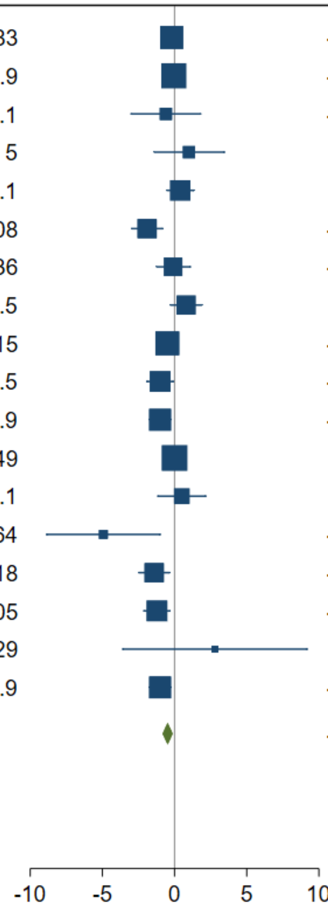
PP, posterior pericardiotomy; CI, confidence.

Study	PP N	PP Mean	PP SD	Control N	Control Mean	Control SD	Mean diff. with 95% CI	Weight (%)
Abd El-Wahab 2022	50	6.1	1.25	50	6.3	1.83	-0.20 [-0.81, 0.41]	8.24
Ahmad 2011	50	5.32	.95	50	5.38	.9	-0.06 [-0.42, 0.30]	9.83
Amr 2012	32	7.9	4.7	32	8.5	5.1	-0.60 [-3.00, 1.80]	1.81
Arbatli 2003	54	14	8	59	13	5	1.00 [-1.44, 3.44]	1.77
Bakhshandeh 2009	205	5.9	4.7	205	5.5	5.1	0.40 [-0.55, 1.35]	6.13
Benyameen 2020	48	10.5	2.27	50	12.4	3.08	-1.90 [-2.97, -0.83]	5.46
Cakalagaoglu 2012	50	9.58	2.6	50	9.68	3.36	-0.10 [-1.28, 1.08]	4.96
Erdil 2005	50	7.7	3.7	50	6.9	1.5	0.80 [-0.31, 1.91]	5.30
Ezelsoy 2019	110	7.3	1.65	110	7.8	2.15	-0.50 [-1.01, 0.01]	8.95
Farsak 2002	75	7	3.7	75	8	1.5	-1.00 [-1.90, -0.10]	6.40
Fawzy 2015	100	8	2.5	100	9	2.9	-1.00 [-1.75, -0.25]	7.35
Gaudino 2021	209	5.7	1.49	211	5.7	1.49	0.00 [-0.28, 0.28]	10.23
Kaleda 2017	49	12.4	4.3	51	11.9	4.1	0.50 [-1.15, 2.15]	3.25
Kaya 2014	30	6.63	2.71	33	11.56	10.64	-4.93 [-8.85, -1.01]	0.76
Kaya 2015	70	6.29	1.87	72	7.7	4.18	-1.41 [-2.48, -0.34]	5.48
Kaya2016	103	6.11	2.31	107	7.33	4.05	-1.22 [-2.12, -0.32]	6.44
Kongmalai2014	10	16.4	6.08	10	13.6	8.29	2.80 [-3.57, 9.17]	0.30
Kuralay1999	100	7	2.5	100	8	2.9	-1.00 [-1.75, -0.25]	7.35
Overall							-0.48 [-0.84, -0.13]	

Heterogeneity: $\tau^2 = 0.30$, $I^2 = 67.74\%$, $H^2 = 3.10$

Test of $\theta_i = \theta_j$: $Q(17) = 46.64$, $p < 0.001$

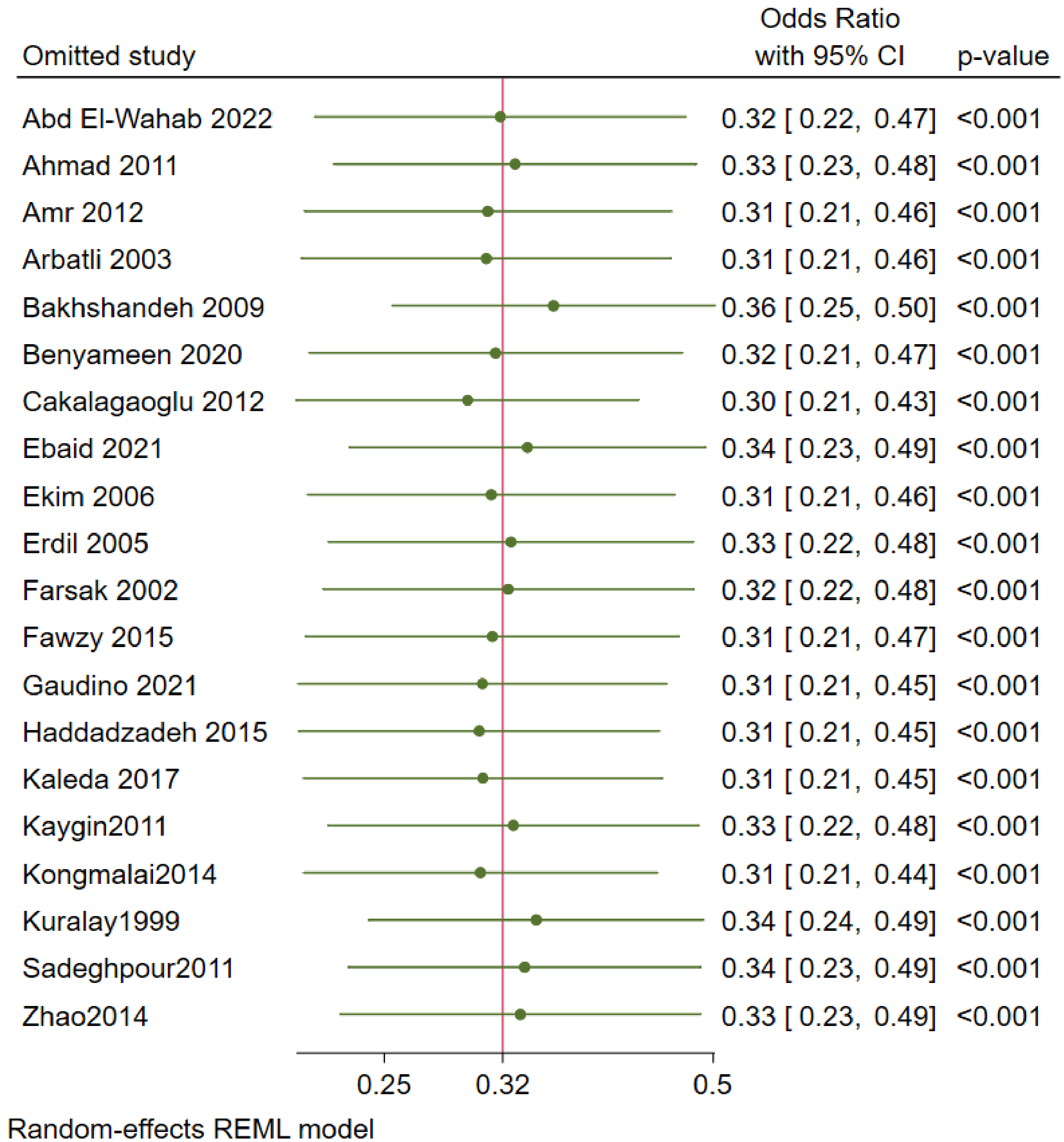
Test of $\theta = 0$: $z = -2.66$, $p = 0.01$



Random-effects REML model

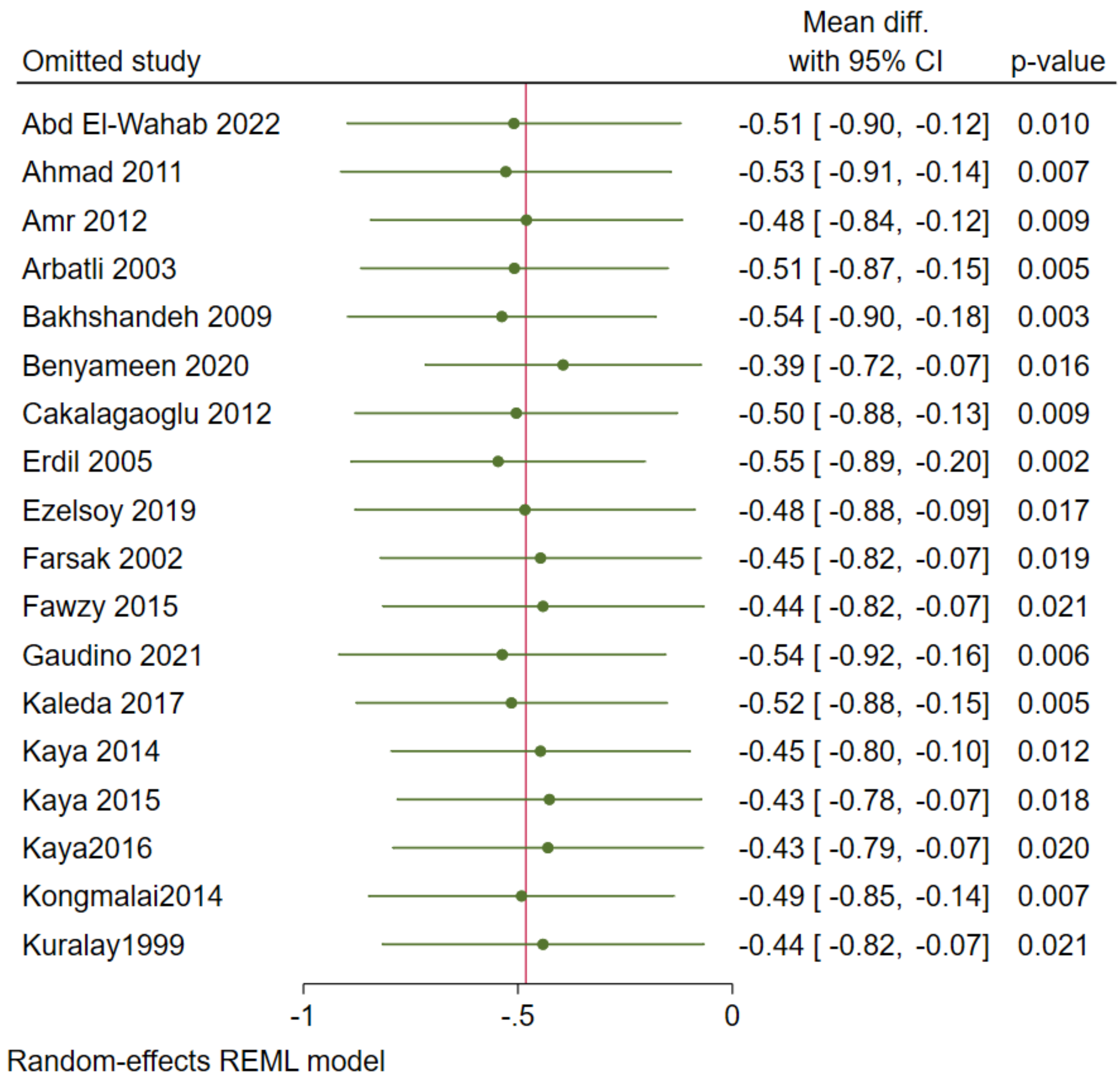
Supplementary Figure 9. Pooled estimates from RCTs evaluating the effect of PP on hospital stay after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



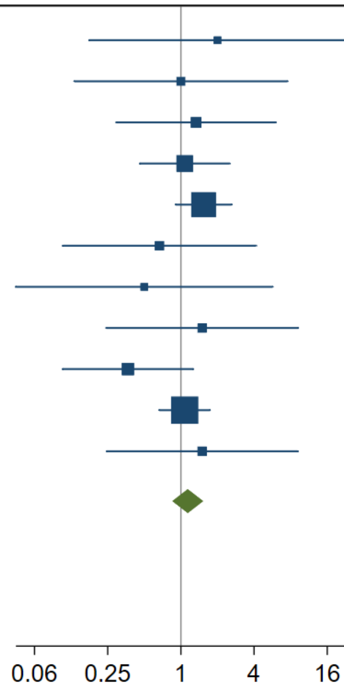
Red line refers to the summary estimate (OR: 0.32, 95% CI 0.22 to 0.46). The green magnitude refers to the change of the summary estimate when excluding each study. Overall, the effect was quite consistent.

Supplementary Figure 10. Leave-one-out analysis of early pericardial effusion.



Red line refers to the summary estimate (MD: -0.48, 95% CI [-0.84 to -0.13). The green magnitude refers to the change of the summary estimate when excluding each study. Overall, the effect was quite consistent.

Supplementary Figure 11. Leave-one-out analysis of hospital stay.



Study	PP Event	PP Total	Control Event	Control Total	Odds Ratio with 95% CI	Weight (%)
Ahmad 2011	2	50	1	50	2.00 [0.18, 22.77]	1.43
Amr 2012	2	32	2	32	1.00 [0.13, 7.54]	2.07
Bakhshandeh 2009	4	205	3	205	1.33 [0.29, 6.03]	3.71
Cakalagaoglu 2012	14	50	13	50	1.08 [0.46, 2.52]	11.67
Ebaid 2021	40	200	26	200	1.54 [0.90, 2.62]	29.93
Ekim 2006	2	50	3	50	0.67 [0.11, 4.16]	2.52
Erdil 2005	1	50	2	50	0.50 [0.04, 5.69]	1.43
Farsak 2002	3	75	2	75	1.50 [0.24, 9.24]	2.56
Kaya 2014	4	30	12	33	0.37 [0.11, 1.26]	5.54
Kaygin2011	41	213	38	212	1.07 [0.66, 1.74]	36.57
Kuralay1999	3	100	2	100	1.50 [0.25, 9.17]	2.58
Overall					1.14 [0.85, 1.52]	

Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$

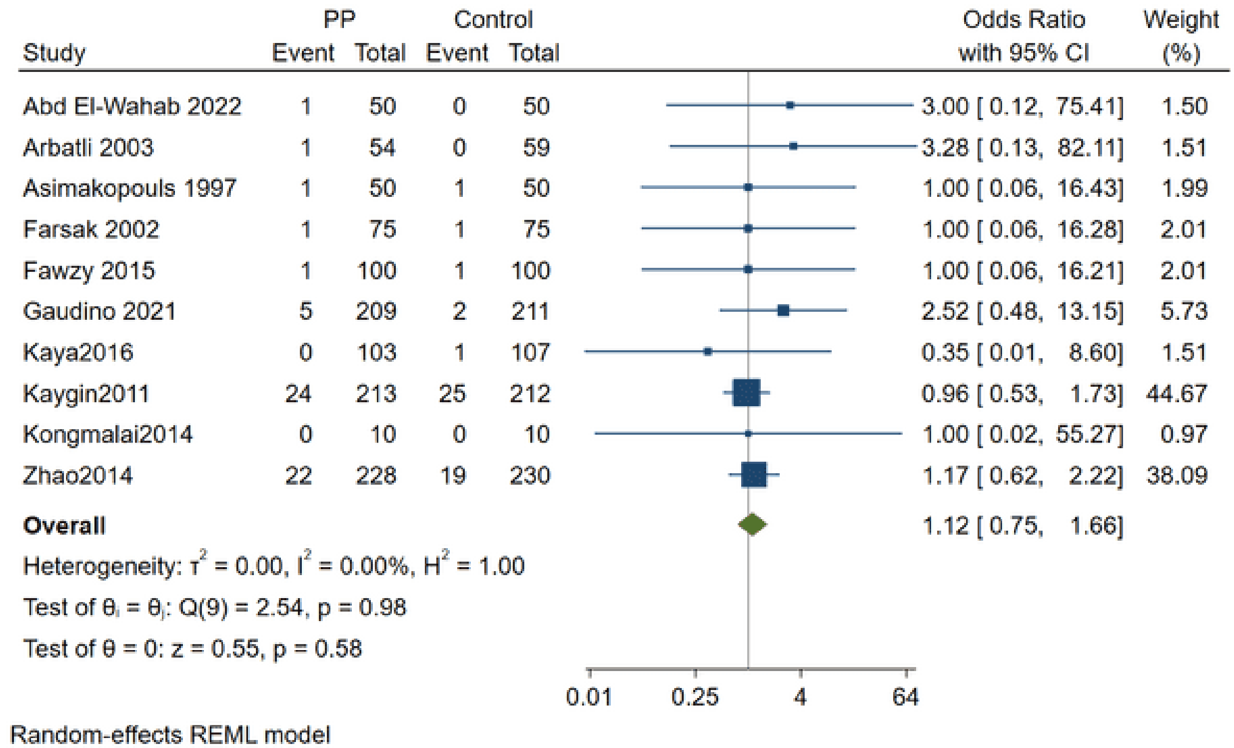
Test of $\theta_i = \theta_j$: Q(10) = 5.75, p = 0.84

Test of $\theta = 0$: z = 0.87, p = 0.38

Random-effects REML model

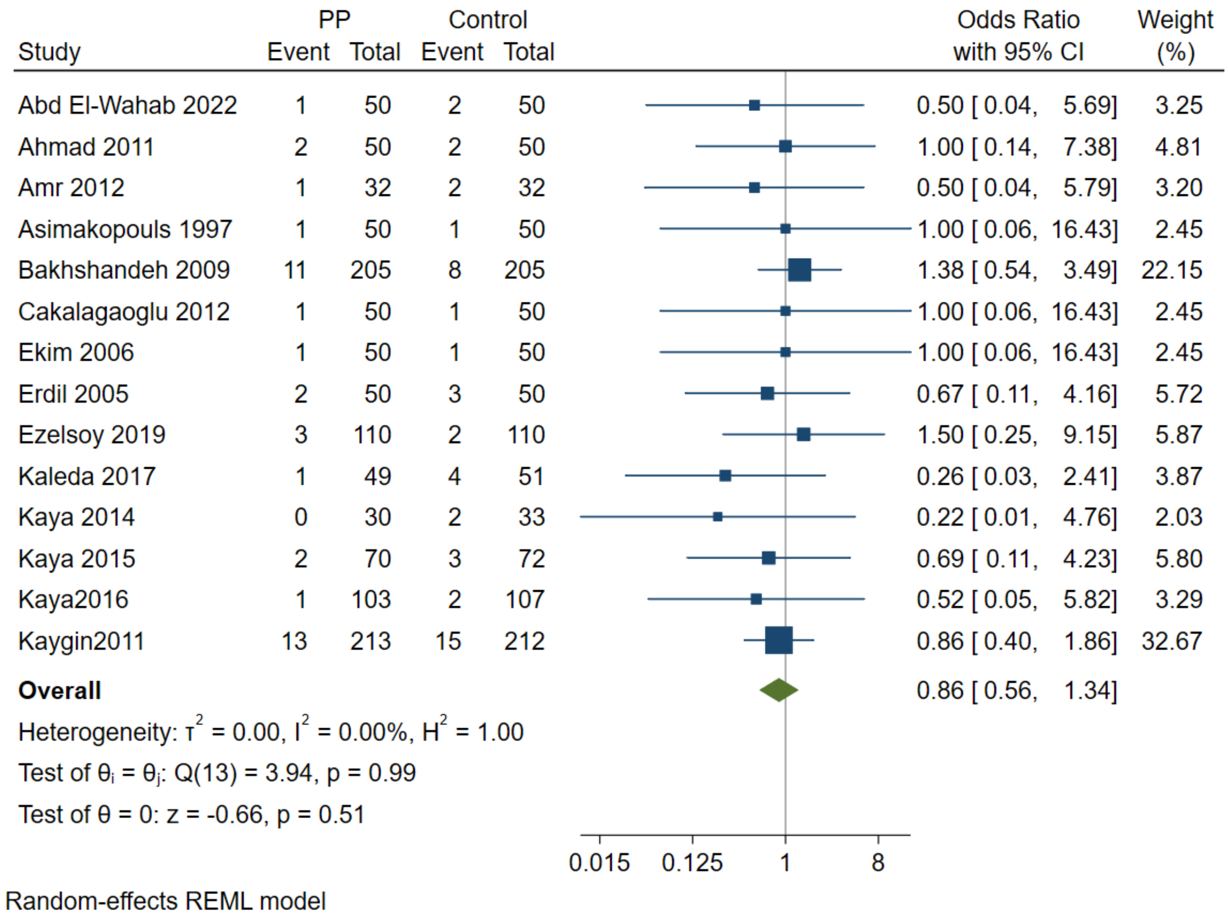
Supplementary Figure 12. Pooled estimates from RCTs evaluating the effect of PP on pulmonary complications after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



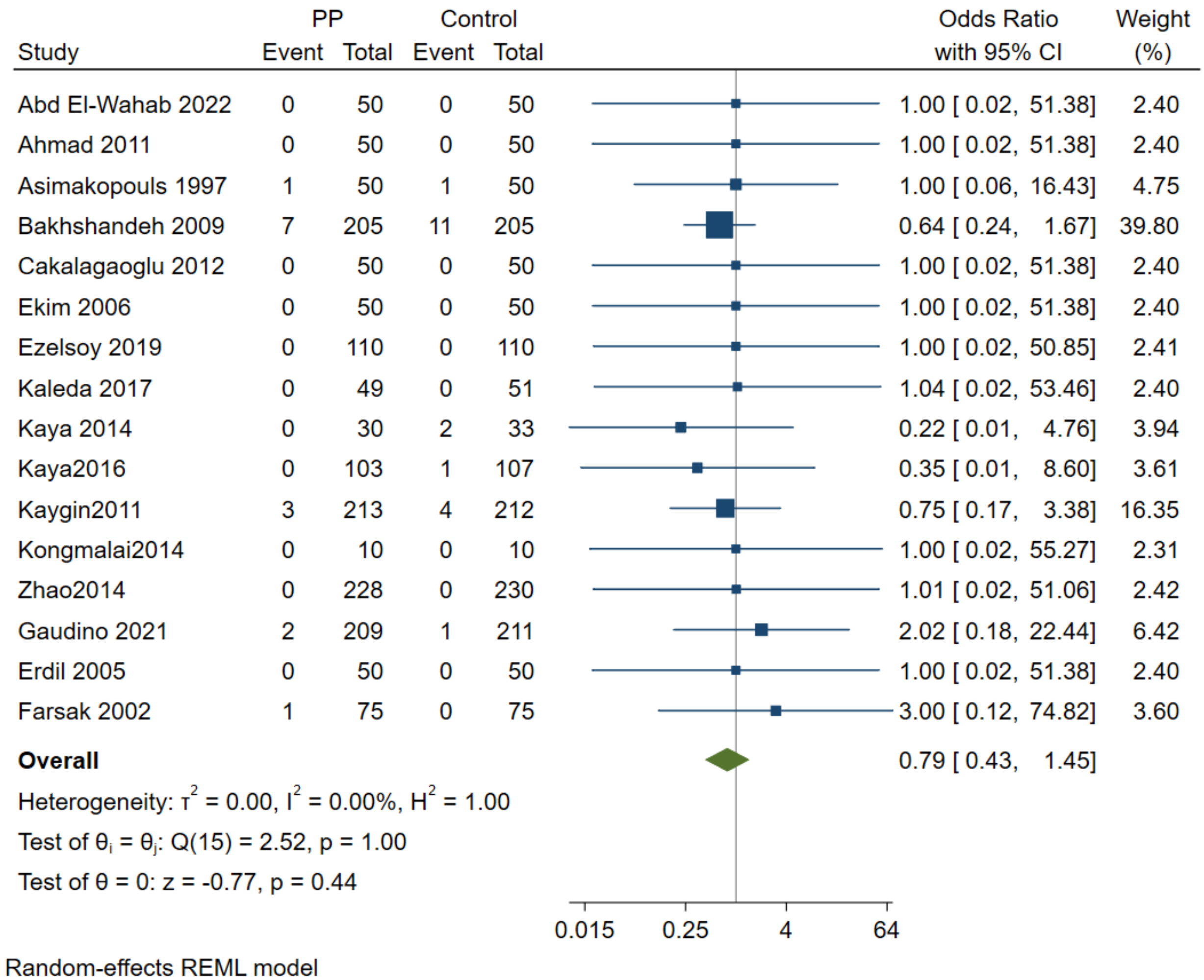
Supplementary Figure 13. Pooled estimates from RCTs evaluating the effect of PP on need for IABP after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



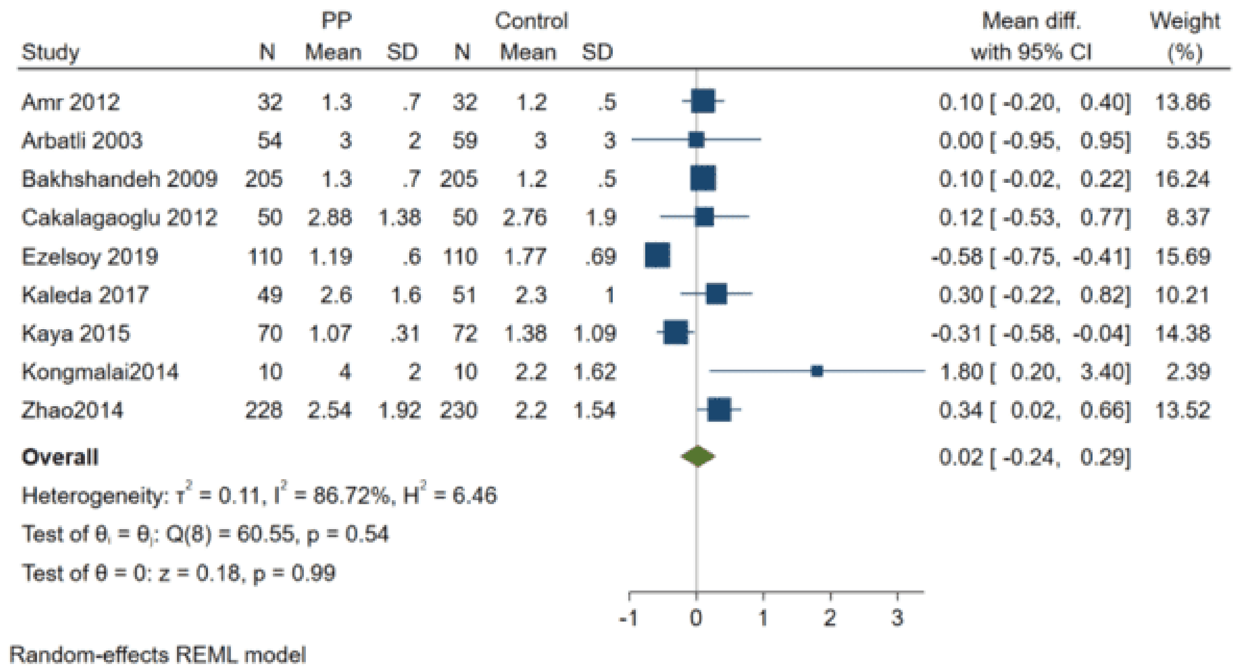
Supplementary Figure 14. Pooled estimates from RCTs evaluating the effect of PP on the incidence of revision surgery for bleeding after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



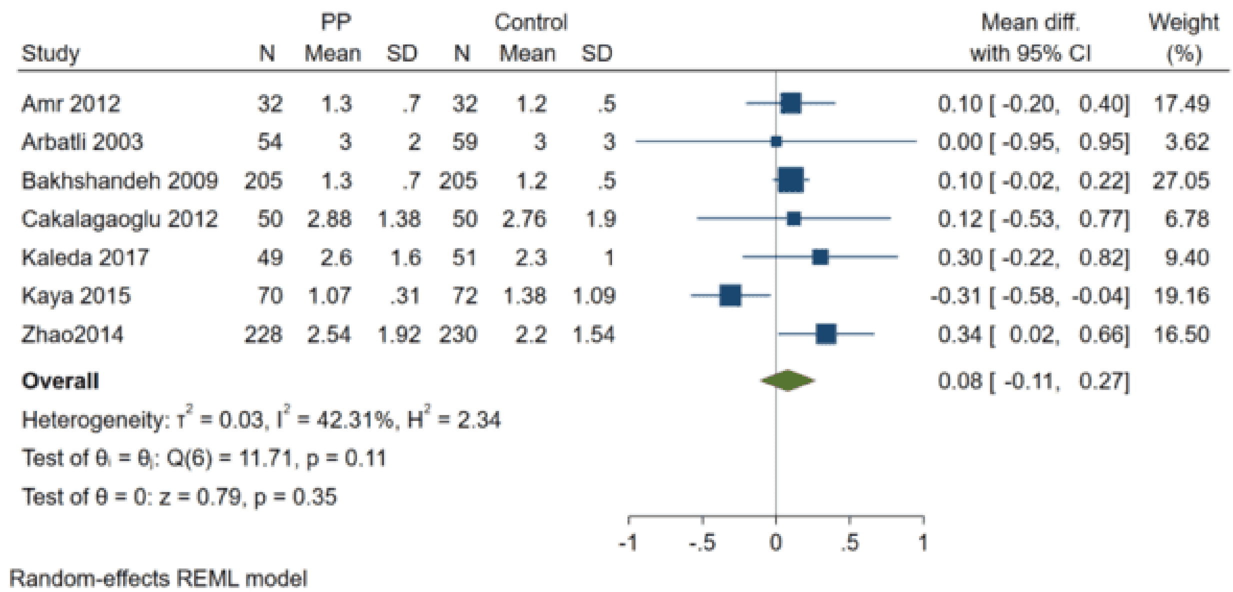
Supplementary Figure 15. Pooled estimates from RCTs evaluating the effect of PP on mortality after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



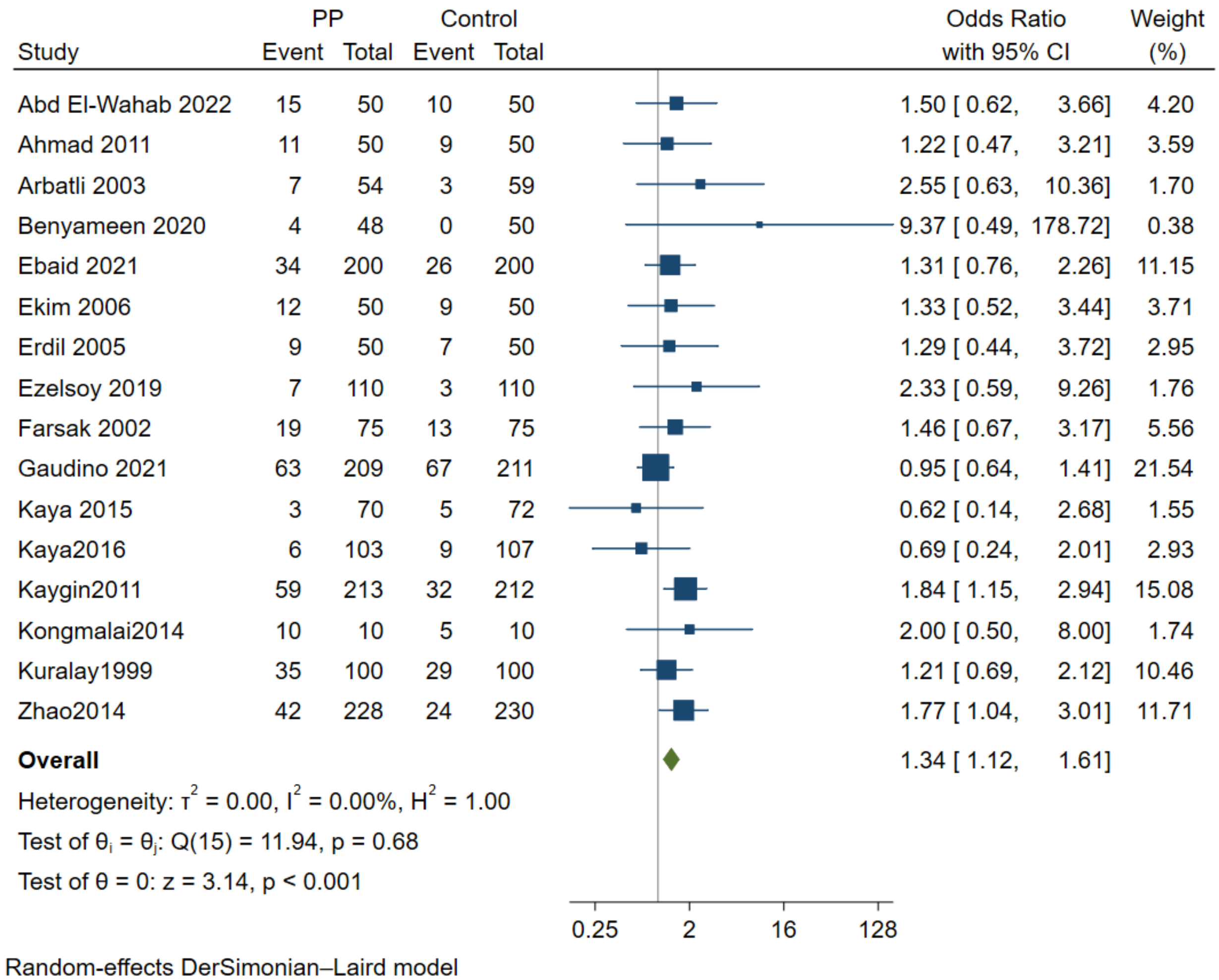
Supplementary Figure 16. Pooled estimates from RCTs evaluating the effect of PP on ICU stay after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



Supplementary Figure 17. Sensitivity analysis from RCTs evaluating the effect of PP on ICU stay after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.



Supplementary Figure 18. Pooled estimates from RCTs evaluating the effect of PP on pleural effusion after cardiac surgery with a random-effects model.

PP, posterior pericardiotomy; CI, confidence.