Systematic review and meta-analysis of randomized controlled trials assessing safety and efficacy of posterior pericardial drainage in patients undergoing heart surgery

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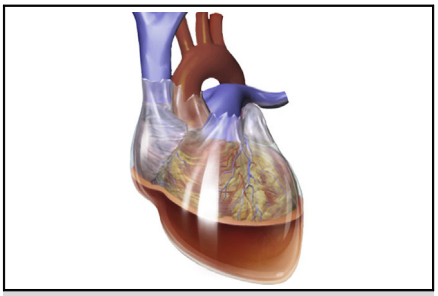
ABSTRACT

Objectives: To investigate the potential beneficial effects of posterior pericardial drainage in patients undergoing heart surgery.

Methods: Multiple online databases and relevant congress proceedings were screened for randomized controlled trials assessing the efficacy and safety of posterior pericardial drainage, defined as posterior pericardiotomy incision, chest tube to posterior pericardium, or both. Primary endpoint was in-hospital/30 days' cardiac tamponade. Secondary endpoints comprised death or cardiac arrest, early and late pericardial effusion, postoperative atrial fibrillation (POAF), acute kidney injury, pulmonary complications, and length of hospital stay.

Results: Nineteen randomized controlled trials that enrolled 3425 patients were included. Posterior pericardial drainage was associated with a significant 90% reduction of the odds of cardiac tamponade compared with the control group: odds ratio (95% confidence interval) 0.13 (0.07-0.25); $P < .001$. The corresponding event rates were 0.42% versus 4.95%. The odds of early and late pericardial effusion were reduced significantly in the intervention arm: 0.20 (0.11-0.36); $P < .001$ and 0.05 (0.02-0.10); $P < .001$, respectively. Posterior pericardial drainage significantly reduced the odds of POAF by 58% ($P < .001$) and was associated with significantly shortened (by nearly 1 day) overall length of hospital stay ($P < .001$). Reductions in postoperative complications translated into significantly reduced odds of death or cardiac arrest ($P = .03$) and numerically lower odds of acute kidney injury ($P = .08$).

Conclusions: Posterior pericardial drainage is safe and simple technique that significantly reduces not only the prevalence of early pericardial effusion and POAF but also late pericardial effusion and cardiac tamponade. These benefits, in turn, translate into improved survival after heart surgery. (J Thorac Cardiovasc Surg 2017;153:865-75)



Pericardial effusion often leads to delayed cardiac tamponade after heart surgery.

Central Message

Posterior pericardial drainage was found to reduce postoperative complications, such as cardiac tamponade and atrial fibrillation, among others. In addition, it improved survival after heart surgery.

Perspective

Pericardial effusion may be a source of morbidity after heart surgeries. Posterior pericardial drainage allows free escape of the fluid to the pleural space or on the outside via chest tubes. Previous studies showed that by reducing the amount of pericardial effusion, one can avoid postoperative atrial arrhythmias; whether other postoperative complications may be reduced remains unresolved.

See Editorial Commentary page 876.

Despite several recent improvements in intraoperative management and postoperative care, pericardial effusion remains a common clinical problem after cardiac surgery and may represent an important cause of morbidity.[1,2] Although limited pericardial effusion usually does not need any treatment (it is self-limiting and an incidental

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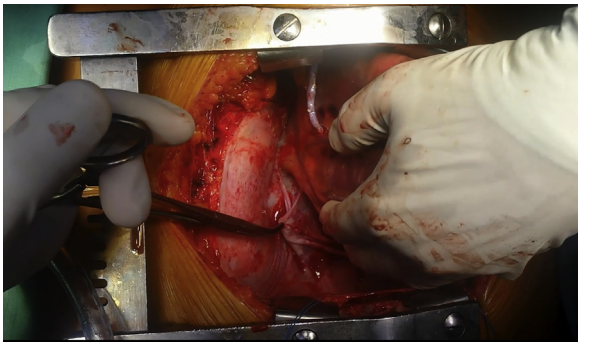
Abbreviations and Acronyms

AKI = acute kidney injury
CABG = coronary artery bypass grafting
CI = confidence interval
POAF = postoperative atrial fibrillation
PP = posterior pericardiotomy
OR = odds ratio
RCT = randomized controlled trial

Scanning this QR code will take you to supplemental figures, tables, and a procedural video.



VIDEO 1. Posterior pericardiotomy procedure. The "inverse T" incision is performed by the end of the surgical procedure to the posterior aspect of the pericardium. Attention is given not to dissect the phrenic nerve (to the right from the incision site) and that any bleeding vessels from the pericardiotomy site are clipped or meticulously cauterized. Video available at: http://www.jtcvsonline.org/article/S0022-5223(16)31682-8/addons.

finding during control echocardiography or computed tomography), large effusion may prolong recovery and be life-threatening in case of cardiac tamponade with hemodynamic compromise and/or multiorgan failure.[3] The reported incidence of postoperative pericardial effusion ranges between 1% and 85%, depending on study definitions and designs.[4-6]

In the majority of heart surgery procedures, the pericardium usually is opened longitudinally, because this allows free access to the heart and proximal great vessels. At the end of the procedure, the pericardium usually is left open, although some surgeons choose to close it, except for a small portion at the most caudal part. A second, or auxiliary, incision in the posterior pericardium (Video 1) sometimes is used to facilitate drainage of blood into the pleural cavity, where it can be evacuated with chest tubes. This technique has been shown in nonrandomized trials to reduce the incidence of both postoperative pericardial effusion and postoperative supraventricular tachycardia,[7] suggesting that a large volume of pericardial effusion is one of the main triggers of atrial fibrillation after cardiac surgery.[8]

The 2005 American College of Chest Physicians and subsequent 2006 European Association for Cardiothoracic Surgery Guidelines recommended that posterior pericardiotomy (PP) may be a useful, small step to reduce the incidence of postoperative atrial arrhythmias[9,10]; however, this recommendation was based on a single, small-scale randomized controlled trial[11] (RCT; strength of recommendation, B; evidence grade, fair; net benefit, intermediate). PP is not a current standard of care thus far and it is not used widely.

Because of the moderate strength of the recommendations, and because more RCTs that assess safety and efficacy of posterior pericardial drainage have been available since 2006, we performed a systematic review and meta-analysis to investigate whether potential reduction of pericardial effusion and atrial arrhythmias may affect positively the incidence of other potentially life-threatening conditions.

METHODS

Data Sources and Search Strategy

This current systematic review and meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement meta-analyses in health care interventions[12]; the checklist is available as Table E1. Relevant RCTs to be included were searched until March 2016 through PubMed, EMBASE, CINAHL, the Web of Science, the Cochrane Register of Controlled Clinical Trials (ie, CENTRAL), and Google Scholar as well as congress proceedings from major cardiac, thoracic, and cardiothoracic, as well as cardiology societies meetings. An exemplary PubMed search strategy is attached as Table E2. Abstracts were eligible for detailed assessment if available online and reporting outcomes of interest. Search terms were: "pericardiotomy," "pericardial incision," "pericardial window," "posterior pericardiotomy," "pericardial drainage," "posterior pericardium drainage," "posterior pericardial chest tube," "additional chest tube," "randomized," and "study/trial." No language restrictions were imposed. Both blinded and open-label trials were considered eligible. The most updated or inclusive data for each study were used for abstraction. References of original articles and previous meta-analyses were reviewed manually and cross-checked.

Selection Criteria, Quality Assessment, and Outcomes

Studies were included if they met all of the following criteria: (1) RCT; (2) human study; (3) study comparing strategy of posterior pericardial drainage with no intervention to the pericardium during heart surgery; and (4) studies reporting outcomes of interest within the investigated follow-up. Studies were only excluded if they (1) were nonrandomized or (2) had no control group. Narrative reviews, case reports, letters to the editor, etc, were not considered.

Posterior pericardial drainage was defined as (1) PP incision allowing drainage of the pericardial blood/effusion into the pleural cavity; (2) insertion of a chest tube in the posterior pericardium or; (3) both PP and insertion

of a chest tube in the pericardium. Patients in the control group underwent no intervention to the posterior pericardium.

Two independent reviewers (M.G. and M.K.) selected the studies for the inclusion and extracted studies and patients characteristics of interest and relevant outcomes. Two authors (M.G. and M.K.) independently assessed the trials' eligibility and risk of bias. Any divergences relative to study inclusion/exclusion or bias assessment were resolved after discussion with the third reviewer (L.A.). The bias risk for randomized studies was assessed by use of the components recommended by the Cochrane Collaboration,[13] ie, random sequence generation and random allocation; allocation concealment; blinding of participants, personnel, and outcome assessors; incomplete outcome data; selective outcome reporting; and other sources of bias. The discrepancies in bias assessment between assessors were recorded and reported as Cohen's kappa.[14]

Endpoints Selection

Primary clinical outcome was in-hospital/30 days' cardiac tamponade defined according to study protocol; remaining outcomes assessed were in-hospital/30 days: death or cardiac arrest; early and late pericardial effusion; postoperative atrial fibrillation (POAF); total chest drainage volume; pleural effusion with or without intervention; reoperation for bleeding; acute kidney injury (AKI); pulmonary complications; and length of intensive care unit and hospital stay. Late pleural effusion could have occurred beyond the investigated follow-up.

Statistical Analysis

Data were analyzed according to intention-to-treat principle wherever applicable. Odds ratios (ORs) and 95% confidence intervals (CIs) served as primary index statistics for dichotomous outcomes; for continuous outcomes, mean difference and corresponding 95% CIs were calculated by the use of a random effects model. To overcome the low statistical power of Cochran Q test, the statistical inconsistency test $I^2 = [(Q - df)/Q] \times 100\%$, where Q is the χ^2 statistic and df its degrees of freedom, was used to assess heterogeneity.[15] It examines the percentage of interstudy variation, with values ranging from 0% to 100%. An I^2 value less than 40% indicated no obvious heterogeneity, values between 40% and 70% were suggestive of moderate heterogeneity, and $I^2 > 70\%$ were considered high heterogeneity.

Pooled ORs were calculated via the Mantel-Haenszel model with weight assigned to each included study adjusted to include a measure of variation (τ^2) in the effects reported between studies. This approach estimates the amount of between-study variation by comparing each study's result with a Mantel-Haenszel fixed-effect meta-analysis result and is most conservative in case of low between study heterogeneity.[16] In case the degree of heterogeneity exceeded 40%, an inverse variance (DerSimonian-Laird) random-effects model was applied. As a preferred approach when intervention effects are small (ORs are close to one) and events are not particularly common, estimates were calculated by the use of the fixed-effects Peto method.[17] In case there were "0 events" reported in both arms, calculations were repeated, as a sensitivity analysis, by the use of risk difference and respective 95% CIs.

Furthermore, an attempt was made to explore the possible relationship between age, sex, hypertension, type 2 diabetes, type of the surgery, mean number of grafts, duration of cardiopulmonary bypass, crossclamp, and study total number of patients and the occurrence of primary endpoint. Depending on availability of the data, studies were dichotomized separately by these characteristics. The cutoff points were made so as to have equal, or nearly equal, numbers of studies on each side of the dichotomy. Pooled ORs were obtained for each subset of studies and combined in a random-effect meta-analysis. As a sensitivity analysis, the calculations were repeated stratified by the operative technique and after deleting studies, one in a turn, to see whether the results for the primary endpoint were not influenced by single report. In addition, studies not reporting the exact definition/diagnostic criteria for the primary endpoint also were excluded in the sensitivity analysis and estimates recalculated.

Potential publication bias was evaluated by constructing a funnel plot in which the standard error of the log OR was plotted against the OR. The asymmetry of the plot was estimated both visually and by a linear regression approach.[18] Review Manager V.5.1 (The Nordic Cochrane Centre, København, Denmark) and Comprehensive Meta-Analysis, v. 2 (Biostat, Englewood, NJ) were used for statistical computations. P values $\leq .05$ were considered statistically significant and reported as 2-sided, without adjustment for multiple comparisons.

RESULTS

Study Selection

The study selection process and reasons for exclusion of some studies are described in Figure 1. A systematic search of the online databases allowed us to collect 37 potentially eligible records that were retrieved for scrutiny. Of those, 18 were further excluded because they were not pertinent to the design of the meta-analysis or did not meet the explicit inclusion criteria. Nineteen RCTs[11,19-37] that enrolled 3425 patients eventually were included in the analysis. Patients were divided into 2 groups: those with a posterior pericardial drainage (n = 1723) and control group without (n = 1702). In the group of patients who received a posterior pericardial drainage, 1447 patients underwent PP[11,19-26,28-30,33-37]; in 103 patients, a chest tube was placed within the posterior pericardium[27,30]; 173 patients received both PP and posterior pericardium chest tube.[31,32] On-pump coronary artery bypass grafting (CABG) was the most frequently performed cardiac procedure,[11,19,20,23,25,28,30-36] followed by combined CABG and/or valve replacement.[21,22,24,37] Two studies reported on patients undergoing valve replacement and/or ascending aorta surgery[26,27] and another on patients who received off-pump CABG alone.[29] Summaries of the studies, as well as patients' baseline characteristics, are reported in Table 1. Table E3 lists exclusion criteria within single studies; these were predominantly renal dysfunction, endocrine disorders, severe left ventricle dysfunction, history of arrhythmias, and previous cardiac surgery. Definitions or diagnostic criteria for assessed clinical endpoints are listed in Table E4.

In most studies, 2 drains were placed at the end of surgery: one in the left pleural cavity and the other in the anterior mediastinum, whereas the pericardium was left open anteriorly. PP was performed as described by Mulay and colleagues[38] and comprised a longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm in most cases.[11,19-26,28-32,35,36] A detailed technique is reported in Table E5. Table E6 includes an analysis of potential sources of bias for randomized studies using the components recommended by the Cochrane Collaboration. Further publication bias as assessed by funnel plots for the investigated endpoints is shown in Figure E1, *A* to *H*. Two of the included studies reported intervention-

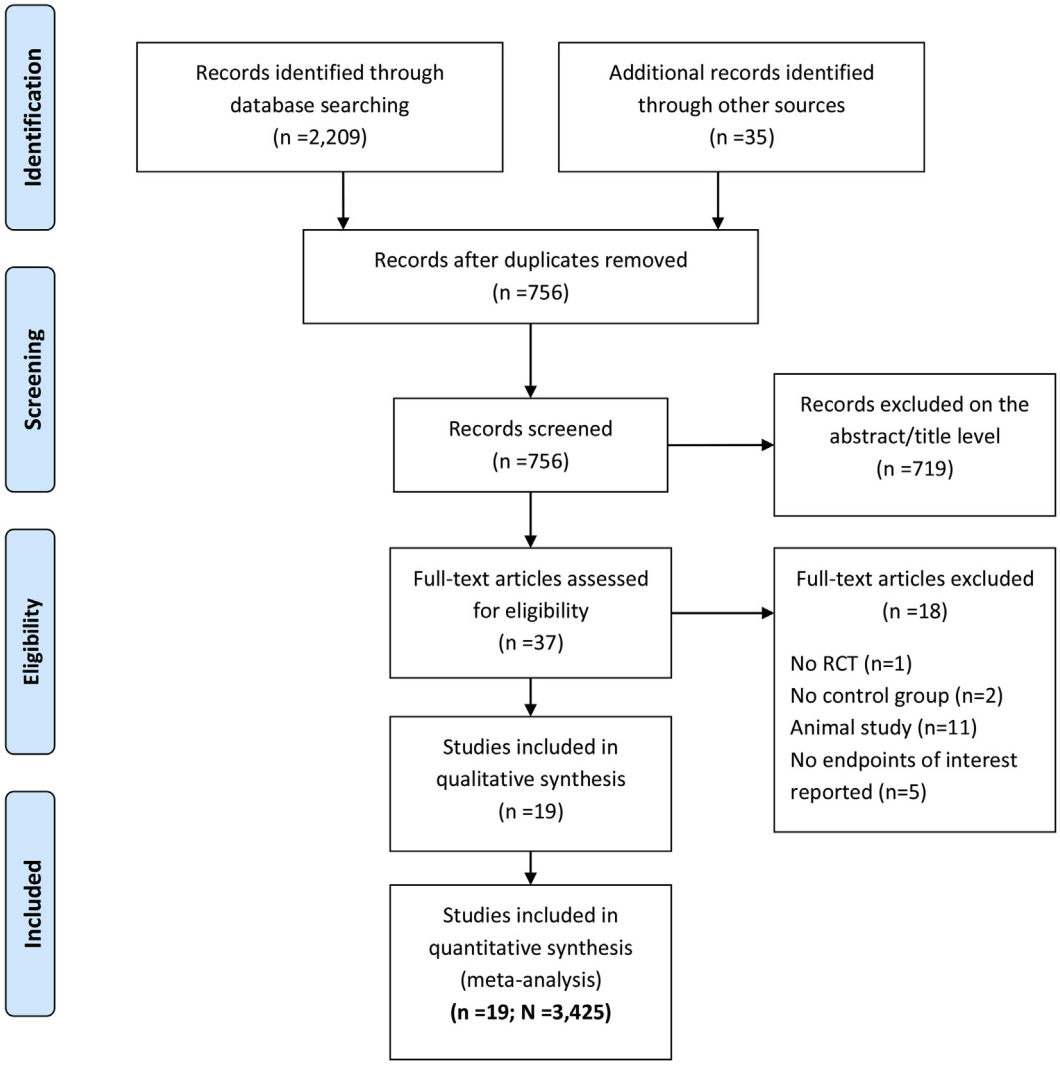


FIGURE 1. Flow diagram according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. *RCT*, Randomized controlled trial.

related complications: Zhao and colleagues[37] reported one case of postoperative bleeding due to dropping of the hemoclip from the inverse-T incision and Farsak and colleagues[11] reported one case of re-exploration of the grafts because of hemodynamic instability and uncontrollable arrhythmia. The reason was found to be attributable to a protruding sequential vein graft from the pericardiotomy side.

Primary Endpoint

A funnel plot constructed for the primary endpoint revealed signs of moderate asymmetry (Figure E1, *A*), but this was not significant (Egger test, $P = .11$). Fourteen studies (n = 2844) were included. Individual and overall ORs for cardiac tamponade are depicted in Figure 2. Posterior pericardial drainage was associated with a significant approximately 90% reduction of the odds of cardiac tamponade compared with the control group: OR (95% CI) 0.13 (0.07-0.25); $P < .001$; $I^2 = 0\%$ in the fixed-effects model. The corresponding event rates were 0.42% (6/1431) versus 4.95% (70/1413).

Death or Cardiac Arrest

No asymmetry, thus, no signs of publication bias, was noted in the analysis of death or cardiac arrest (Figure E1, *B*). Ten RCTs enrolling 2141 patients provided data for the analysis. The ORs of death or cardiac arrest were significantly decreased by roughly 50% in the posterior pericardial drainage group compared with controls: Peto OR (95% CI): 0.49 (0.25-0.94); $P = .03$; $I^2 = 0\%$. There were 12 deaths (1.11%) or cardiac arrests compared with 24 (2.26%), respectively, in the posterior pericardial drainage and control groups (Figure 3).

Early and Late Pericardial Effusion

Figure 4 lists individual and overall ORs for early (Figure 4, *A*) and late (Figure 4, *B*) pericardial effusion

TABLE 1. Baseline characteristics of included studies

Study	Setting	Intervention	No. patients	Mean age, y	Male (%)	CPB, min	Crossclamp, min	HT, %	DM, %	Mean no. grafts
Arbatli and colleagues[19]	CABG	Posterior pericardiotomy	54	62 ± 8	83	117 ± 32	58 ± 17	61	26	2.9 ± 0.9
		Control	59	60 ± 9	74	112 ± 35	60 ± 19	59	26	2.9 ± 0.9
Asimakopoulos and colleagues[20]	CABG	Posterior pericardiotomy	50	61 ± 9	nd	66 ± 17	35 ± 2	20	20	2.7 ± 0.6
		Control	50	61 ± 2	nd	62 ± 17	33 ± 8	38	10	2.7 ± 0.7
Bakhshandeh and colleagues[21,22]	CABG	Posterior pericardiotomy	205	67 ± 8	38	NR	NR	55	40	3.2 ± 0.9
	Valve replacement	Control	205	68 ± 9	42			46	47	3.3 ± 0.7
Bolourian and colleagues[23]	CABG	Posterior pericardiotomy	87	60 ± 11	71	95 ± 38	56 ± 24	47	NR	3.4 ± 0.7
		Control	87	60 ± 10	71	94 ± 38	54 ± 22	47		3.1 ± 0.9
Cakalagaoglu and colleagues[24]	CABG	Posterior pericardiotomy	50	63 ± 8	80	92 ± 22	55 ± 19	68	28	2.8 ± 0.9
	Valve replacement	Control	50	59 ± 13	86	88 ± 38	53 ± 30	62	30	2.5 ± 0.75
Ekim and colleagues[25]	CABG	Posterior pericardiotomy	50	59 ± 9	66	89 ± 21	63 ± 19	52	20	2.8 ± 0.4
		Control	50	60 ± 3	64	87 ± 26	62 ± 12	48	22	2.7 ± 0.9
Erdil and colleagues[26]	Valve replacement	Posterior pericardiotomy	50	41 ± 14	46	114 ± 51	86 ± 40	NR	NR	NA
	Ascending aorta surgery	Control	50	43 ± 15	32	115 ± 44	86 ± 37			
Eryilmaz and colleagues[27]	Valve replacement	Additional chest tube	70	55 ± 7	41	171 ± 22	NR	NR	NR	NA
	Ascending aorta surgery	Control	70	56 ± 7	46	176 ± 19				
Farsak and colleagues[11]	CABG	Posterior pericardiotomy	75	64 ± 9	36	57 ± 6	35 ± 11	41	17	NR
		Control	75	63 ± 5	32	61 ± 9	40 ± 9	36	15	
Fawzy and colleagues[28]	CABG	Posterior pericardiotomy	100	54 ± 9	64	89 ± 29	55 ± 21	56	48	2.7 ± 0.6
		Control	100	56 ± 10	68	87 ± 23	59 ± 17	54	46	2.6 ± 0.4
Haddadzadeh and colleagues[29]	OPCAB	Posterior pericardiotomy	105	61 ± 10	69	NA	NA	55	41	2.1 ± 0.7
		Control	102	61 ± 11	69			44	31	2.1 ± 0.7
Kaya and colleagues[30]	CABG	Posterior pericardiotomy	30	60 ± 10	77	80 ± 26	43 ± 16	50	53	3.37 ± 1.19
		Additional chest tube	33	59 ± 8	76	82 ± 21	43 ± 15	70	61	3.18 ± 0.85
		Control	33	59 ± 11	88	86 ± 27	46 ± 21	55	36	3.0 ± 0.90
Kaya and colleagues[31]	CABG	Posterior pericardiotomy + additional chest tube	70	58 ± 9	86	78 ± 20	44 ± 13	44	56	3.33 ± 0.94
		Control	72	56 ± 9	81	80 ± 23	45 ± 13	40	57	3.15 ± 0.69
Kaya and colleagues[32]	CABG	Posterior pericardiotomy + additional chest tube	103	58 ± 9	78	82 ± 26	45 ± 19	47	47	3.01 ± 1.08
		Control	107	57 ± 9	79	77 ± 23	43 ± 15	38	53	2.88 ± 0.85
Kaygin and colleagues[33]	CABG	Posterior pericardiotomy	213	59 ± 11	50	NR	NR	NR	55	NR
		Control	212	59 ± 11	50				56	
Kongmalai and colleagues[34]	CABG	Posterior pericardiotomy	10	65 ± 13	nd	128 ± 49	84 ± 38	NR	NR	NR
		Control	10	59 ± 5	nd	152 ± 45	107 ± 39			
Kuralay and colleagues[35]	CABG	Posterior pericardiotomy	100	57 ± 12	77	48 ± 5	36 ± 12	NR	NR	2.8 ± 0.8
		Control	100	61 ± 8	73	51 ± 4	43 ± 9			3.1 ± 0.5
Sadeghpour and colleagues[36]	CABG	Posterior pericardiotomy	40	61 ± 8	78	NR	NR	NR	65	3.2 ± 0.7
		Control	40	60 ± 13	80				37	3.5 ± 1.5
Zhao and colleagues[37]	CABG	Posterior pericardiotomy	228	54 ± 16	60	110 ± 46	67 ± 29	41	43	NR
	Valve replacement	Control	230	56 ± 18	54	103 ± 51	62 ± 23	39	47	

CPB, Cardiopulmonary bypass; *crossclamp*, aortic cross clamp; *HT*, hypertension; *DM*, diabetes mellitus; *CABG*, coronary artery bypass grafting; *nd*, not done; *NR*, not reported; *NA*, not applicable; *OPCAB*, off-pump coronary artery bypass.

within the investigated comparison. Sixteen studies (3009 patients) were included in the analysis of early pericardial effusion: posterior pericardial drainage was associated with 80% reduction of the odds of early effusion: 0.20 (0.11-0.36); $P < .001$; $I^2 = 71\%$. Early pericardial effusion occurred in 6.2% (94/1516) of the patients who received a posterior pericardial drainage compared with 23.38% (249/1493) in the control group. Even a greater protective

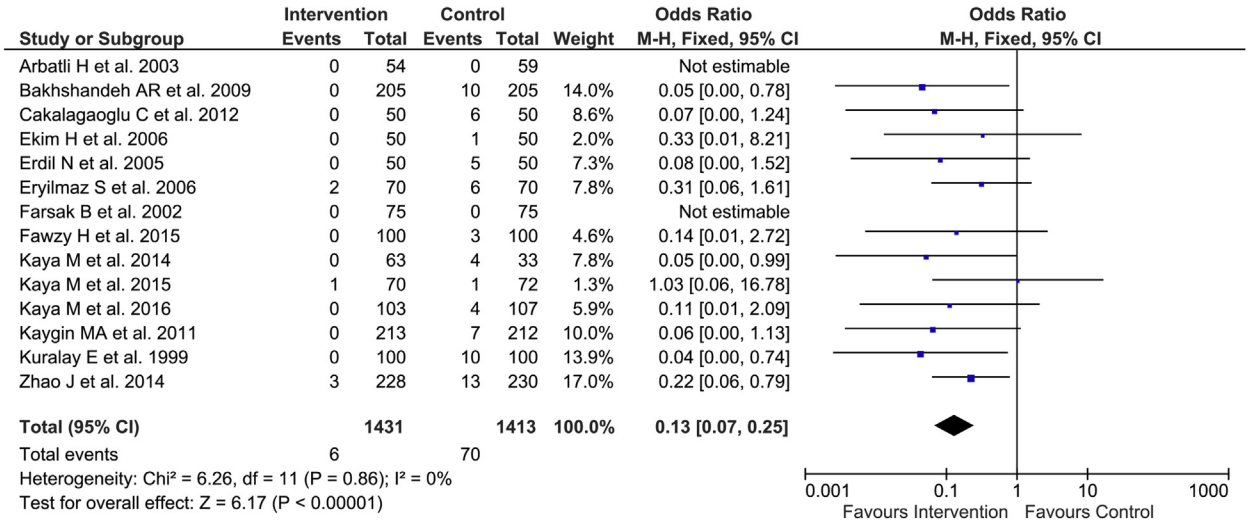


FIGURE 2. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for prevention of primary endpoint cardiac tamponade after heart surgery. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

effect of posterior pericardial drainage was seen in the analysis of late pericardial effusion: only 5 patients (0.51%) in the intervention group were diagnosed with late pericardial effusion compared with 121 patients (12.82%) in the control group (OR [95% CI]: 0.05 [0.02-0.10]; $P < .001$; $I^2 = 0\%$).

Postoperative Atrial Fibrillation

Incidence of POAF was reported in 17 RCTs enrolling 3245 patients. Individual and overall ORs are depicted in Figure 5. Posterior pericardial drainage significantly reduced the odds of POAF by 58%: 0.42 (0.29-0.59); $P < .001$; $I^2 = 66\%$. The incidence of POAF ranged from 12.55% (205/1633) to 24.81% (400/1612) in the group of patients who received a posterior pericardial drainage and in those who did not, respectively.

Posterior pericardial drainage did not increase significantly the volume of total chest tube drainage (mean difference [95% CI]: 24.85 [−21.48 to 71.17] mL; $P = .29$; $I^2 = 91\%$; Figure E2) but was associated with a 64% increase in the OR of pleural effusion managed with or without intervention: OR (95% CI): 1.64 (1.27-2.13); $P < .001$; $I^2 = 1\%$; and reported in 18.56% and 12.35% of cases in posterior pericardial drainage and control groups, respectively (Figure E3), although there was no difference between posterior pericardial drainage and usual drainage with regard to pulmonary complications: 0.89 (0.65-1.23); $P = .48$; $I^2 = 0\%$ (Figure E4). Similarly, no differences were observed in the incidence of reoperations for bleeding (3.50% [36/1028] vs 4.16% [42/1008]): 0.83 (0.53-1.30); $P = .42$; $I^2 = 0\%$ (Figure E5).

Analysis of studies with a focus to the incidence of AKI (4 studies; 816 patients) showed that posterior pericardial drainage compared with the control group was associated with a statistical trend favoring the intervention: Peto OR (95% CI): 0.41 (0.15-1.10); $P = .08$; $I^2 = 5\%$. Respective

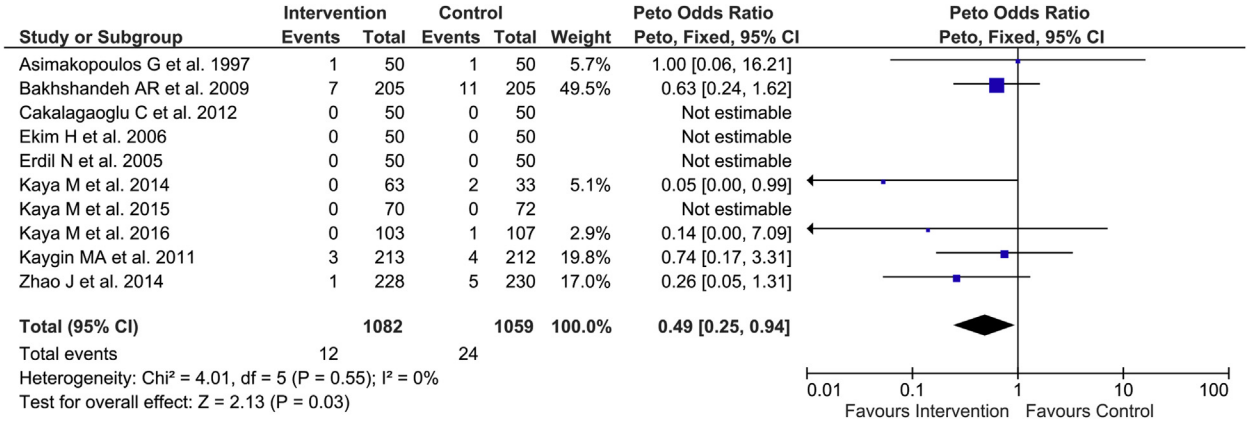
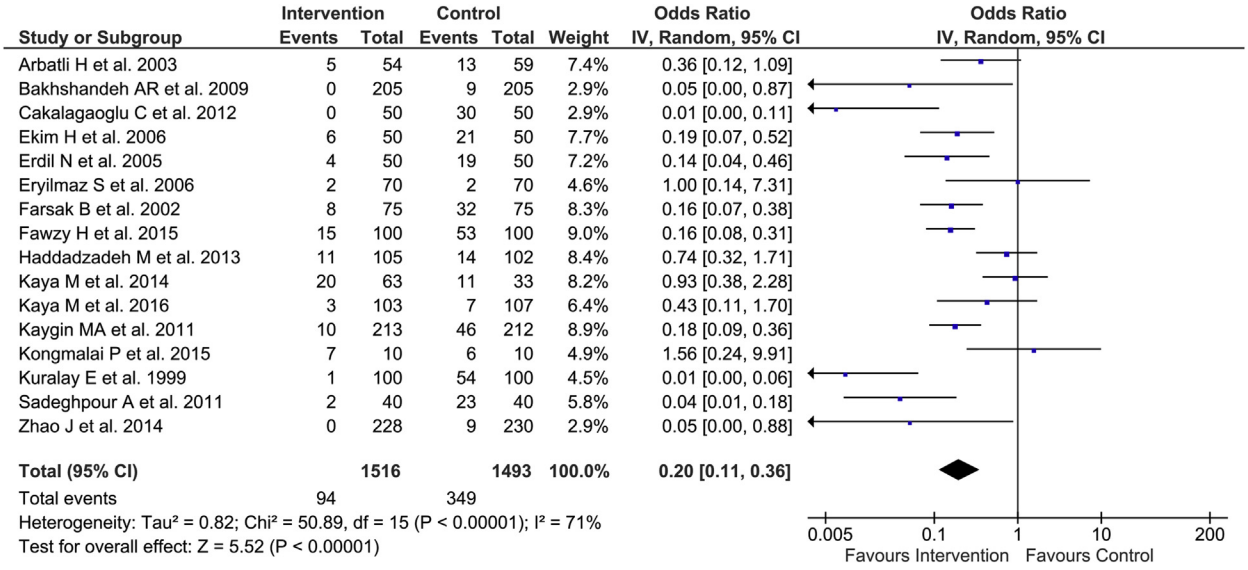


FIGURE 3. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for prevention of death or cardiac arrest after heart surgery. *CI*, Confidence interval.



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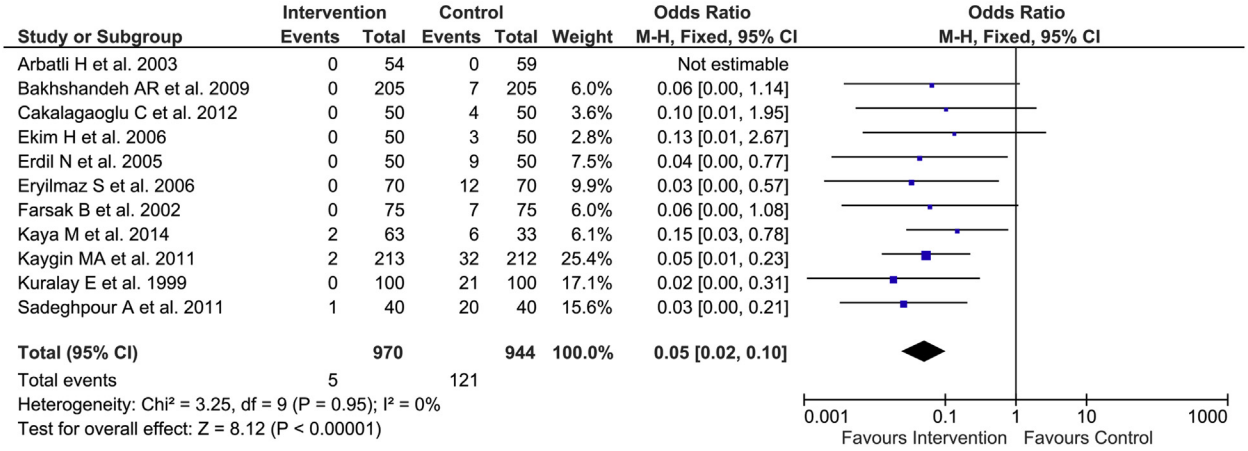

B

FIGURE 4. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for prevention of early (A) and late (B) pericardial effusion after heart surgery. *IV*, Inverse variance; *CI*, confidence interval; *M-H*, Mantel-Haenszel.

event rates were 1.66% (7/421) and 2.78% (11/395) (Figure E6).

In addition, although the length of stay in the intensive care unit was not significantly different with either approach (mean difference [95% CI]: 0.03 [−0.21 to 0.28] days; $P = .80$; $I^2 = 64\%$ [Figure E7, *A*]), a significant reduction of nearly 1 day was observed when the overall length of hospital stay was investigated: −0.82 (−1.12 to −0.51) days; $P < .001$; $I^2 = 57\%$ (Figure E7, *B*).

Sensitivity Analyses

In a prespecified subgroup analysis, calculations repeated for the primary endpoint stratified by study/patients' baseline characteristics confirmed the consistency of the effect of posterior pericardial drainage throughout different patient populations, study designs, and operative characteristics. *P* values for interaction ranged from .20 to .79 (Figure 6). Calculations repeated for the primary endpoint after we accounted for studies reporting "0 events" in both arms with risk difference effect measure did not change the direction nor the magnitude of the effect: −0.04 (−0.06 to −0.02; $P < .001$; $I^2 = 64\%$; Figure E8). Additionally performed sensitivity subgroup analysis stratified by the operative technique (PP vs posterior pericardium chest tube vs both) did not reveal any between subgroup interaction and indirectly demonstrated that there were no differences between the approaches to posterior pericardial drainage. ($P_{int} = 0.42$; Figure E9). There was no sign of "big-study effect" in the influence analysis performed by deleting studies, one in a turn, and repeating the calculations for the primary endpoint (Figure E10). Similarly, exclusion of studies not reporting the exact

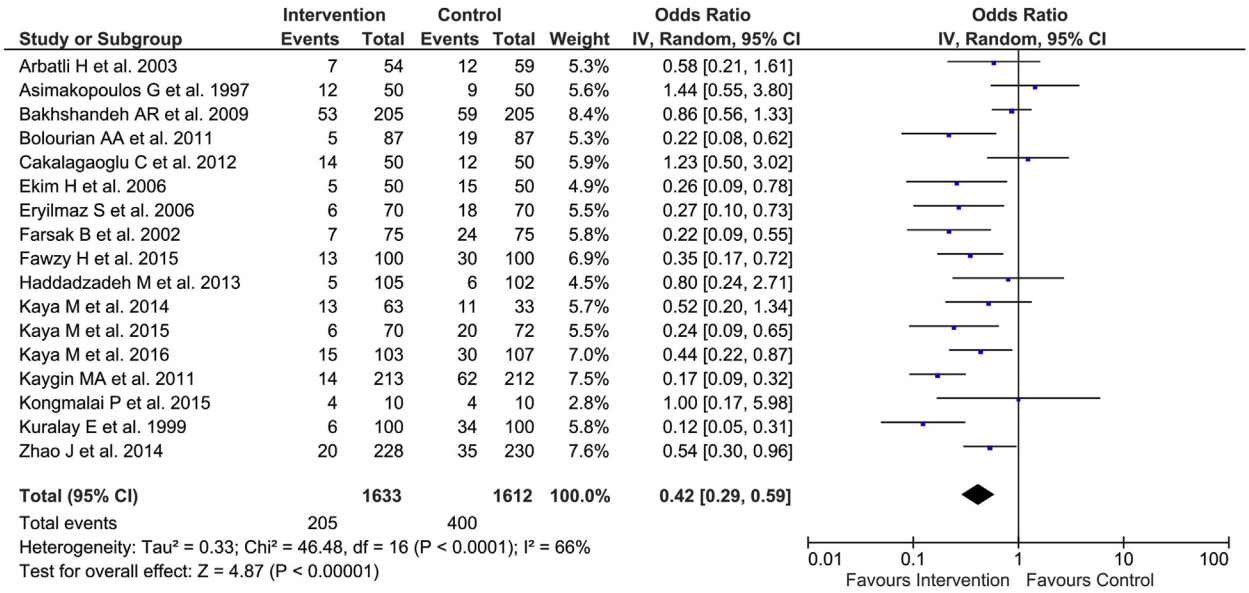

FIGURE 5. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for prevention of postoperative atrial fibrillation after heart surgery. *IV*, Inverse variance; *CI*, confidence interval.

definition/diagnostic criteria for the primary endpoint did not alter the final estimates.

DISCUSSION

The current systematic review and meta-analysis of RCTs is the largest database that analyzes the potential beneficial value of a posterior pericardial drainage after heart surgery. The principle finding is the high effectiveness of posterior pericardial drainage in preventing early and late pericardial effusions, cardiac tamponade, and possibly mortality without compromising safety. Posterior pericardial drainage, whether performed by PP, a chest tube to posterior pericardium, or both PP and a chest tube, was demonstrated to (1) significantly reduce the odds of primary endpoint 30-day cardiac tamponade by nearly 90%; (2) significantly reduce the odds of early and late pericardial effusions by 80% and 95%, respectively; (3) significantly reduce the odds of POAF by almost 60%; and (4) significantly shorten the length of hospital stay. In addition, the present meta-analysis with 19 RCTs and 3425 patients is able to demonstrate significantly reduced odds of death or cardiac arrest. A statistical trend towards lesser odds of AKI was shown as well. Although there were no differences regarding the total volume of chest tube drainage, more pleural effusions (requiring intervention or not) were reported in the intervention arm; this, however, did not translate into a greater incidence of pulmonary complications compared with control group.

Delayed-onset pericardial effusion after heart surgery may produce significant morbidity as the result of its presentation as well as management by traditional surgical techniques not uncommonly involving resternotomy. The pericardial fluid collected in a gap in front of the heart usually is drained easily via a chest drain just behind the sternum. In contrast, pericardial adhesions frequently are observed between the inferior and posterior surfaces of the heart and the diaphragm that in turn may create an enclosed gap that makes drainage difficult. The use of pericardiotomy technique enables better drainage of the pericardial fluid and prevents the formation of effusion or tamponade. Typically, PP is performed as a longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.[38] This allows unobstructed drainage of the blood and fluids from the pericardium directly to the pleural space. PP is easy to perform and it is cost-effective. Compared with a simple chest tube drainage, however, PP may not be entirely free from intervention-related complications; in addition to a potential risk of cardiac herniation, PP also may exert some adverse influence on bypass grafts as a result of compression by pericardiotomy edges[11,39] or bleeding from the incision site.[37] These complications may be minimized by performing a limited PP at the end of the procedure at a distance from the bypass grafts.

Meta-analyses of studies conducted so far are not conclusive regarding the prevention of cardiac tamponade, and guidelines recommendations are still weak with regard to routine posterior pericardial drainage.[8-10] Although partially reflecting the findings of previous reports[7,40] as of reduction of the incidence of POAF, the current meta-analysis with 19 RCTs and 3425 patients represents the most robust data source suggesting significantly reduced odds of cardiac tamponade after posterior pericardial drainage. It represents a good report to show consistent

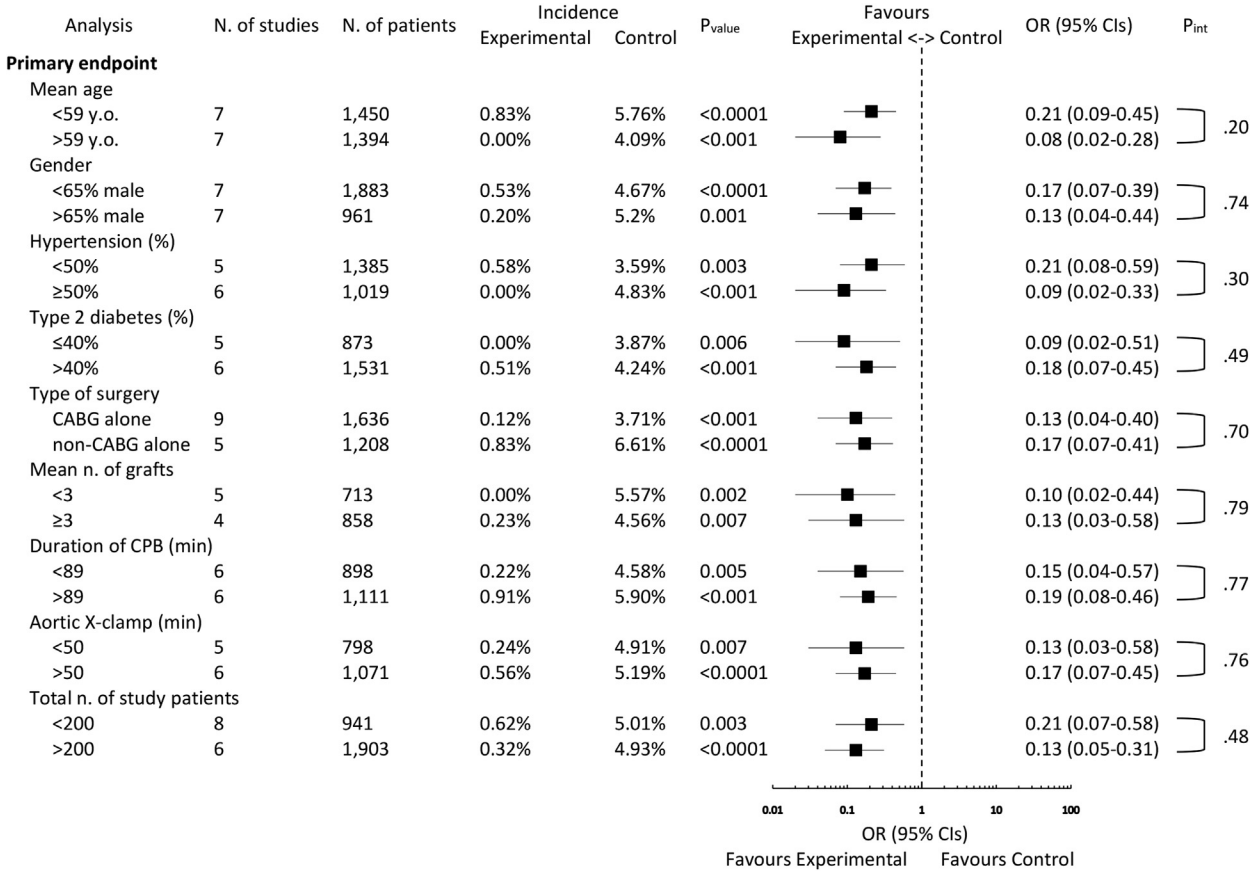

FIGURE 6. Subgroup analysis conducted for the primary endpoint cardiac tamponade stratified by patients' baseline- and procedural characteristics (age, sex, hypertension, diabetes, type of surgery, number of grafts, duration of CPB and crossclamp, and number of patients within the study). *OR*, Odds ratio; *95% CI*, 95% confidence interval; *CABG*, coronary artery bypass grafting; *CPB*, cardiopulmonary bypass; *X-clamp*, crossclamp.

extent of this benefit regardless of patients' baseline risk characteristics. In addition, this study is the first to suggest that benefit in terms of reduced incidence of cardiac tamponade translated into lower odds of mortality or cardiac arrest.

Several mechanisms are speculated to predispose to POAF. Among them is a hypothesis that a certain amount of fluid/hematoma into the pericardium may represent a mechanical irritating stimulus to the atria, whose function can be affected by external compression. In the first prospective study designed to assess safety and effectiveness of PP in reduction of the incidence of pericardial effusion and, consequently, reducing the incidence of supraventricular arrhythmias in the postoperative period, Mulay and colleagues[38] reported the incidence of pericardial effusion in 4 of 50 patients after a PP, whereas effusion occurred in 20 of 50 patients in whom a pericardiotomy was not created ($P < .0005$). The following studies have confirmed these findings; a randomized study by Kuralay and colleagues[35] showed statistically significant difference in both early (1 vs 54 patients; $P < .001$) and late pericardial effusion (defined as occurring more than 30 days after operation) (0 vs 21 patients; $P < .001$). In addition, nearly half (10 of 21) of the patients presenting with delayed pericardial effusion developed pericardial tamponade ($P = .01$).

Because of the limited size and thus statistical power of the next studies to come, several meta-analyses have addressed the efficacy of PP and development of both arrhythmias and pericardial effusion. Biancari and colleagues,[41] in a meta-analysis of 6 RCTs reporting on POAF in 763 patients after CABG, demonstrated that the cumulative incidence of atrial fibrillation was 10.8% in the PP and 28.1% in the control group (OR, 0.33; 95% CI, 0.16-0.69]; $P = .003$). To our knowledge, the most recent meta-analysis[42] available, including 10 RCTs and 1648 patients, reported the cumulative incidence of atrial fibrillation of 10.6% in the PP and 24.9% in the control group, respectively (OR, 0.36; 95% CI, 0.23-0.56; $P < .001$).

A present meta-analysis corroborates previous findings on a larger scale; probably as the result of more extensive and systematic search and no publication language restrictions, 17 RCTs with more than 3200 patients were included for the analysis of POAF; odds were significantly reduced in

the posterior pericardial drainage subset of patients as compared with controls by 58%: 0.42 (0.29-0.59); $P < .001$. A moderate heterogeneity observed was most probably due to different definitions and time frames required for a definitive diagnosis of POAF in patients after heart surgery.

In the present meta-analysis, we assessed safety and efficacy of posterior pericardial drainage compared with control regardless whether it was performed by PP, chest tube to posterior pericardium, or both PP and a chest tube. A number of surgeons do routinely place a posterior pericardial tube (usually soft flexible rubber tube) in addition to an anterior mediastinal tube in the same time avoiding potential risk of PP-related complications. Yet, no consensus exists on the required duration of such drainage[27,30] and its efficacy in preventing particularly delayed cardiac tamponade. In a subgroup analysis stratified by operative technique, we demonstrated that there were no statistically significant differences between the technical approaches to posterior pericardial drainage in regard to the risk of primary endpoint. Such an indirect comparison was, however, not the principal objective of the current investigation.

Limitations

Several shortcoming of the current analysis should be acknowledged. First, the present analysis shares also the limitations of original studies. The results were therefore analyzed on a trial and not patient level. Given heterogeneity in the study protocols, clinically relevant differences could have been missed and would have been better assessed in a meta-analysis of individual patient data. Second, the present meta-analysis is limited by inclusion of studies that, although randomized, are of suboptimal methodological quality. Indeed, none of the studies provided a detailed randomization protocol. Same uncertainty applies to randomization concealment and incomplete outcome data reporting. Although the vast majority of included studies reported in-hospital mortality, only 5 reported the incidence of neurologic complications, which are essential in studies directed at reducing the incidence of POAF. More importantly, baseline drugs, for instance, oral anticoagulants, antiplatelet therapies, antiarrhythmic drugs, or prophylaxis for atrial fibrillation in early postoperative period, were seldom reported. Small number of studies available for inclusion along with small number of participants poses another limitation; indeed, the largest study analyzed included only 458 patients, and 6 studies included 100 or fewer patients. We accounted for bias and excluded studies at high risk in the sensitivity analysis for the primary endpoint.

CONCLUSIONS

Posterior pericardial drainage is technically easy to perform and represents a safe and effective technique that significantly reduces not only the prevalence of early pericardial effusion and related POAF but also delayed pericardial effusion and cardiac tamponade. These benefits, in turn, translate into lower odds of AKI and improved survival after heart surgery.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: pericardial effusion, coronary artery bypass grafting, atrial fibrillation, cardiac tamponade, posterior pericardiotomy, systematic review, meta-analysis

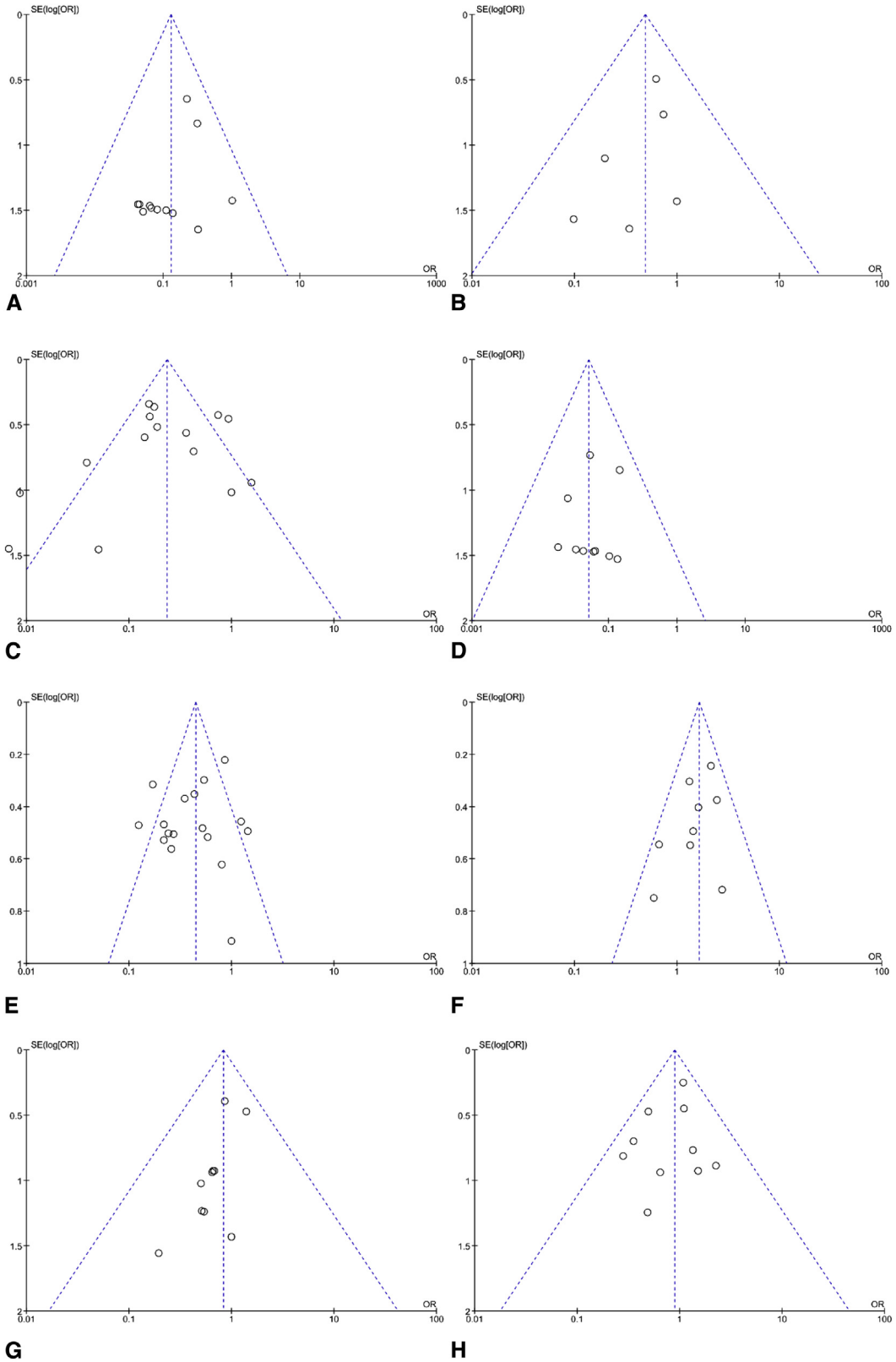

FIGURE E1. Publication bias analysis. Funnel plots constructed for studies included in the meta-analysis for the following investigated endpoints: A, cardiac tamponade; B, death or cardiac arrest; C, early pericardial effusion; D, late pericardial effusion; E, postoperative atrial fibrillation; F, pleural effusion with or without intervention; G, pulmonary complications; H, reoperation for bleeding.

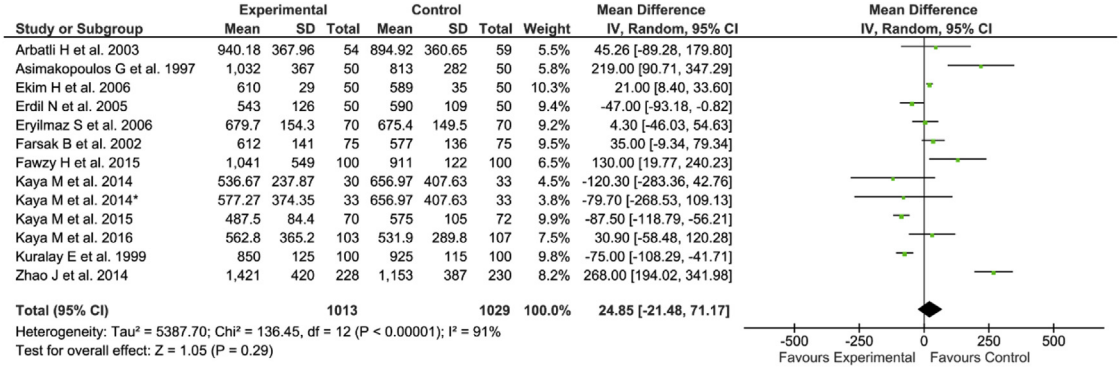

FIGURE E2. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for the total chest drainage volume expressed as mean difference and 95% CIs. *SD*, Standard deviation; *IV*, inverse variance; *CI*, confidence interval.

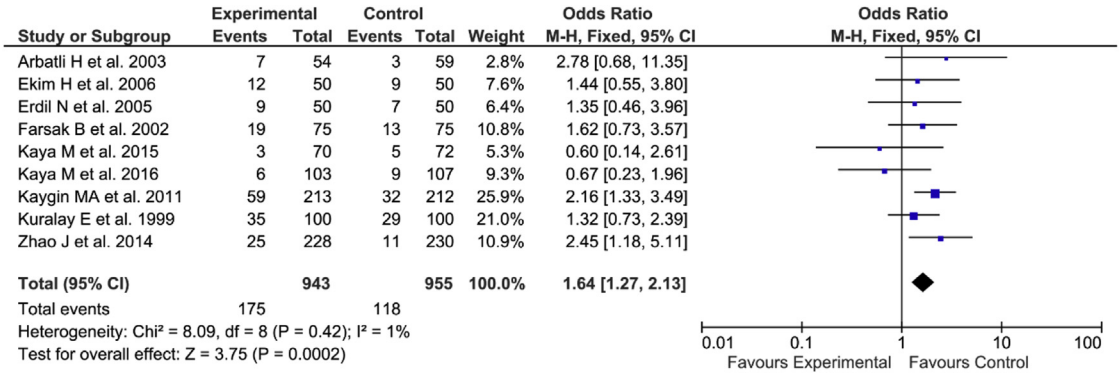

FIGURE E3. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for the incidence of pleural effusion with or without intervention after heart surgery. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

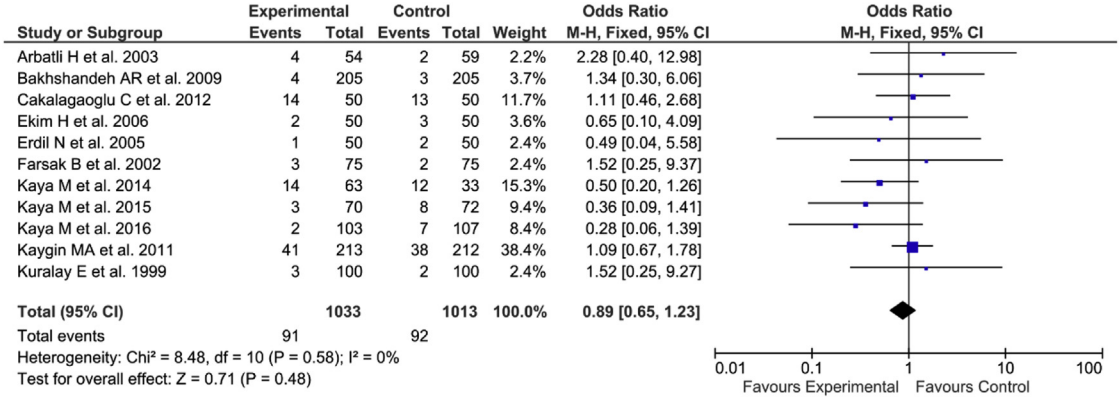

FIGURE E4. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for the prevention of pulmonary complications after heart surgery. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

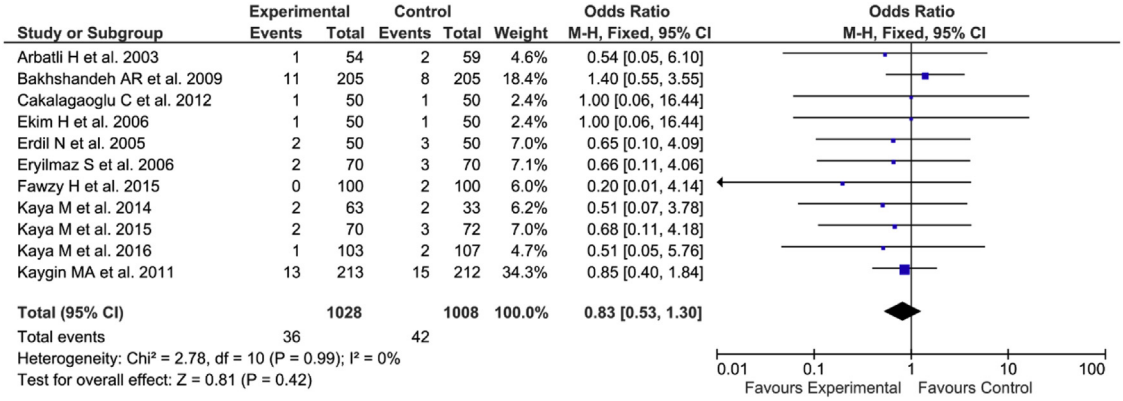

FIGURE E5. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for the incidence of reoperation for bleeding after heart surgery. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

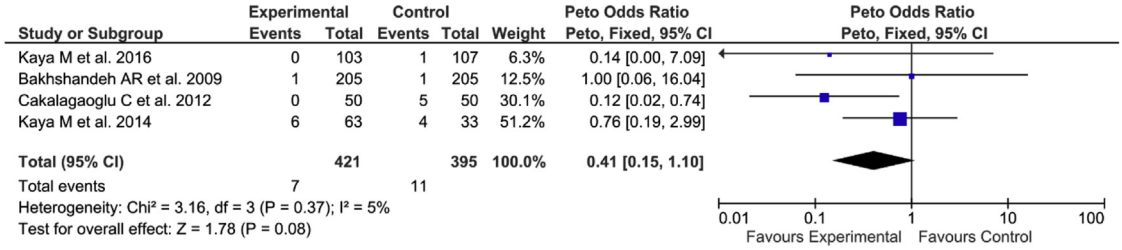

FIGURE E6. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for prevention of acute kidney injury after heart surgery. *CI*, Confidence interval.

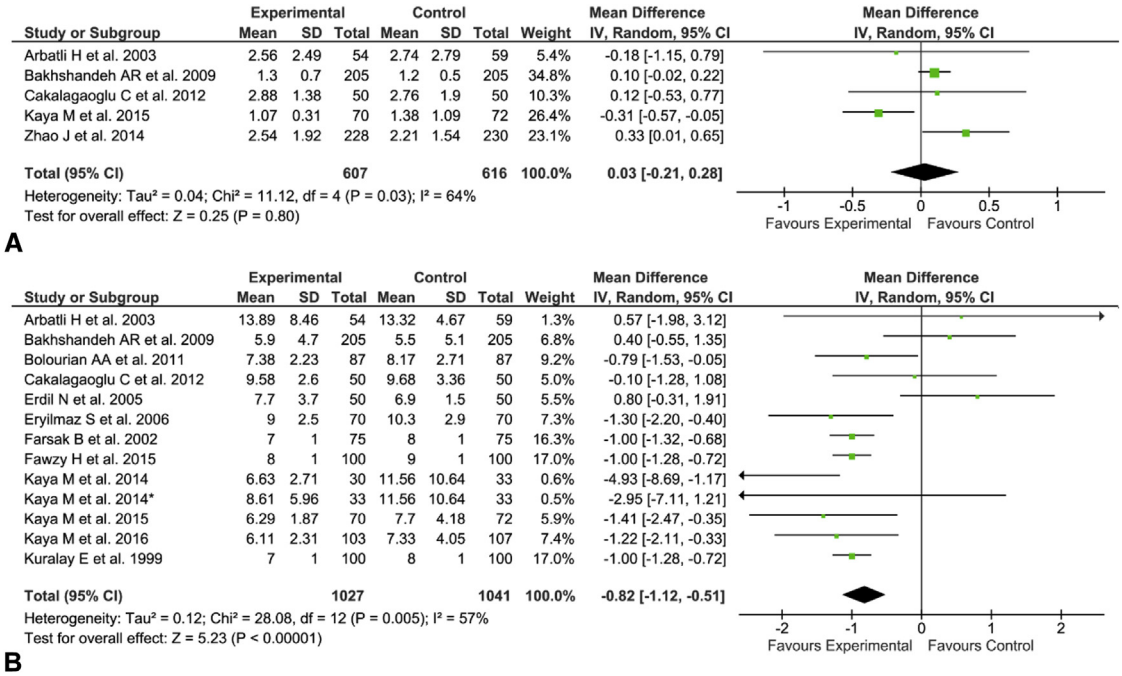

FIGURE E7. Forest plot of the comparison between posterior pericardial drainage (intervention) and control group for the length of ICU stay (A) and overall length of hospital stay (B) expressed as mean difference and 95% CIs. *SD*, Standard deviation; *IV*, inverse variance; *CI*, confidence interval.

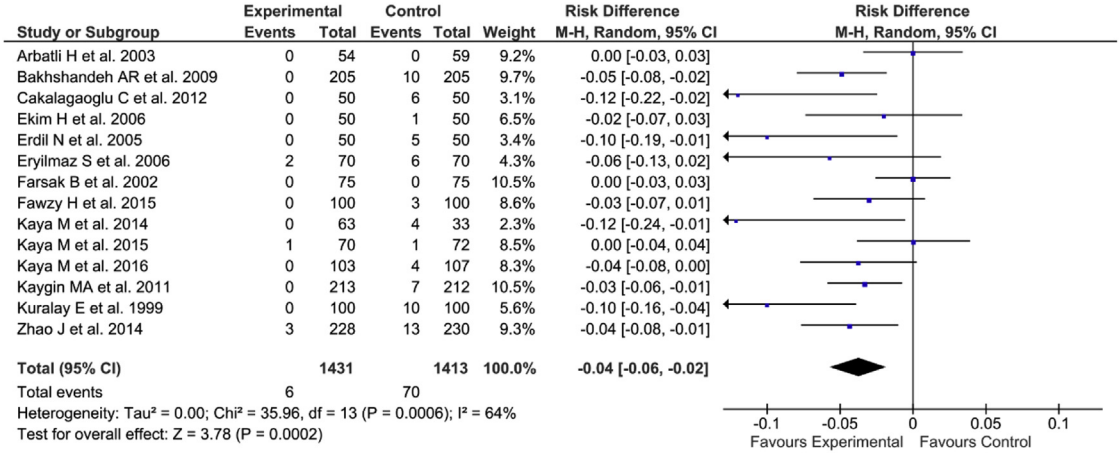

FIGURE E8. Sensitivity analysis conducted for the primary endpoint after accounting for studies reporting 0 events. The individual and overall estimates are expressed as risk difference and 95% CIs. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

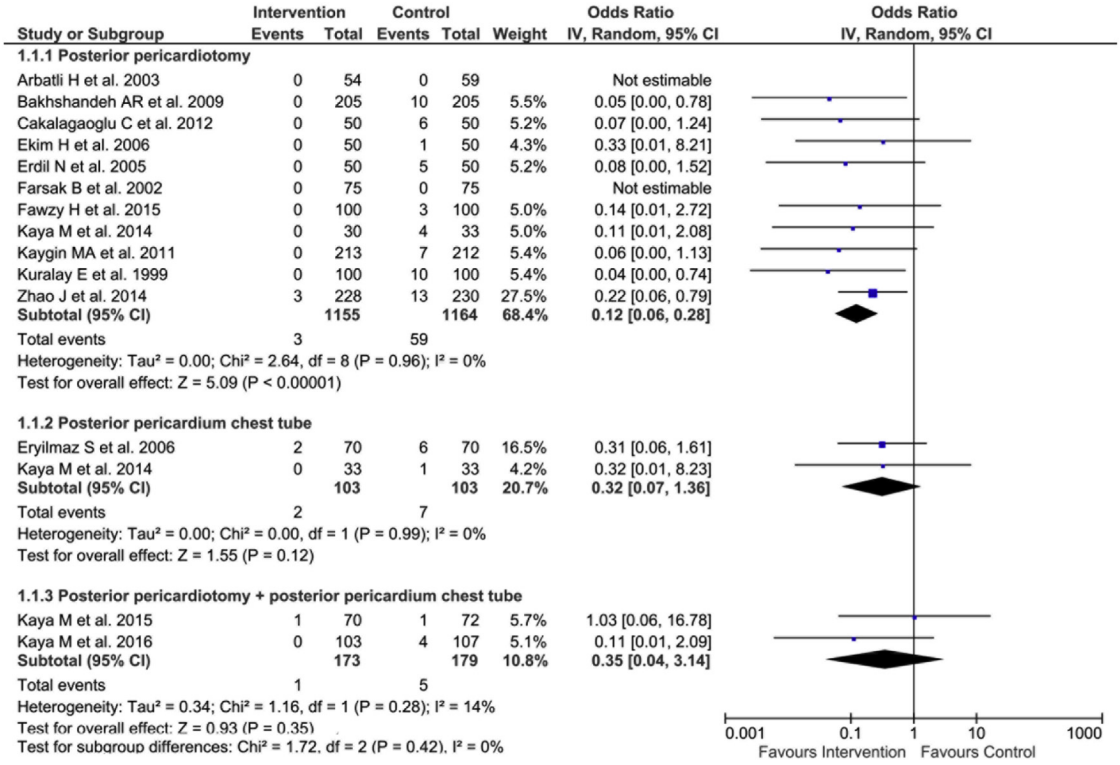

FIGURE E9. Sensitivity subgroup analysis for the comparison between posterior pericardial drainage (intervention) and control group stratified by operative technique conducted for the primary endpoint. The added total number of patients is greater than 3425 because of exact same control groups in one study.[30] *IV*, Inverse variance; *CI*, confidence interval.

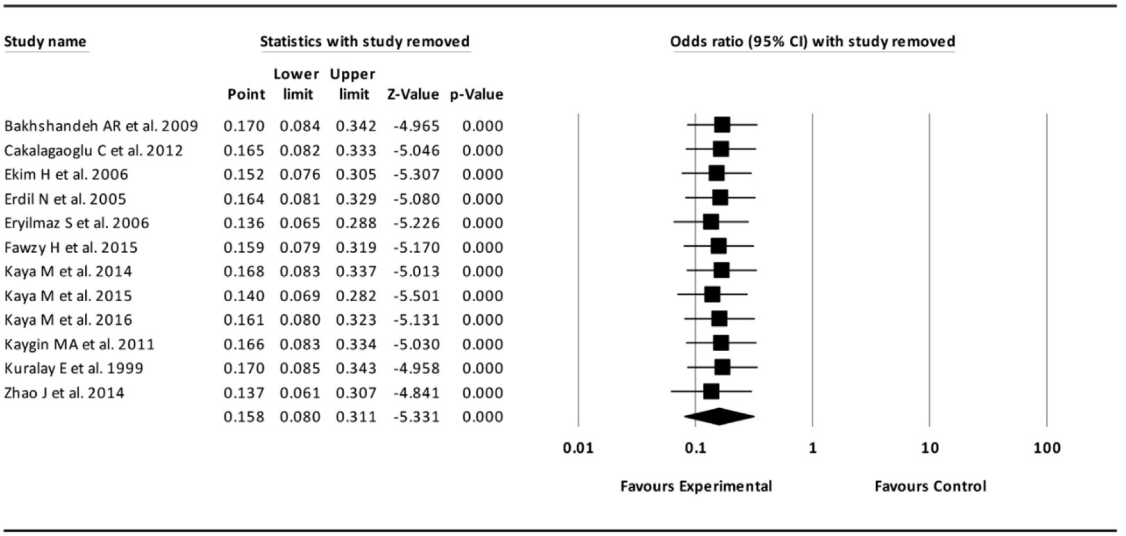

FIGURE E10. Sensitivity analysis (influence analysis) for the primary endpoint conducted by deleting each study at a time and repeating the calculations. Analysis shows that no single study has influenced the overall effect of the intervention. *CI*, Confidence interval.

TABLE E1. PRISMA checklist

Section/topic	No.	Checklist item	Reported on page no.
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
Abstract			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	3
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to PICOS.	5,6
Methods			
Protocol and registration	5	Indicate whether a review protocol exists, if and where it can be accessed (eg, Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (eg, PICOS, length of follow-up) and report characteristics (eg, years considered, language, publication status) used as criteria for eligibility, giving rationale.	6-7
Information sources	7	Describe all information sources (eg, databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6-7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6-7, Appendix
Study selection	9	State the process for selecting studies (ie, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6-7, Figure 1
Data collection process	10	Describe method of data extraction from reports (eg, piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6-7
Data items	11	List and define all variables for which data were sought (eg, PICOS, funding sources) and any assumptions and simplifications made.	6-8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6-7
Summary measures	13	State the principal summary measures (eg, risk ratio, difference in means).	8-9
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (eg, I^2) for each meta-analysis.	8-9
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (eg, publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (eg, sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	9
Results			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9-10, Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (eg, study size, PICOS, follow-up period) and provide the citations.	9-10
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Appendix
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	11-13, Figures 2-5

(Continued)

TABLE E1. Continued

Section/topic	No.	Checklist item	Reported on page no.
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	11-13, Figures 2-5
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Appendix
Additional analysis	23	Give results of additional analyses, if done (eg, sensitivity or subgroup analyses, meta-regression [see Item 16]).	13, Appendix
Discussion			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (eg, healthcare providers, users, and policy makers).	13,14
Limitations	25	Discuss limitations at study and outcome level (eg, risk of bias), and at review-level (eg, incomplete retrieval of identified research, reporting bias).	16-17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13-17
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (eg, supply of data); role of funders for the systematic review.	17

PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; *PICOS*, participants, interventions, comparisons, outcomes, and study design. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. *PLoS Med*. 2009;6(7): e1000097. http://dx.doi.org/10.1371/journal.pmed1000097. For more information, visit: www.prisma-statement.org.

TABLE E2. Medline search strategy

Search	Query	Items found
1	Pericardiotomy	2249
2	Pericardiotomy AND randomized	62
3	Pericardial incision	405
4	Pericardial incision AND randomized	24
5	Pericardial window	760
6	Pericardial window AND randomized	6
7	Posterior pericardiotomy	73
8	Posterior pericardiotomy AND randomized	22
9	Pericardial drainage	2222
10	Pericardial drainage AND randomized	57
11	Posterior pericardium drainage	34
12	Posterior pericardium drainage AND randomized	2
13	Posterior pericardial chest tube	10
14	Posterior pericardial chest tube AND randomized	1
15	Additional chest tube	480
16	Additional chest tube AND randomized	57

TABLE E3. Exclusion criteria and institutional review board approval

Study	Exclusion criteria	IRB approval
Arbatli and colleagues[19]	Renal dysfunction, LV aneurysm, severe LV dysfunction, MR, evident COPD, history of AF, endocrine disorders, β-blocker therapy end dense adhesion inside the pericardium or left pleural cavity	NR
Asimakopoulos and colleagues[20]	Not specified	NR
Bakhshandeh and colleagues[21,22]	Not specified	NR
Bolourian and colleagues[23]	Severe LV dysfunction with LVEF <25%, history of AF, concomitant valvular disease, ''abnormal'' left atrial dimensions (NS); participation in another study.	Yes
Cakalagaoglu and colleagues[24]	Re-do cases, left-sided pleural adhesions, arrhythmias, in particular AF, documented depression and anxiety, hyperthyroidism, LV aneurysm, renal failure (plasma creatinine >2.0 mg/dL), use of β-blocker, and inability to provide informed consent because of a neurologic or psychiatric illness	Yes
Ekim and colleagues[25]	Hyperthyroidism, COPD, renal dysfunction, LV aneurysm, severe LV dysfunction, history of AF, previous CABG, concomitant valvular disease, dense adhesion of the lung, β-blocker therapy	NR
Erdil and colleagues[26]	CAD	Yes
Eryilmaz and colleagues[27]	Re-do cases, CAD requiring CABG, any form of anticoagulation before surgical intervention, a second operative procedure (apart from bleeding or tamponade) during the same hospital stay	Yes
Farsak and colleagues[11]	Hyperthyroidism, COPD, renal dysfunction, LV aneurysm, valvular heart disease, preoperative AF, and β-blocker therapy	NR
Fawzy and colleagues[28]	Previous AF or antiarrhythmic drugs therapy, severe LV dysfunction (LVEF $\leq$30%), COPD, renal impairment, hyperthyroidism, redo and emergency CABG, combined cardiac procedures	Yes
Haddadzadeh and colleagues[29]	Cardiac arrhythmia, pericardial effusion, electrolyte or hemodynamic disturbances, previous CABG, and valvular repair	Yes
Kaya and colleagues[30]	Renal failure, hyperthyroidism, emergency coronary artery surgery, history of cardiac operations associated with valvular heart disease, LVEF <35%, and preoperative AF or other rhythm disorders, no consent	Yes
Kaya and colleagues[31]	P2Y12 inhibitor therapy, valve regurgitation, kidney failure, hyper- and or hypothyroidism, emergency or re-do cases, preoperative rhythm disorders, patients with pacemakers, and OPCAB	Yes
Kaya and colleagues[32]	Renal insufficiency, concomitant valve surgery, emergency surgery, preoperative AF, and redo cases	NR
Kaygin and colleagues[33]	Renal failure, ventricular arrhythmias; LV aneurysm, COPD, severe LV dysfunction, hyperthyroidism, valvular heart disease, bleeding disorders, patients with rhythm problems and valvular pathologies on OAC; more than 2 chest tubes, and those who required concomitant surgery.	Yes
Kongmalai and colleagues[34]	Not specified	NR
Kuralay and colleagues[35]	Hyperthyroidism, COPD, renal dysfunction, LV aneurysm, severe LV dysfunction, combined valvular heart disease, β-blocker therapy	NR
Sadeghpour and colleagues[36]	Coagulation disorder, renal and hepatic insufficiency, re-do cases, and OAC	NR
Zhao and colleagues[37]	Re-do cases, paroxysmal AF, preoperative coagulant disorders that could have influenced the postoperative results, asthma, and hepatic or renal dysfunction	Yes

LV, Left ventricular; *MR*, mitral regurgitation; *COPD*, chronic obstructive pulmonary disease; *AF*, atrial fibrillation; *NR*, not reported; *LVEF*, left ventricle ejection fraction; *NS*, not specified; *CABG*, coronary artery bypass grafting; *CAD*, coronary artery disease; *OPCAB*, off-pump coronary artery bypass graft; *OAC*, oral anticoagulation.

TABLE E4. Endpoint definitions

Study	Cardiac tamponade (definition; diagnostic criteria)	Pericardial effusion criteria	Early effusion	Late effusion	Postoperative AF
Arbatli and colleagues[19]	Not defined; NS	minimal 0-50 mL, mild 50-100 mL, moderate 100-500 mL, severe > 500 mL	Not defined	Not defined	AF sustained <15 min
Asimakopoulos and colleagues[20]	Not defined; NS	NR	NR	NR	Not defined
Bakhshandeh and colleagues[21,22]	Not defined; NS	Echo-free space in diastole, small <10 mm, moderate >10 to <20 mm posteriorly, large >20 mm, very large >20 mm, and compression of the heart	<30 d after surgery	>30 d after surgery	Not defined
Bolourian and colleagues[23]	Not defined; NS	NR	NR	NR	NR
Cakalagaoglu and colleagues[24]	Not defined; NS	Echo-free space in diastole, small <10 mm, moderate >10 to <20 posteriorly, large >20 mm, very large >20 mm, and compression of the heart	Before discharge	≥15 d after surgery	AF or atrial flutter >20 min
Ekim and colleagues[25]	Not defined; hemodynamic data and/or the echocardiographic findings	Maximum diastolic separation between pericardium and epicardium measured at the level of the tip of the mitral valve leaflet. Any effusion >1 cm was considered significant	Not defined	Not defined	AF or atrial flutter >20 min
Erdil and colleagues[26]	Hemodynamic data and/or the echocardiographic findings	Maximum diastolic separation between pericardium and epicardium measured at the level of the tip of the mitral valve leaflet. Any effusion >1 cm was considered significant	<24 h	5-7 d after surgery	NR
Eryilmaz and colleagues[27]	Not defined; NS	Effusion ≥10 mm were considered significant	first postoperative week	after the first week	NR
Farsak and colleagues[11]	Not defined; NS	Maximum diastolic separation between pericardium and epicardium measured at the level of the tip of the mitral valve leaflet. Any effusion >1 cm was considered significant	<30 d after surgery	≥30 d after surgery	NR
Fawzy and colleagues[28]	Not defined; NS	Effusion ≥10 mm were considered significant	Not defined	Not defined	AF or atrial flutter >30 min even after correction of hypoxia and electrolyte imbalance
Haddadzadeh and colleagues[29]	Not defined; NS	Effusion ≥10 mm were considered significant	NR	NR	AF or atrial flutter >30 min
Kaya and colleagues[30]	Clinical signs and symptoms in addition to echocardiographic criteria	Echo-free space in diastole, small <10 mm, moderate >10 to <20 mm posteriorly, large >20 mm, very large >20 mm, and compression of the heart	<30 d after surgery	≥30 d after surgery	AF or atrial flutter >5 min
Kaya and colleagues[31]	Not defined; NS	Echo-free space in diastole, small <10 mm, moderate >10 to <20 posteriorly, large >20 mm, very	Not defined	Not defined	Presence of irregular ventricular rate and absence of consistent P-waves before each

(Continued)

TABLE E4. Continued

Study	Cardiac tamponade (definition; diagnostic criteria)	Pericardial effusion criteria	Early effusion	Late effusion	Postoperative AF
		large >20 mm, and compression of the heart			QRS complex; persistence not specified
Kaya and colleagues[32]	Not defined; NS	Echo-free space in diastole, small <10 mm, moderate >10 to <20 mm posteriorly, large >20 mm, very large >2 mm, and compression of the heart	Not defined	Not defined	Absence of consistent P waves before each QRS complex and an irregular ventricular rate; persistence not specified
Kaygin and colleagues[33]	Not defined; NS	Any effusion between the epicardial and pericardial surfaces >1 cm in echocardiogram image was considered as significant	Before discharge	1 mo after discharge	Not defined; persistence not specified
Kongmalai and colleagues[34]	Not defined; NS	Not defined	Not defined	Not defined	Not defined
Kuralay and colleagues[35]	Hemodynamic data and the echocardiographic findings	Maximum diastolic separation between pericardium and epicardium measured at the level of the tip of the mitral valve leaflet. Any effusion >1 cm was considered significant	<30 d after surgery	≥30 d after surgery	AF or atrial flutter >30 min
Sadeghpour and colleagues[36]	Not defined; NS	Not defined; NS	<3 d after surgery	>3 d after surgery	Not defined
Zhao and colleagues[37]	Not defined; NS	<10 mm, localized in posterior pericardial cavity, small 10–20 mm, involving anterior wall of right ventricle, moderate >20 mm, circumferential effusion, large	Not defined, NS effusion measured at 10 postoperative day		Not defined; persistence not specified

AF, Atrial fibrillation; *NS*, not specified; *NR*, not reported.

TABLE E5. Chest drainage and posterior pericardiotomy technique

Study	Chest drainage technique	Posterior pericardiotomy technique
Arbatli and colleagues[19]	Two drains in both groups. One in the left pleural cavity and the other in the anterior mediastinum. Lower part of the pericardium left open.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Asimakopoulos and colleagues[20]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Bakhshandeh and colleagues[21,22]	NR	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein toward the inferior vena cava and diaphragm.
Bolourian and colleagues[23]	NR	Incision along the posterior length of left phrenic nerve, 4-6 cm long, extending from left inferior pulmonary vein to the diaphragm.
Cakalagaoglu and colleagues[24]	Two drains in study and control group in CABG cases: one in the left pleural cavity and the other in the anterior mediastinum. Two drains in study and control group in valve cases: anterior mediastinum (or 3 when left pleural cavity was opened). Pericardium left open anteriorly.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Ekim and colleagues[25]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Erdil and colleagues[26]	Two drains in study group, one in the left pleural cavity and the other in the anterior mediastinum. One drain in the control group positioned in the anterior mediastinum.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Eryilmaz and colleagues[27]	Two drains in study group, one in the anterior mediastinum and the other (thin closed-suction drain system) behind the heart. One drain in control group: anterior mediastinum plus another drain in both group when left or right pleura was opened.	NA
Farsak and colleagues[11]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum. Pericardium left open anteriorly.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Fawzy and colleagues[28]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum. Pericardium left open anteriorly.	A longitudinal, 4-cm long and 2-cm wide incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Haddadzadeh and colleagues[29]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum. Pericardium left open anteriorly.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Kaya and colleagues[30]	Two or three drains in study group. One in the left pleural cavity and the other in the anterior mediastinum. Third drain in 33 patients positioned behind the heart. Two drains in control group, one in the left pleural cavity and the other in the anterior mediastinum. Pericardium left open (2 cm).	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm. The left pleural cavity was opened.
Kaya and colleagues[31]	Three drains in study group, one in the left pleural cavity, one in the anterior mediastinum and the other in the pericardial sac along the right atrium. Pericardium was closed. Two drains in control group. Left pleural cavity and anterior mediastinum. Pericardium left open (2 cm).	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.

(Continued)

TABLE E5. Continued

Study	Chest drainage technique	Posterior pericardiotomy technique
Kaya and colleagues[32]	Three drains in study group, one in the left pleural cavity, one in the anterior mediastinum and the other in the pericardial sac along the right atrium. Proximal anastomoses of the bypass grafts and nearly half of the anterior surface of the heart were covered by pericardium. Two drains in control group: left pleural cavity and anterior mediastinum.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Kaygin and colleagues[33]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum. Pericardium left open anteriorly.	A circular, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Kongmalai and colleagues[34]	NR	NR
Kuralay and colleagues[35]	Two drains in both groups, one in the left pleural cavity and the other in the anterior mediastinum. Pericardium left open anteriorly.	A longitudinal, 4-cm long incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Sadeghpour and colleagues[36]	NR	A longitudinal, 4 cm long, incision parallel and posterior to the phrenic nerve, extending from left inferior pulmonary vein to the diaphragm.
Zhao and colleagues[37]	Two or three drains in study group, one in the left or both pleural cavities, one in the anterior mediastinum. Two drains in control group, one in the pericardial sac along the right atrium and the other in the anterior mediastinum.	Inverse T, 2.5 cm long in both dimensions (left, right, or bilateral window) incision, parallel and posterior to the phrenic nerve, extending from inferior pulmonary vein to the diaphragm.

NR, Not reported; *CABG*, coronary artery bypass grafting; *NA*, not applicable.

TABLE E6. Publication bias analysis

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias	Jadad score
Arbatli and colleagues[19]	±	−	−	−	+	+	+	2
Asimakopoulos and colleagues[20]	±	−	−	−	+	+	+	1
Bakhshandeh and colleagues[21,22]	±	−	−	−	−	+	+	1
Bolourian and colleagues[23]	±	±	−	−	−	−	+	1
Cakalagaoglu and colleagues[24]	±	−	−	−	+	+	+	2
Ekim and colleagues[25]	±	−	−	−	+	+	+	2
Erdil and colleagues[26]	+	−	−	−	+	+	+	2
Eryilmaz and colleagues[27]	±	−	−	+	+	+	+	2
Farsak and colleagues[11]	+	−	−	−	+	±	+	3
Fawzy and colleagues[28]	+	−	−	−	+	+	+	3
Haddadzadeh and colleagues[29]	±	−	−	−	+	+	+	2
Kaya and colleagues[30]	+	−	+	+	+	+	+	4
Kaya and colleagues[31]	+	+	+	±	+	+	+	5
Kaya and colleagues[32]	+	−	−	+	+	+	+	3
Kaygin and colleagues[33]	±	−	±	±	+	+	+	3
Kongmalai and colleagues[34]	±	−	−	−	+	+	+	1
Kuralay and colleagues[35]	+	−	−	−	+	+	+	3
Sadeghpour and colleagues[36]	±	−	−	−	+	+	+	2
Zhao and colleagues[37]	+	+	−	−	+	+	+	3
Cohen's kappa	0.89	0.84	0.79	0.84	0.84	0.89	0.84	

±, Unclear risk of bias; −, high risk of bias; +, low risk of bias.