



Research Article

Continuous wound infiltration with local anesthetics in adult patients undergoing cardiac surgery: A PRISMA-compliant systematic review and meta-analysis

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ABSTRACT

Background: Effective postoperative analgesia is critical to recovery after cardiac surgery. Continuous wound infiltration (CWI) with local anesthetics (LAs) has been proposed as an opioid-sparing adjunct, but its efficacy beyond pain control and its safety profile remain incompletely defined.

Methods: We conducted a PRISMA-compliant systematic review and meta-analysis of randomized controlled trials (RCTs) comparing CWI with control in adult cardiac surgery. PubMed, Embase, and Cochrane CENTRAL were searched from inception to August 30, 2025, and updated on April 2, 2026. Primary outcomes were postoperative Visual Analogue Scale (VAS) pain scores and cumulative morphine consumption. Secondary outcomes included mechanical ventilation duration, length of stay, mortality, complications, patient satisfaction, and adverse events. Risk of bias was assessed using the Cochrane RoB 2.0 tool, and certainty of evidence was evaluated using Grading of Recommendations Assessment, Development and Evaluation (GRADE).

Results: Twelve RCTs involving 2,117 patients were included. CWI significantly reduced VAS during mobilization at 24 h (MD=−0.93, 95% confidence interval [CI]: −1.53–−0.33, $P = 0.002$) and 48 h (MD=−0.80, 95% CI: −1.17–−0.44, $P < 0.001$), and decreased 48-hour morphine consumption (MD=−8.10 mg, 95% CI: −13.41–−2.79, $P = 0.003$). No significant effects were observed on VAS at rest, mechanical ventilation duration, ICU or hospital length of stay, mortality, or major cardiovascular, pulmonary, renal, gastrointestinal complications, or postoperative infections. Patient satisfaction was higher with CWI. Technical complications were uncommon, and no clinically significant LA toxicity was reported.

Conclusions: In adult cardiac surgery, CWI with LAs modestly improves analgesia during mobilization and reduces opioid requirements without clear improvement in major clinical outcomes or length of stay. CWI appears safe and feasible and may serve as an adjunct in multimodal, opioid-sparing analgesia strategies. Further adequately powered trials are warranted to define its comparative effectiveness within contemporary enhanced recovery after surgery pathways.

1. Introduction

Postoperative pain after cardiac surgery remains a clinically important barrier to recovery. Pain from median sternotomy or thoracotomy may impair coughing, deep breathing, and early mobilization, thereby increasing cardiopulmonary risk and delaying discharge from the intensive care unit (ICU) or hospital.^{1,2} Within enhanced recovery after surgery (ERAS) programs, effective analgesia is therefore not only a comfort measure but also a prerequisite for functional recovery.³

Opioids remain widely used after cardiac surgery, but opioid-related nausea, vomiting, respiratory depression, ileus, and delirium may hinder recovery.^{4,5} These limitations have prompted increasing use of multimodal analgesic strategies, including neuraxial techniques, fascial plane blocks, peripheral nerve blocks, and local anesthetic infiltration.^{6–11}

Continuous wound infiltration (CWI) delivers local anesthetics (LAs) directly into the surgical wound through indwelling catheters. The technique is relatively simple, targets incisional nociception, and avoids the neuraxial bleeding concerns that are particularly relevant in anticoagu-

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lated cardiac surgical patients.¹² However, individual randomized controlled trials (RCTs) have reported inconsistent effects on pain, opioid use, mobilization, respiratory outcomes, and length of stay.^{13–27}

To clarify this uncertainty, the current study was designed to systematically evaluate the efficacy and safety profiles of CWI with LAs on postoperative pain, opioid consumption, and clinically relevant outcomes in adult patients undergoing cardiac surgery.

2. Methods

2.1. Ethical approval

This systematic review and meta-analysis was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Supplement Table S1).¹⁶ Because only published aggregate data were analyzed, approval from the Ethical Committee of Fuwai Hospital or the Institutional Review Board of UTHealth Houston was not required. The protocol was registered in PROSPERO (CRD420251136731).

2.2. Search strategy

Two reviewers (YY and SH) independently searched PubMed, Embase, and Cochrane CENTRAL from database inception to August 30, 2025, using terms related to cardiac surgery, sternotomy or thoracotomy, continuous wound infiltration, LA infusion, ropivacaine, and bupivacaine (Appendix). The search was updated on April 2, 2026. Reference lists of eligible articles and relevant reviews were also screened to identify additional trials.

2.3. Inclusion and exclusion criteria

Eligible studies were English-language RCTs comparing CWI with a control intervention, defined as sham infusion, placebo infusion, or standard care without an active CWI catheter, in adult patients undergoing cardiac surgery. Trials were required to report at least one pre-specified analgesic outcome, including postoperative VAS pain score or cumulative morphine consumption. We excluded studies without a control group, studies comparing CWI only with neuraxial anesthesia, peripheral nerve blocks, or fascial plane blocks, pediatric studies, observational studies, surveys, questionnaires, conference abstracts, editorials, and trials without extractable analgesic outcomes.

2.4. Outcomes of interest

The primary outcomes included VAS of postoperative pain and cumulative morphine consumption after surgery. Secondary outcomes included postoperative mechanical ventilation duration (MVD), length of stay (LOS) in the ICU and hospital, incidences of mortality and morbidities (e.g. cardiac complications, neurological complications, pulmonary complications, renal complications, gastrointestinal complications, and infections), patient satisfaction, CWI instrument/catheter dysfunction, LAs toxicity events, and follow-ups.

2.5. Study quality assessment

Risk of bias in each included RCT was assessed independently by two reviewers (YY and AM) using the Cochrane Risk of Bias 2.0 tool.¹⁷ Disagreements were resolved by discussion with a third reviewer (MC). The certainty of evidence for major outcomes was evaluated using the GRADE framework, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias. Certainty was categorized as high, moderate, low, or very low.

2.6. Data extraction

Two authors (YY and SH) independently extracted predetermined data: (1) author, year, country of included studies; (2) number of patients in the CWI and control groups; and (3) data regarding outcomes of interest. Disagreements were resolved by discussion among three authors (YY, SH and AM) during data extraction.

2.7. Statistical analysis

Meta-analyses were performed with RevMan 5.4.1 (Cochrane Collaboration, Oxford, UK). Dichotomous outcomes were summarized as odds ratios (ORs) with 95% confidence intervals (CIs). Continuous outcomes were summarized as mean differences (MDs) with 95% CIs. Heterogeneity was assessed using both the Cochran Q test and the I^2 statistic. We considered I^2 values of approximately 25%, 50%, and 75% to represent low, moderate, and high heterogeneity, respectively. A fixed-effect model was used when clinical and statistical heterogeneity were low; otherwise, a random-effects model was used. Sensitivity analyses examined the influence of statistical model choice and individual studies. Publication bias was not formally tested when fewer than 10 studies were available for an outcome; funnel plots for the primary outcomes were therefore considered exploratory. All P values were two-sided, with $P < 0.05$ considered statistically significant.

3. Results

3.1. Characteristics of included studies

The database search identified 479 records for screening (Fig. 1). After study selection, 12 eligible RCTs^{12,15,18–27} involving 2,117 randomized participants were included in the quantitative synthesis (Table 1).

3.2. Risk of bias

Using the Cochrane RoB 2.0 tool, we judged 8 trials^{12,18,19,22,23,25–27} to be at overall low risk of bias, whereas 4^{15,20,21,24} were rated as having some concerns (Supplement Table S2). Potential bias most commonly stemmed from randomization and outcome measurement. No trial was judged to be at high risk of bias.

3.3. Postoperative VAS scores and morphine consumption

Pooled analysis of 5 studies^{12,15,23–25} (5 comparisons, 1,699 patients) and 4 studies^{12,15,23,24} (4 comparisons, 1,652 patients) showed that CWI did not significantly reduce VAS scores at rest at 24 h ($MD = -0.59$, 95% CI: $-1.38-0.20$, $P = 0.15$) or 48 h postoperatively ($MD = -0.80$, 95% CI: $-1.62-0.02$, $P = 0.06$) (Fig. 2A). In contrast, pooled analysis of 4 studies^{15,21,23,24} (4 comparisons, 204 patients) showed that CWI reduced VAS scores during mobilization at both 24 h ($MD = -0.93$, 95% CI: $-1.53-0.33$, $P < 0.01$) and 48 h postoperatively ($MD = -0.80$, 95% CI: $-1.17-0.44$, $P < 0.01$) (Fig. 2B). Data from 6 studies^{12,19,21,22,26,27} (7 comparisons, 1,747 patients) showed that CWI decreased cumulative morphine consumption within the first 48 h postoperatively ($MD = -8.10$, 95% CI: $-13.41-2.79$, $P < 0.01$) (Fig. 2C).

Heterogeneity for the primary analgesic outcomes was assessed using both the Cochran Q test and the I^2 statistic. The degree of heterogeneity varied across outcomes, with higher heterogeneity observed for VAS scores at rest and lower or acceptable heterogeneity for VAS scores during mobilization and 48-hour morphine consumption. Therefore, model selection and interpretation were based on both statistical heterogeneity and clinical consistency.

3.4. Postoperative recovery profiles

Pooled results from 10 studies^{12,15,18,19,21,22,24–27} (11 comparisons, 2,038 patients) reported that CWI did not affect postoperative MVD

Table 1
Characteristics of 12 eligible randomized controlled trials.

Trials (Country)	Surgery (Incision)	Sample size		Age (years, mean $\pm$ SD)		Sex (M/F)		Interventions		Outcomes
		CWI	Control	CWI	Control	CWI	Control	CWI	Control	
Mijovski 2020 ¹⁸ (Slovenia)	AVR On-pump (Thoracotomy)	35	35	74 $\pm$ 7	76 $\pm$ 7	20/15	19/16	Bolus: 0.75% Ropivacaine 10 mL CWI: 0.20% Ropivacaine, 5 mL/h, 48 h [Catheter + PCA pump]	NS	②③④⑦⑧⑩
Florkiewicz 2019 ¹⁵ (Finland)	CABG/VS On-pump (Sternotomy)	47	43	63 $\pm$ 8	62 $\pm$ 9	40/7	35/8	Bolus: no CWI: 0.20% Ropivacaine, 4 mL/h, 48 h [Catheter + PCA pump]	NS	②③④⑤⑨⑩
Amour 2019 ¹² (France)	CS On-pump (Sternotomy)	746	739	67 $\pm$ 13	66 $\pm$ 13	526/220	542/197	Bolus: L-Bupivacaine 10 mL CWI: 12.5 mg/h L-Bupivacaine, 10 mL/h, 48 h [Catheter + PCA pump]	NS	①②③④⑤⑥⑦⑩
Eljezi 2017 ¹⁹ (France)	CS On-pump (Sternotomy)	55	60	68 $\pm$ 9	68 $\pm$ 9	46/9	51/9	Bolus: 0.20% Ropivacaine 10 mL CWI: 0.20% Ropivacaine, 6 mL/h, 48 h [Catheter + Perfusin device]	SC	①②③④⑤⑥⑦⑧⑨⑩
Hong 2017 ²⁰ (Australia)	CABG On-pump (Sternotomy)	26	25	60 $\pm$ 9	62 $\pm$ 9	21/5	20/5	Bolus: 0.50% Ropivacaine 10 mL CWI: 0.50% Ropivacaine, 4 mL/h, 96 h [Catheter + Elastomeric pump]	NS	②③
Nasr 2015 ²¹ (Egypt)	CABG On-pump (Sternotomy)	19	18	54 $\pm$ 5	53 $\pm$ 6	11/8	10/8	Bolus: 0.25% Bupivacaine 5 mL CWI: 0.25% Bupivacaine 5 mL/h, >48 h [Catheter + Elastomeric pump]	NS	②③④⑤⑥⑦⑩
Agarwal 2013 ²² (USA)	CS On-pump (Sternotomy)	44	41	64 $\pm$ 14	64 $\pm$ 14	33/11	32/9	Bolus: no CWI: 0.30% Ropivacaine, 4 mL/h, 64 h [Catheter + PainPump2]	NS	①②③④⑤ ⑥⑦⑩
Eljezi 2012 ²³ (France)	CABG/VS On-pump (Sternotomy)	20	20	68 $\pm$ 13	64 $\pm$ 12	NR	NR	Bolus: 0.20% Ropivacaine 5 mL CWI: 0.20% Ropivacaine 4 mL/h, 48 h [Catheter + Flow device]	NS	②③④⑧⑨⑩
Chiu 2008 ²⁴ (China)	CABG/VS On-pump (Thoracotomy)	19	19	59 $\pm$ 14	57 $\pm$ 15	13/6	12/7	Bolus: 0.15% Bupivacaine 10 mL CWI: 0.15% Bupivacaine, 2 mL/h, 48 h [Catheter + Elastomeric pump]	NS	③④⑤⑥⑦⑨⑩
Magnano 2005 ²⁵ (Italy)	CS On-pump (Sternotomy)	23	24	68 $\pm$ 12	67 $\pm$ 9	NR	NR	Bolus: no CWI: 0.50% Bupivacaine, 5 mL/h, 36 h [Catheter + Infusin device]	NS	①②③⑤
Dowling 2003 ²⁶ (USA)	CABG On-pump (Sternotomy)	16	19	60 $\pm$ 10	60 $\pm$ 8	13/3	14/5	Bolus: no CWI: 0.20% Ropivacaine, 4 mL/h, 48 h [Catheters + Elastomeric pump]	NS	②③④⑤⑦⑩
White 2003 ²⁷ (USA)	CS On-pump (Sternotomy)	12	12	55 $\pm$ 11	61 $\pm$ 8	8/4	10/2	Bolus: no ①CWI: 0.25% Bupivacaine 4 mL/h, 48 h ②CWI: 0.50% Bupivacaine 4 mL/h, 48 h [Catheters + Elastomeric pump]	NS	②③④⑤⑥⑦⑧⑩

AVR: aortic valve replacement; CABG: coronary artery bypass grafting; CS: cardiac surgery; CWI: continuous wound infiltration; F: female; h: hour; M: male; NR: not reported; NS: normal saline; R: repair; SC: standardized care; USA: United States of America; VS: valve surgery. Outcomes: ①=mortality, ②=morbidities, ③=pain score, ④=analgesic consumption, ⑤=mechanical ventilation duration, ⑥=length of stay in the ICU, ⑦=length of stay in the hospital, ⑧=patient satisfaction, ⑨=follow-ups, ⑩=local anesthetic toxicity/blood concentration/infusion system malfunction.

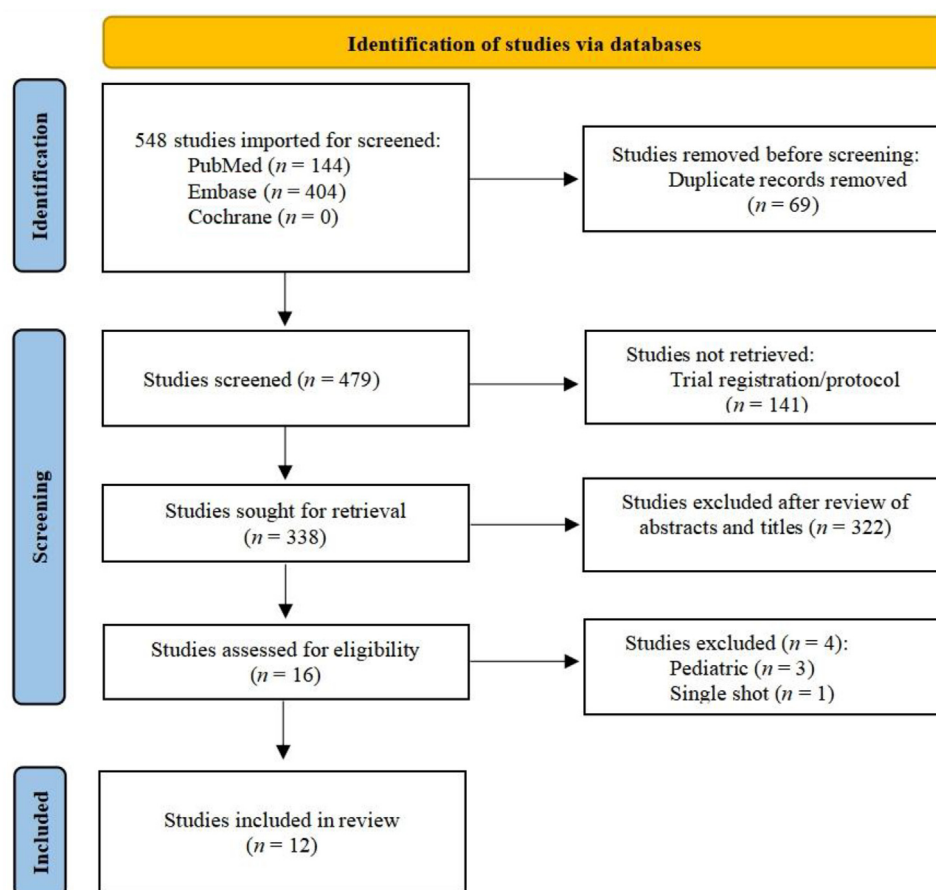


Fig. 1. Study identification, screening, and inclusion diagram.

($MD = 7.65$, 95% CI : -33.86 – 49.16 , $P = 0.72$) (Fig. 3A). Similarly, pooled analysis of 6 studies^{12,19,21,22,24,27} (7 comparisons, 1,796 patients) and 8 studies^{12,18,19,21,22,24,26,27} (9 comparisons, 1,901 patients) suggested that CWI did not change either postoperative LOS in the ICU ($MD = -0.35$, 95% CI : -6.14 – 5.43 , $P = 0.90$) (Fig. 3B) or postoperative LOS in the hospital ($MD = -0.17$, 95% CI : -0.48 – 0.14 , $P = 0.29$) (Fig. 3C).

In the trial by Eljezi et al.¹⁹ patients in the CWI group exhibited a similar median chest tube removal time (64 h), as compared to that (65 h) in the control group ($P = 0.99$). Two studies^{23,27} reported on early postoperative mobilization. Eljezi et al.²³ found that CWI significantly facilitated earlier mobilization compared with the control group (65% vs. 5.3%, $P < 0.01$). Similarly, White et al.²⁷ reported that all patients in the CWI (bupivacaine 0.5%) group were able to sit in a chair and ambulate with assistance on the first postoperative day. These findings also indicated that CWI might promote faster postoperative mobility and recovery by pain attenuation.

3.5. Mortality

Pooled results from 4 studies^{12,19,22,25} (4 comparisons, 1,732 patients) reported that CWI did not affect in-hospital mortality ($OR = 1.89$, 95% CI : 0.95 – 3.79 , $P = 0.07$). Additionally, Amour et al.¹² and Eljezi et al.²³ reported CWI had no effect on 30-day mortality ($OR = 1.92$, 95% CI : 0.92 – 4.00 , $P = 0.08$) and 6-month mortality ($OR = 3.00$, 95% CI : 0.11 – 78.27 , $P = 0.51$), respectively (Fig. 4A).

3.6. Complications

3.6.1. Cardiovascular complications

Pooled analyses revealed that CWI had no effect on postoperative cardiac arrest (2 studies^{12,22} [2 comparisons, 1,570 patients];

$OR = 0.80$, 95% CI : 0.33 – 1.92 , $P = 0.61$), high-degree heart block (3 studies^{12,19,22} [3 comparisons, 1,685 patients]; $OR = 1.10$, 95% CI : 0.49 – 2.49 , $P = 0.82$), supraventricular arrhythmia (2 studies^{19,22} [2 comparisons, 200 patients]; $OR = 1.04$, 95% CI : 0.26 – 4.20 , $P = 0.96$), ventricular arrhythmia (3 studies^{12,19,22} [3 comparisons, 1,685 patients]; $OR = 1.13$, 95% CI : 0.56 – 2.28 , $P = 0.74$), or major adverse cardiac event (4 studies^{12,19,22,25} [4 comparisons, 1,732 patients]; $OR = 0.99$, 95% CI : 0.59 – 1.67 , $P = 0.97$). Eljezi et al.¹⁹ reported that CWI did not affect either the incidence of postoperative tamponade ($OR = 0.21$, 95% CI : 0.01 – 4.49 , $P = 0.32$) or the incidence of pulmonary embolism ($OR = 3.33$, 95% CI : 0.13 – 83.47 , $P = 0.46$). Taken together, meta-analysis demonstrated that CWI did not affect the composite incidence of postoperative cardiovascular complications ($OR = 1.03$, 95% CI : 0.76 – 1.39 , $P = 0.84$) (Fig. 4B).

3.6.2. Cerebral complications

Pooled analyses revealed that CWI had no effect on postoperative stroke (2 studies^{12,19} [2 comparisons, 1,600 patients]; $OR = 0.39$, 95% CI : 0.08 – 2.04 , $P = 0.27$) or seizures (2 studies^{12,22} [2 comparisons, 1,570 patients]; $OR = 0.74$, 95% CI : 0.17 – 3.33 , $P = 0.70$). Pooled results from 2 studies^{19,23} (2 comparisons, 154 patients) reported that CWI decreased the occurrence of postoperative delirium or confusion ($OR = 0.16$, 95% CI : 0.04 – 0.63 , $P < 0.01$) (Fig. 4C).

3.6.3. Pulmonary complications

Five RCTs^{12,19,21–23} evaluated the effect of CWI on postoperative respiratory outcomes. Eljezi et al.²³ and Agarwal et al.²² reported no significant differences in forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), or FEV_1/FVC between the CWI and control groups postoperatively. In contrast, Nasr et al.²¹ found generally better respiratory parameters in the CWI group, with higher partial pressure of

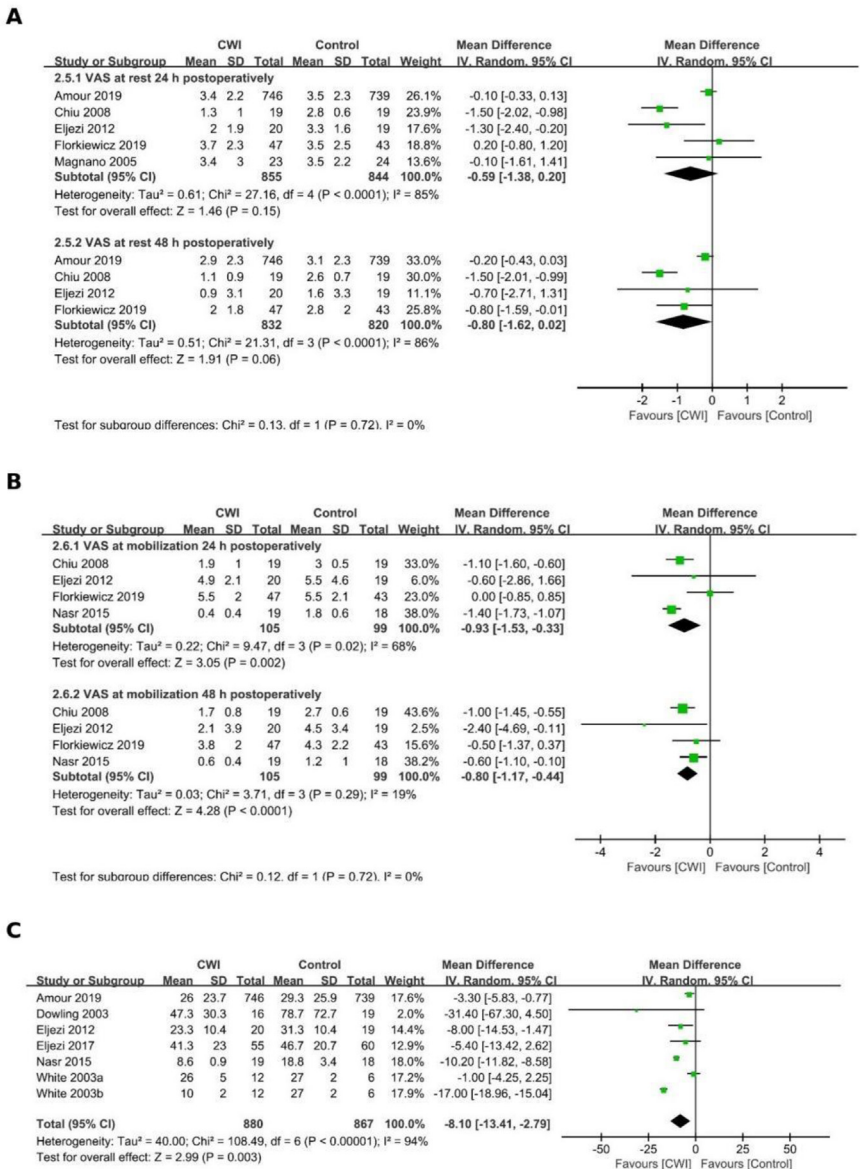


Fig. 2. Comparisons of postoperative VAS scores and morphine consumption between CWI and controls. (A) visual Analogue Scale (VAS) score at rest; (B) VAS score during mobilization; and (C) postoperative morphine consumption.

oxygen in arterial blood / fraction of inspired oxygen ($\text{PaO}_2/\text{FiO}_2$) at extubation and at 6, 12, and 24 h. Eljezi et al.¹⁹ reported a lower incidence of respiratory complications in the CWI group than controls (5.5% vs. 23.3%, $P = 0.02$), whereas Amour et al.¹² observed no significant effect of CWI on postoperative pneumonia (4.9% vs. 5.7%, $P = 0.22$).

3.6.4. Renal and urinary complications

Pooled results from 3 studies^{12,19,22} (3 comparisons, 1,685 patients) reported that CWI had no effect on postoperative renal dysfunction ($OR = 0.87$, 95% CI : 0.51–1.46, $P = 0.59$) (Fig. 4D). In the trial by White et al.²⁷ urinary catheter removal occurred one day earlier in patients in the CWI group with 0.5% bupivacaine compared with patients in the control group and CWI group with 0.25% bupivacaine (both $P < 0.05$), indicating that improved pain management through CWI may contribute to faster recovery of bladder function and earlier catheter removal.

3.6.5. Gastrointestinal complications

Pooled results from five studies^{15,18,19,23,27} (6 comparisons, 350 patients) showed that CWI had no significant effect on the incidence of

postoperative nausea and vomiting (PONV) ($OR = 0.74$, 95% CI : 0.42 to 1.30, $P = 0.29$) (Fig. 4E).

Three RCTs^{19,23,27} evaluated the timing of postoperative resumption of oral dietary intake. In the trial by Eljezi et al.²³ patients in the CWI group resumed oral intake earlier than controls (0 days vs. 5 days, $P = 0.01$). Similarly, White et al.²⁷ reported earlier resumption of normal diet in CWI patients compared with controls ($P < 0.05$). In contrast, Eljezi et al.¹⁹ found no significant difference between groups (64 h vs. 64 h, $P = 0.99$). Overall, the evidence regarding CWI and earlier dietary resumption is mixed.

Two RCTs^{19,23} reported the time to first flatus after surgery. In the trial by Eljezi et al.²³ flatus within 48 h postoperatively occurred in 19 patients (95%) in the CWI group and 16 patients (84.2%) in the control group ($P = 0.27$). In the trial by Eljezi et al.¹⁹, the median time to first flatus was 72 h in the CWI group and 64 h in the control group ($P = 0.78$).

Three RCTs^{19,23,27} reported postoperative feces. In the trial by Eljezi et al.,²³ feces within 48 h postoperatively occurred in 2 patients (10%) in the CWI group and 0 patients (0%) in the control group ($P = 0.16$).

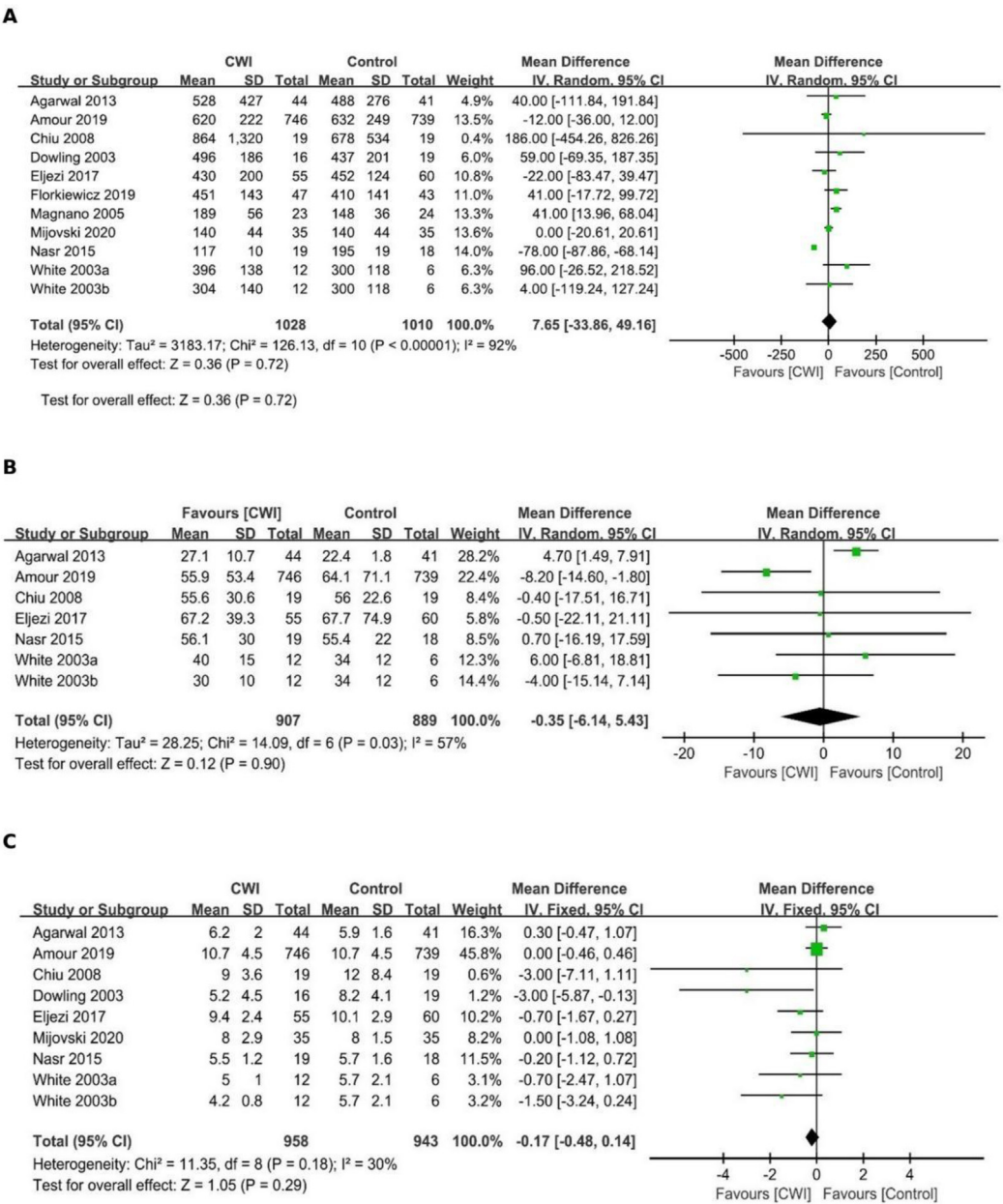


Fig. 3. Postoperative recovery profiles in pooled analyses. (A) mechanical ventilation duration; (B) length of ICU stay; and (C) length of hospital stay.

In the trial by Eljezi et al.,¹⁹ the median time to first feces was 100 h in the CWI group and 80 h in the control group (P = 0.09). White et al.²⁷ reported mean time to first feces of (4.6 ± 1.4) days in the control group, (4.3 ± 1.3) days in the CWI (0.25% bupivacaine) group, and (4.0 ± 1.5) days in the CWI (0.5% bupivacaine) group (P > 0.05).

3.6.6. Infectious complications

Pooled analyses revealed CWI had no effect on postoperative sternal wound infection (4 studies^{15,19,21,22} [4 comparisons, 327 patients]; OR = 2.60, 95% CI: 0.59–11.42, P = 0.21), postoperative sepsis (3 studies^{12,18,19} [3 comparisons, 1,670 patients]; OR = 1.31, 95% CI: 0.35–4.97, P = 0.69), postoperative pneumonia (2 studies^{12,23} [2 comparisons, 1,508 patients]; OR = 0.83, 95% CI: 0.53–1.30, P = 0.41), postoperative mediastinitis (2 studies^{12,19} [2 comparisons, 1,584 patients]; OR = 0.90, 95% CI: 0.53–1.52, P = 0.69), or other site infection (3 studies^{15,19,25} [3 comparisons, 252 patients]; OR = 0.48, 95% CI: 0.18–1.25, P = 0.13). Taken together, meta-analysis demonstrated that CWI did not

affect the composite incidence of postoperative infectious complications (OR = 0.87, 95% CI: 0.64–1.18, P = 0.36) (Fig. 4F).

3.7. Patient satisfaction

Three RCTs^{17,19,23} specifically assessed patient-reported satisfaction with postoperative analgesia following CWI after cardiac surgery. Mijovski et al.¹⁸ found a median satisfaction score of 1 in the CWI group and 2 in the control group, with no significant difference between groups (P = 0.13). Eljezi et al.²³ reported that most patients receiving CWI were “rather satisfied” or “very satisfied” (35.0% and 65.0%, respectively), compared with 52.6% and 5.3% in the control group (P < 0.001). Eljezi et al.¹⁹ found again higher satisfaction in the CWI group, with 27.1% reporting “very good” and 54.2% “good,” vs. 70.4% “very good” and 25.9% “good” in the control group (P < 0.01). Across these trials, patients receiving CWI consistently reported high levels of satisfaction, generally exceeding those of the control group. While the magnitude

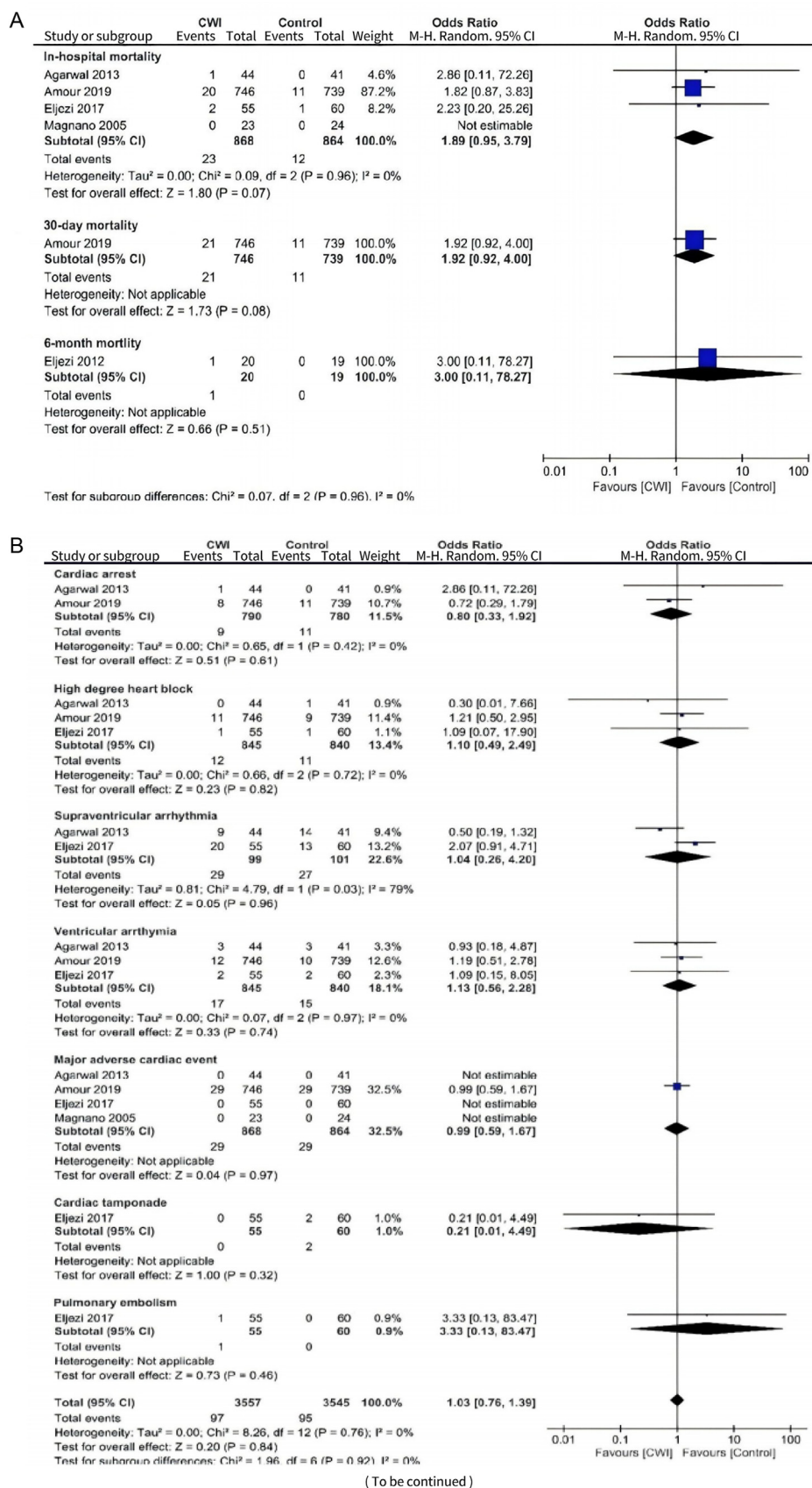


Fig. 4. Postoperative mortality and complications in pooled analyses. (A) mortality; (B) cardiovascular complications.

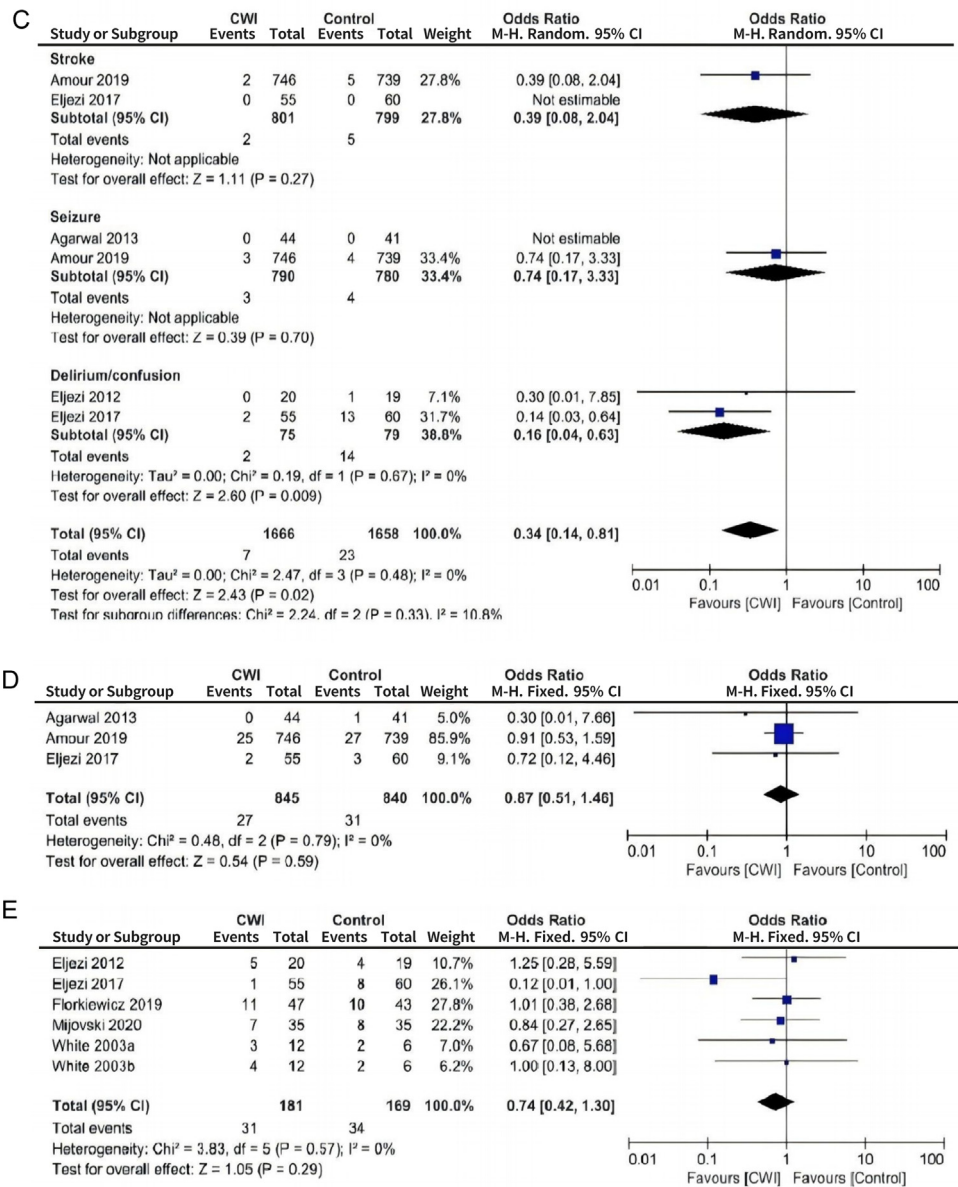


Fig. 4. Postoperative mortality and complications in pooled analyses (continued). (C) cerebral complications; (D) acute acute kidney failure; and (E) nausea and vomiting.

of improvement varied among studies, these findings indicate that CWI may enhance the overall patient experience after cardiac surgery.

3.8. Adverse events

Six RCTs^{18,21,24–27} explicitly reported monitoring for delayed wound healing or wound dehiscence. Across all included patients in these trials, no events were observed in either the CWI or control groups. These findings indicated that CWI itself or CWI with LAs did not appear to increase the risk of impaired wound healing or wound separation, supporting its overall safety in cardiac surgical patients.

Complications related to the CWI delivery system were infrequent and generally minor. Reported issues included catheter occlusion,^{15,18} leakage of the catheter,¹⁵ accidental dislodgement or removal,²¹ and a broken catheter tip.²⁷ These events occurred in both the CWI and control groups and did not result in excess morbidity. With respect to LAs safety, no trial reported definitive evidence of systemic toxicity. Plasma concentrations of ropivacaine and bupiva-

caine largely remained below toxic thresholds,^{18,21,27} although isolated patients demonstrated higher levels without symptoms.²³ Additionally, two suspected overdose-related events (ventricular arrhythmia and seizure) were described,¹⁹ but causality was uncertain. Importantly, no study identified clinically significant neurotoxicity, cardiotoxicity, or fatal events attributable to CWI. Overall, CWI with LAs for cardiac surgical patients was well tolerated across trials, with rare technical complications and no consistent signal of LAs-related side effects.

3.9. Long-term effects

Four RCTs^{12,15,19,23} assessed the impact of CWI on long-term postoperative outcomes following cardiac surgery. Florkiewicz et al.¹⁵ reported there was 1 sternotomy infection in the CWI group and 5 leg wound infections (2 in the CWI group and 3 in the control group), which were all treated with antibiotics at 3 months. Amour et al.¹² reported 28 cases (4.0%) of mediastinitis in the CWI group and 31 pa-

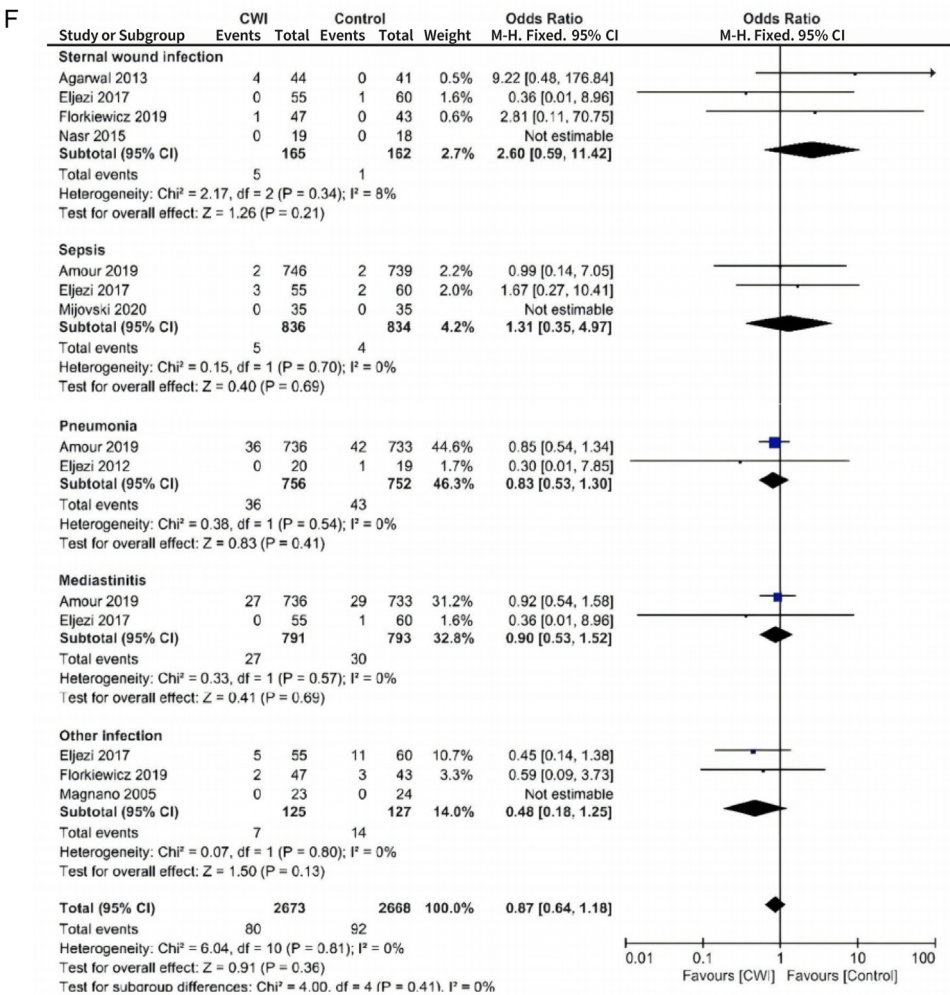


Fig. 4. Postoperative mortality and complications in pooled analyses (continued). (F) infectious complications.

tients (4.0%) of mediastinitis in the control group 3 months postoperatively ($P = 0.48$). Eljezi et al.¹⁹ evaluated the impact of CWI on the long-term pain outcomes. They reported that, 4 patients (6.9%) in the CWI group and 3 (6.0%) patients in the control group had persistent sternal pain at rest ($P = 0.85$), and that 11 patients (19.0%) in the CWI group and 17 (34.0%) patients in the control group had persistent sternal pain at movement ($P = 0.08$), and that 1 patient (1.7%) in the CWI group and 1 (2.0%) patients in the control group had persistent sternal neuropathic pain ($P = 1.00$) 6 months after surgery. Similarly, Eljezi et al.²³ found no impact of CWI on the incidences of both postoperative mortality ($P = 1.00$) and persistent sternal pain ($P = 1.00$) 6 months postoperatively.

3.10. Certainty of evidence

The certainty of evidence was moderate for VAS scores during mobilization at 24 h and 48 h and for 48-hour morphine consumption because the direction of effect was consistent but the number of contributing trials was limited. Certainty was low for VAS at rest, MVD, ICU and hospital LOS, mortality, and most complication outcomes because of imprecision, heterogeneity, or sparse events. Certainty was very low for outcomes reported by only one or two small trials, including delirium/confusion, early mobilization, dietary recovery, catheter-related technical events, and long-term pain (Supplementary Table 3).

3.11. Subgroup, sensitivity, and publication bias analyses

The limited amount of available data precluded pre-specified subgroup analyses exploring effect modifiers such as surgical type, catheter location, LA type, concentration, and infusion duration. Several secondary outcomes were informed by only one or two trials, and some pooled estimates were derived from two or three small studies with few events. These findings should therefore be interpreted as exploratory and hypothesis-generating rather than definitive evidence of benefit or harm.

Sensitivity analyses were conducted to evaluate robustness. When fixed- and random-effects models were compared, the direction of treatment effects was generally similar. The beneficial effects on VAS score during mobilization and 48-hour morphine consumption persisted in sensitivity analyses, whereas VAS score at rest and mechanical ventilation duration were less stable (Supplementary Table S4). Sensitivity analyses excluding potentially influential studies were also performed. The reductions in VAS score during mobilization at 24 h and 48-hour morphine consumption remained robust, whereas VAS score at rest, mechanical ventilation duration, and ICU LOS were less stable or remained non-significant. These findings support the robustness of the analgesic benefit of CWI, but not its effects on recovery-related outcomes (Supplementary Table S5).

Because fewer than 10 studies were available for all outcomes, formal tests for publication bias, including Egger and Begg tests, were not

Table 2
Comparison between CWI and commonly used regional anesthesia techniques.

Technique	Main advantages	Main limitations	Potential clinical positioning
Continuous wound infiltration	Simple catheter-based technique; no deep needle placement; avoids neuraxial bleeding concerns; continuous incisional analgesia	Limited mainly to incisional pain; catheter leakage or occlusion can occur; heterogeneous LA regimens	Adjunct to multimodal analgesia, particularly when neuraxial techniques or complex blocks are undesirable
Erector spinae plane block	Broader thoracic analgesic coverage; ultrasound-guided fascial plane technique; increasingly used after cardiac surgery	Requires ultrasound expertise; optimal dosing and comparative effectiveness remain uncertain	Alternative or complement to CWI when block expertise is available
Parasternal or intercostal plane block	Targets anterior chest wall and sternotomy pain; can be performed under ultrasound guidance	Single-shot duration may be limited unless catheter used; may not cover drain or graft-harvest pain	Useful for sternotomy-related pain within ERAS pathways

LA: local anesthetics; CWI: continuous wound infiltration; ERAS: enhanced recovery after surgery.

performed. Funnel plots for primary outcomes are provided only as exploratory visual assessments (**Supplementary Figures S1A–S1C**).

4. Discussion

This meta-analysis of 12 RCTs involving 2,117 patients showed that CWI with LAs provided modest postoperative analgesic benefits after adult cardiac surgery. The clearest signal was a reduction in pain during mobilization and a decrease in 48-hour opioid consumption. However, these analgesic effects did not translate into shorter MVD or LOS, nor into lower mortality or major complication rates.

The analgesic benefits observed with CWI are biologically plausible. Continuous administration of LAs at the incision site attenuates afferent nociceptive input, thereby reducing central sensitization and the need for systemic opioids.²⁸ The greater effect on pain during mobilization, compared with pain at rest, may reflect the role of incisional pain as a dominant contributor to activity-related discomfort in the early postoperative period.²⁹

The reduction in pain during mobilization is clinically relevant even though the absolute mean difference was modest. Activity-related pain is a key determinant of deep breathing, coughing, chest physiotherapy, transfer from bed to chair, and early ambulation after cardiac surgery. Therefore, a reduction of approximately 0.8 to 0.9 points on a 10-point VAS should be interpreted as a supportive effect that may facilitate participation in recovery activities rather than as a stand-alone analgesic solution. This interpretation is consistent with the absence of a clear effect on pain at rest and on downstream outcomes such as length of stay.

The absence of benefit on recovery-related endpoints has several plausible explanations. Pain after cardiac surgery is multifactorial and may arise from sternotomy or thoracotomy, chest drains, graft harvest sites, musculoskeletal traction, and pleural irritation, while CWI mainly targets the incisional component.³⁰ Trial protocols also varied substantially in catheter placement, LA type, concentration, and infusion duration, which may have diluted measurable effects. In addition, contemporary multimodal analgesia and ERAS-based care may reduce the incremental effect of any single analgesic intervention.^{30,31}

Clinically, CWI is best positioned as an adjunct to multimodal analgesia rather than as a replacement for more comprehensive regional techniques. Compared with erector spinae plane block or parasternal/intercostal plane blocks, CWI is technically simpler and avoids deep needle placement, but its analgesic coverage is more limited and primarily incisional (**Table 2**). It may be most useful when neuraxial analgesia is undesirable because of anticoagulation, when expertise or time for ultrasound-guided blocks is limited, or as part of an opioid-sparing pathway in patients at risk of opioid-related complications. The possible reduction in delirium/confusion should be interpreted cautiously because it was based on limited data, but it is biologically plausible through opioid reduction and improved mobilization.

Several limitations merit discussion. First, although this is the most comprehensive synthesis to date of RCTs evaluating CWI in adult cardiac surgery, many contributing trials were small, and only a few large multicenter studies were available. Second, several outcomes were reported by only one or two trials or were pooled from a small number of studies with few events. These estimates are statistically underpowered and should not be interpreted as firm evidence of no effect. Third, heterogeneity in patient populations, surgical procedures, catheter techniques, LA regimens, co-interventions, and outcome definitions contributed to uncertainty in pooled estimates. Fourth, long-term outcomes such as chronic pain, functional recovery, and quality of life were rarely reported. Fifth, because fewer than 10 trials contributed to each outcome, formal statistical assessment of publication bias was not appropriate. Finally, although GRADE assessment was added to summarize certainty of evidence, the certainty for many secondary outcomes remained low or very low because of imprecision and sparse data.

5. Conclusions

In adult cardiac surgery, CWI with LAs reduces pain during mobilization and decreases early opioid consumption, but it does not clearly improve mortality, major complications, MVD, or LOS. CWI appears safe and feasible and may be used as an opioid-sparing adjunct within multimodal analgesia pathways. Larger contemporary RCTs with standardized local anesthetic regimens, active comparators, and patient-centered recovery outcomes are needed to better define its role in ERAS-era cardiac surgical care.

Authors’ contributions

YY designed the study. YY and SH conducted the database searches, screened eligible studies, and extracted the data. YY and AM assessed risk of bias and performed the statistical analyses. YY, AM, and MC interpreted the results. YY drafted the manuscript. All authors critically revised the manuscript and approved the final version.

Declaration of generative AI and AI-assisted technologies use

The author(s) declare that they have not used any Generative AI or AI-assisted technologies in the writing process of this manuscript, nor for creating any images or figures.

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Conflict of interests

The authors declared no potential conflict of interests.

Data availability

The data and materials generated and/or analyzed during the present study are available from the corresponding author upon reasonable request.

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Supplementary materials

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References

- Strumia A, Lusini M, Costa F, et al. Management of analgesia in cardiac surgery. *Pain Manag.* 2025;15(9):595–609. doi:10.1080/17581869.2025.2532359.
- Dost B, Turunc E, Aydin ME, et al. Pain management in minimally invasive cardiac surgery: a review of current clinical evidence. *Pain Ther.* 2025;14(3):913–930. doi:10.1007/s40122-025-00739-1.
- Culp C, Manning MW. How we would use enhanced recovery after cardiac surgery: what we would do for ourselves during the perioperative period. *J Cardiothorac Vasc Anesth.* 2025;39(8):1950–1960. doi:10.1053/j.jvca.2025.02.040.
- Zhang Y, Ma D, Lang B, et al. Effect of opioid-free anesthesia on the incidence of postoperative nausea and vomiting: a meta-analysis of randomized controlled studies. *Med (Baltim).* 2023;102(38):e35126. doi:10.1097/MD.00000000000035126.
- Mertes PM, Kindo M, Amour J, et al. Guidelines on enhanced recovery after cardiac surgery under cardiopulmonary bypass or off-pump. *Anaesth Crit Care Pain Med.* 2022;41(3):101059. doi:10.1016/j.jaccpm.2022.101059.
- Laferrière-Langlois P, Jeffries S, Harutyunyan R, et al. Epidural catheterization in cardiac surgery: a systematic review and risk assessment of epidural hematoma. *Ann Card Anaesth.* 2024;27(2):111–120. doi:10.4103/aca.aca.160.23.
- Sandeep B, Huang X, Jiang F, et al. Meta-analysis of erector spinae plane block efficacy in managing postoperative pain following cardiac surgery. *Curr Probl Cardiol.* 2025;50(8):103098. doi:10.1016/j.cpcardiol.2025.103098.
- Dost B, De Cassai A, Amaral S, et al. Regional anesthesia for pediatric cardiac surgery: a review. *BMC Anesth.* 2025;25(1):77. doi:10.1186/s12871-025-02960-z.
- Lombardi RA, Pereira EM, Amaral S, et al. Erector spinae plane block versus intravenous opioid for analgesia in pediatric cardiac surgery: a systematic review and meta-analysis. *Paediatr Anaesth.* 2025;35(1):17–24. doi:10.1111/pan.15027.
- Hargrave J, Grant MC, Kolarczyk L, et al. An expert review of chest wall fascial plane blocks for cardiac surgery. *J Cardiothorac Vasc Anesth.* 2023;37(2):279–290. doi:10.1053/j.jvca.2022.10.026.
- Tripodi VF, Sardo S, Ippolito M, et al. Effectiveness and safety of opioid-free anesthesia compared to opioid-based anesthesia: a systematic review and network meta-analysis. *J Anesth Analg Crit Care.* 2025;5(1):53. doi:10.1186/s44158-025-00272-9.
- Amour J, Cholley B, Ouattara A, et al. The effect of local anesthetic continuous wound infusion for the prevention of postoperative pneumonia after on-pump cardiac surgery with sternotomy: the STERNOCAT randomized clinical trial. *Intensive Care Med.* 2019;45(1):33–43. doi:10.1007/s00134-018-5497-x.
- Mattila I, Pätäli T, Rautiainen P, et al. The effect of continuous wound infusion of ropivacaine on postoperative pain after median sternotomy and mediastinal drain in children. *Paediatr Anaesth.* 2016;26(7):727–733. doi:10.1111/pan.12919.
- Tirotta CF, Munro HM, Salvaggio J, et al. Continuous incisional infusion of local anesthetic in pediatric patients following open heart surgery. *Paediatr Anaesth.* 2009;19(6):571–576. doi:10.1111/j.1460-9592.2009.03009.x.
- Florkiewicz P, Musialowicz T, Hippeläinen M, et al. Continuous ropivacaine infusion offers no benefit in treating postoperative pain after cardiac surgery. *J Cardiothorac Vasc Anesth.* 2019;33(2):378–384. doi:10.1053/j.jvca.2018.09.006.
- Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021;372:n71. doi:10.1136/bmj.n71.
- Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ.* 2019;366:l4898. doi:10.1136/bmj.l4898.
- Mijovski G, Podbregar M, Kšela J, et al. Effectiveness of wound infusion of 0.2% ropivacaine by patient control analgesia pump after minithoracotomy aortic valve replacement: a randomized, double-blind, placebo-controlled trial. *BMC Anesth.* 2020;20(1):172. doi:10.1186/s12871-020-01093-9.
- Eljezi V, Imhoff E, Bourdeaux D, et al. Bilateral sternal infusion of ropivacaine and length of stay in ICU after cardiac surgery with increased respiratory risk: a randomised controlled trial. *Eur J Anaesthesiol.* 2017;34(2):56–65. doi:10.1097/EJA.0000000000000564.
- Hong SS, Alison JA, Milross MA, et al. Does continuous infusion of local anaesthesia improve pain control and walking distance after coronary artery bypass graft surgery? A randomised controlled trial. *Physiotherapy.* 2017;103(4):407–413. doi:10.1016/j.physio.2017.02.002.
- Nasr DA, Abdelhamid HM, Mohsen M, et al. The analgesic efficacy of continuous presteral bupivacaine infusion through a single catheter after cardiac surgery. *Ann Card Anaesth.* 2015;18(1):15. doi:10.4103/0971-9784.148314.
- Agarwal S, Nuttall GA, Johnson ME, et al. A prospective, randomized, blinded study of continuous ropivacaine infusion in the median sternotomy incision following cardiac surgery. *Reg Anesth Pain Med.* 2013;38(2):145–150. doi:10.1097/AAP.0b013e318281a348.
- Eljezi V, Dualé C, Azarnoush K, et al. The analgesic effects of a bilateral sternal infusion of ropivacaine after cardiac surgery. *Reg Anesth Pain Med.* 2012;37(2):166–174. doi:10.1097/AAP.0b013e318240957f.
- Chiu KM, Wu CC, Wang MJ, et al. Local infusion of bupivacaine combined with intravenous patient-controlled analgesia provides better pain relief than intravenous patient-controlled analgesia alone in patients undergoing minimally invasive cardiac surgery. *J Thorac Cardiovasc Surg.* 2008;135(6):1348–1352. doi:10.1016/j.jtcvs.2008.01.020.
- Magnano D, Montalbano R, Lamarra M, et al. Ineffectiveness of local wound anesthesia to reduce postoperative pain after median sternotomy. *J Card Surg.* 2005;20(4):314–318. doi:10.1111/j.1540-8191.2005.200318.x.
- Dowling R, Thielmeier K, Ghaly A, et al. Improved pain control after cardiac surgery: results of a randomized, double-blind, clinical trial. *J Thorac Cardiovasc Surg.* 2003;126(5):1271–1278. doi:10.1016/s0022-5223(03)00585-3.
- White PF, Rawal S, Latham P, et al. Use of a continuous local anesthetic infusion for pain management after median sternotomy. *Anesthesiology.* 2003;99(4):918–923. doi:10.1097/0000542-200310000-00026.
- Kehlet H, Dahl JB. Anaesthesia, surgery, and challenges in postoperative recovery. *Lancet.* 2003;362(9399):1921–1928. doi:10.1016/S0140-6736(03)14966-5.
- Lahtinen P, Kokki H, Hynynen M. Pain after cardiac surgery: a prospective cohort study of 1-year incidence and intensity. *Anesthesiology.* 2006;105(4):794–800. doi:10.1097/0000542-200610000-00026.
- Paladini G, Di Carlo S, Musella G, et al. Continuous wound infiltration of local anesthetics in postoperative pain management: safety, efficacy and current perspectives. *J Pain Res.* 2020;Volume 13:285–294. doi:10.2147/JPR.S211234.
- Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. *JAMA Surg.* 2017;152(3):292. doi:10.1001/jamasurg.2016.4952.