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# Lower Preoperative Serum Magnesium Is Associated With Postoperative Atrial Fibrillation After Coronary Artery Bypass Grafting: A Single-Center Retrospective Cohort Study

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**Research Article**

**Keywords:** Coronary artery bypass grafting, Postoperative atrial fibrillation, Pleural drainage, Serum magnesium, Propensity score matching

**Posted Date:** November 12th, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-11215117/v1

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**Additional Declarations:** No competing interests reported.

# Lower Preoperative Serum Magnesium Is Associated With Postoperative Atrial Fibrillation After Coronary Artery Bypass Grafting: A Single-Center Retrospective Cohort Study

**Running title:** Serum magnesium and POAF after CABG

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## Abstract

**Background:** Postoperative atrial fibrillation (POAF) is the most common arrhythmic complication after coronary artery bypass grafting (CABG). We evaluated whether pleural drainage tube placement influences POAF and identified clinical factors associated with POAF, particularly serum magnesium.

**Methods:** In this single-center retrospective cohort study, we screened 602 consecutive adults who underwent CABG between September 2020 and June 2026. The exposure was intraoperative pleural drainage tube placement, and the outcome was POAF. Associations were assessed by multivariable logistic regression, propensity score matching (PSM), inverse probability of treatment weighting, and overlap weighting.

**Results:** A total of 520 patients were included (mean age 64.8 ± 7.9 years; 372 men, 71.5%). Pleural drainage tubes were placed in 166 patients (31.9%), and POAF occurred in 135 patients (26.0%). Lower serum magnesium was independently associated with POAF in a dose-dependent manner: adjusted OR per 0.05 mmol/L increment 0.78 (95% CI 0.67–0.91, $P < 0.001$); magnesium tertiles showed a significant trend (P for trend = 0.011); and magnesium below the internally derived cutoff of 0.815 mmol/L was associated with increased risk (adjusted OR 1.94, 95% CI 1.19–3.15, P = 0.008; AUC 0.612). The E-value for this association was 2.13. Pleural drainage tube placement was not independently associated with POAF: crude OR 1.32 (95% CI 0.87–2.00), adjusted OR 1.36 (95% CI 0.85–2.15), and PSM OR 1.37 (95% CI 0.81–2.33). The study was underpowered to detect an OR below 1.78 for the drainage association.

**Conclusions:** Lower preoperative serum magnesium was independently associated with POAF in a dose-dependent manner, whereas pleural drainage tube placement was not. Because perioperative magnesium supplementation was not recorded, these findings cannot establish whether magnesium optimization would reduce POAF risk; this hypothesis requires prospective randomized trials.

**Clinical trial number:** not applicable.

**Keywords:** Coronary artery bypass grafting; Postoperative atrial fibrillation; Pleural drainage; Serum magnesium; Propensity score matching

## Background

Postoperative atrial fibrillation (POAF) is the most common arrhythmic complication after coronary artery bypass grafting (CABG), with a reported incidence of 20%–40% and a pooled estimate of approximately 25% in most cohorts[1-3]. POAF typically occurs within 5 days after surgery, peaks on postoperative day 2, and coincides with the peak of the perioperative inflammatory response[4]. Although most episodes are self-limiting, POAF is associated with prolonged hospital stay, an increased risk of stroke and heart failure, readmission, and higher healthcare costs[1, 2]. Recent evidence suggests that POAF may be better understood as a marker of underlying patient vulnerability than as a direct driver of adverse outcomes[5].

Established risk factors for POAF include advanced age, reduced left ventricular ejection fraction (LVEF), renal dysfunction, preoperative anemia, hypertension, chronic obstructive pulmonary disease (COPD), and prolonged cardiopulmonary bypass (CPB) and perfusion times[3, 6]. The 2026 clinical practice guidelines of the Society of Thoracic Surgeons (STS) provide systematic recommendations for POAF prevention and treatment across the preoperative, intraoperative, and postoperative phases; perioperative oral amiodarone and rhythm cardioversion for hemodynamically unstable POAF are Class I recommendations, whereas posterior pericardiotomy and perioperative beta-blockers are Class IIa recommendations[7].

In recent years, the role of pericardial effusion and localized pericardial inflammation in the pathogenesis of POAF has attracted increasing attention[8]. Retained intrapericardial blood, its degradation products, activation of the coagulation cascade, and oxidative stress together create a proinflammatory and pro-oxidant microenvironment that can trigger atrial fibrillation in susceptible patients[9]. Consistent with this mechanism, meta-analyses of randomized controlled trials (RCTs) have shown that posterior pericardiotomy (PP), which drains pericardial fluid into the pleural space, significantly reduces the risk of POAF and pericardial effusion: a pooled odds ratio (OR) of 0.49, with a 95% confidence interval (CI) of 0.38–0.61, across 25 RCTs (4,467 patients)[10] and a pooled OR of 0.45 (95% CI 0.32–0.64) across 18 RCTs (3,531 patients), although the incidence of pleural effusion was higher in the PP group (OR 1.42, 95% CI 1.06–1.90)[11]. Similar findings have been reported in isolated CABG populations[12, 13]. In addition, creation of a right pleuro-pericardial window before chest closure has been independently associated with a lower incidence of POAF[14], and replacing mediastinal drainage with a posterior pericardial window combined with a single pleural drain has also been shown to reduce pericardial effusion and atrial fibrillation[15].

However, evidence regarding whether conventional pleural drainage tube placement itself affects POAF remains limited. The proposed mechanism is that drainage reduces fluid accumulation within the pericardial space and alleviates pericardial inflammation and cardiac tamponade, thereby lowering the risk of POAF. Nevertheless, the primary target of a conventional pleural drainage tube is the pleural space rather than the pericardial cavity, so its effect on retained intrapericardial blood and inflammatory mediators may be limited [9, 11, 15].

In parallel, the relationship between serum magnesium and POAF has received increasing attention. Hypomagnesemia is common after cardiac surgery, with a reported incidence of up to 71% after CPB[16]. Several studies have identified hypomagnesemia as an independent predictor of POAF[17, 18]. A meta-analysis of RCTs reported that magnesium supplementation reduced the risk of POAF, with a relative risk (RR) of 0.55 (95% CI 0.41–0.74)[19]. In contrast, another meta-analysis found no benefit when the analysis was restricted to high-quality, double-blind, intention-to-treat trials (OR 0.94)[20], a more recent meta-analysis found no significant reduction in the incidence of new-onset atrial fibrillation[21], and a large randomized clinical trial showed that perioperative magnesium infusion maintaining serum magnesium at 1.5–2.0 mmol/L did not reduce POAF[22]. These conflicting findings may reflect differences in the timing and dose of magnesium supplementation, the target population, and the method of magnesium measurement (total versus ionized magnesium).

The primary aim of this study was to identify modifiable risk factors for POAF, with a particular focus on serum magnesium, in a CABG cohort. A secondary aim was to evaluate whether pleural drainage tube placement was independently associated with POAF. Reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[23].

## Methods

### Study Design and Population

This single-center retrospective observational study was conducted at the Affiliated Hospital of Xuzhou Medical University. We screened 602 consecutive adults who underwent CABG between September 2020 and June 2026. Inclusion criteria were first-time CABG and age ≥ 18 years; patients with pre-existing atrial fibrillation, repeat CABG or extensive missing data on key variables were excluded. A total of 520 patients were included and were grouped by pleural drainage tube placement into a drainage group (n = 166) and a no-drainage group (n = 354). The study protocol was approved by the Medical Ethics Committee of the Affiliated Hospital of Xuzhou Medical University (approval number XYFY2025-KL154-01), and written informed consent was waived because of the retrospective design. Patient selection is shown in Figure 1.

The exposure was pleural drainage tube placement during CABG, ascertained from operative records and verified against postoperative nursing records. The tube used was a 22-Fr chest tube connected to a water-seal system and was removed routinely when the 24-hour drainage volume fell below 100 mL and no air bubbles were seen on coughing. The outcome was POAF, defined as new-onset atrial fibrillation detected by standard electrocardiographic monitoring during the postoperative hospital stay. Diagnostic criteria were absence of P waves with replacement by f waves, an absolutely irregular QRS rhythm, varying RR intervals, and an episode lasting more than 30 seconds[24]. Detection was limited to the hospital stay. Continuous rhythm monitoring was not applied uniformly and monitoring intensity differed between postoperative phases, so transient or asymptomatic episodes may have been missed.

### Data Collection and Covariates

Baseline and perioperative data were extracted from the institutional electronic medical record and the surgical database, and included demographic characteristics (age, sex, body mass index [BMI], smoking, alcohol consumption); comorbidities (diabetes, hypertension, pulmonary hypertension, prior myocardial infarction within 90 days, New York Heart Association [NYHA] class, Canadian Cardiovascular Society [CCS] class); echocardiographic parameters (LVEF, left atrial diameter [LAD], left ventricular end-diastolic diameter [LVDd], valvular disease); laboratory results (estimated glomerular filtration rate [eGFR], creatinine, albumin, magnesium, hemoglobin, B-type natriuretic peptide [BNP], troponin T, white blood cell [WBC] count, platelet count); medications (beta-blockers, statins, angiotensin-converting enzyme inhibitors [ACEIs] or angiotensin receptor blockers [ARBs], diuretics, insulin, oral hypoglycaemic agents, dapagliflozin); and surgical characteristics (number of diseased vessels, concomitant surgery, use of CPB, duration of surgery and anesthesia). Prior myocardial infarction within 90 days was defined as a documented infarction occurring within 90 days before surgery, including patients who presented with acute coronary syndrome and were referred directly for CABG.

### Statistical Analysis

Continuous variables were summarized as mean ± standard deviation (SD) or median [interquartile range (IQR)] according to distribution and compared using the Student t test or the Wilcoxon rank-sum test. Categorical variables were summarized as counts (percentages) and compared using the $\chi^2$ test or the Fisher exact test. Standardized mean differences (SMDs) were calculated, with SMD < 0.10 taken to indicate adequate balance[25].

Univariable logistic regression was used to screen variables associated with POAF. Variables with $P < 0.05$ and those of clinical importance were entered into a multivariable logistic regression model. Retention was based on univariable $P < 0.05$ and clinical relevance while avoiding multicollinearity; some univariable predictors were excluded because of collinearity or because they were considered intermediates rather than independent risk factors. ORs and 95% CIs were reported. Multicollinearity was assessed using the variance inflation factor (VIF), with VIF > 5 taken to indicate collinearity[26].

Propensity score matching (PSM) was used to reduce the influence of measured confounding[27]. A 1:1 nearest-neighbor match was performed with a caliper of 0.2 times the pooled SD of the logit of the propensity score[28], using the R package MatchIt[29]. Balance was assessed with SMDs and Love plots. As sensitivity analyses we repeated the drainage analysis using inverse probability of treatment weighting (IPTW)[30], overlap weighting[31, 32] and conditional logistic regression in the matched cohort.

Serum magnesium was analyzed in three ways. First, as the primary analysis, magnesium was fitted as a continuous variable (per 0.05 mmol/L increment) in the multivariable model. Second, as a pre-specified secondary analysis, magnesium was divided into tertiles and adjusted ORs were calculated with the lowest tertile as reference; the P for trend was obtained by treating tertile rank as a continuous variable. Third, in an exploratory analysis, a cutoff was selected from the receiver operating characteristic (ROC) curve using the Youden index[33]. Because this cutoff was derived from the same cohort in which it was then applied, the associated estimates are subject to optimistic bias and require external validation; this analysis is hypothesis-generating. The conventional reference range for serum magnesium at our institution is 0.75–1.00 mmol/L. The derived cutoff of 0.815 mmol/L lies within that range, at about the 26th percentile of the cohort (median 0.86 mmol/L; IQR 0.81–0.92). We therefore use the term “lower serum magnesium” rather than “hypomagnesemia”, which conventionally denotes magnesium < 0.75 mmol/L. Interaction between pleural drainage and low magnesium status was assessed by including product terms in the multivariable model (Figure S4).

No a priori sample size calculation was performed; the sample size was determined by the availability of consecutive patients during the study period. Post hoc minimum detectable effect (MDE) analyses were performed separately for the primary and secondary associations[34]. For the primary association (lower versus normal magnesium) the observed group sizes were 134 versus 386 and the baseline POAF incidence in the normal-magnesium group was 21.8%, giving an MDE of OR 1.87 at 80% power and OR 2.05 at 90% power. For the secondary association (pleural drainage versus no drainage) the group sizes were 166 versus 354 and the baseline incidence in the no-drainage group was 24.3%, giving an MDE of OR 1.78 at 80% power and OR 1.94 at 90% power.

E-values were calculated using the EValue R package (version 4.1.4) to assess sensitivity to unmeasured confounding[35]; for ORs we used the square-root conversion recommended by VanderWeele and Ding for common outcomes ($RR \approx \sqrt{OR}$)[35]. Interpretation of E-values is subject to known limitations[36]. Two associations were assessed: the primary association between lower serum magnesium and POAF, using the adjusted OR from the multivariable model, and the secondary association between pleural drainage and POAF, using the PSM conditional logistic OR. All analyses were performed in R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria)[37], and a two-sided $P < 0.05$ was considered statistically significant.

## Results

After excluding patients with pre-existing atrial fibrillation, repeat CABG, or extensive missing data on key variables, 520 patients were included for analysis (Figure 1). Mean age was 64.8 ± 7.9 years, 372 patients (71.5%) were men, and pleural drainage tubes were placed in 166 patients (31.9%).

Baseline characteristics by drainage status are shown in Table 1. The two groups were broadly comparable, but several covariates were imbalanced: SMDs exceeded 0.15 for four covariates — aortic stenosis (0.241), CPB (0.170), diuretic use (0.159) and concomitant surgery count (0.153) — and were between 0.10 and 0.15 for seven further covariates (BNP 0.137, albumin 0.148, age 0.127, statin use

0.116, oral hypoglycaemic agents 0.107, troponin T 0.103 and LVEF 0.102). All of these variables were included in the propensity score model, the multivariable model, or both.

Matching yielded 158 pairs. After matching, most covariates had SMDs < 0.10, but five remained mildly imbalanced: pulmonary hypertension (SMD 0.141), creatinine (0.136), eGFR (0.123), aortic regurgitation (0.109) and ARB use (0.105) (Table S1, Figure 2). Pulmonary hypertension and eGFR were included in the multivariable model; the remaining imbalances may represent residual confounding. Propensity score distributions are shown in Figure 7.

In univariable analysis, variables associated with POAF were eGFR ($P < 0.001$), albumin ($P < 0.001$), concomitant surgery ($P < 0.001$), magnesium ($P < 0.001$), pulmonary hypertension ($P < 0.001$), LAD ($P < 0.001$), oral hypoglycaemic agents ($P = 0.002$), BNP ($P = 0.002$), diuretics ($P = 0.003$), LVDd ($P = 0.003$), insulin ($P = 0.003$), hemoglobin ($P = 0.005$), diabetes ($P = 0.007$), LVEF ($P = 0.016$), age ($P = 0.026$), surgery duration ($P = 0.026$), anesthesia duration ($P = 0.030$), number of diseased vessels ($P = 0.033$) and dapagliflozin ($P = 0.036$) (Table 2).

POAF occurred in 29.5% (49/166) of patients in the drainage group and 24.3% (86/354) in the no-drainage group. After matching, the corresponding incidences were 29.1% (46/158) and 20.3% (32/158), and conditional logistic regression in the matched cohort showed no significant association (OR 1.37, 95% CI 0.81–2.33) (Figure 3).

In the multivariable model, pleural drainage tube placement was not independently associated with POAF (adjusted OR 1.36, 95% CI 0.85–2.15, $P = 0.194$) (Table 3A, Figure 4). Lower serum magnesium (< 0.815 mmol/L) was an independent risk factor (adjusted OR 1.94, 95% CI 1.19–3.15, $P = 0.008$). Other independent predictors were concomitant surgery (per additional procedure: OR 7.45, 95% CI 2.91–20.23, $P < 0.001$), pulmonary hypertension (OR 2.97, 95% CI 1.33–6.63, $P = 0.008$), diabetes (OR 1.79, 95% CI 1.13–2.83, $P = 0.013$), age (per year: OR 1.03, 95% CI 1.00–1.06, $P = 0.043$), eGFR (per mL/min/1.73 m²: OR 0.98, 95% CI 0.97–0.99, $P < 0.001$) and albumin (per g/L: OR 0.90, 95% CI 0.85–0.96, $P < 0.001$). All VIFs were below 1.2 (Table S2).

All five analytical approaches gave consistent null results for drainage (Figure 5): crude logistic regression (OR 1.32, 95% CI 0.87–2.00), multivariable logistic regression (OR 1.34, 95% CI 0.84–2.13), IPTW (OR 1.08, 95% CI 0.69–1.69), overlap weighting (OR 1.28, 95% CI 0.83–1.99) and PSM conditional logistic regression (OR 1.37, 95% CI 0.81–2.33). All 95% CIs crossed 1. The multivariable model used for this sensitivity analysis did not include low magnesium status, to assess the robustness of the drainage estimate to model specification.

The drainage association was not statistically significant in any subgroup (Figure 6). P values for interaction were 0.284 for age, 0.942 for sex, 0.173 for diabetes, 0.537 for hypertension, 0.590 for LVEF and 0.806 for low magnesium status (Figure S4); none was below 0.05.

For the primary magnesium analysis, a multivariable model containing continuous magnesium (per 0.05 mmol/L increment) in place of low magnesium status showed higher magnesium to be associated with lower POAF risk (adjusted OR 0.78, 95% CI 0.67–0.91, $P < 0.001$) (Table 3B, Figure S5). This model was identical to that in Table 3A apart from the magnesium term; the two magnesium variables were fitted separately because of collinearity.

Across magnesium tertiles the incidence of POAF fell monotonically: 35.6% (62/174), 24.9% (43/173) and 17.3% (30/173) (Figure S3). With the lowest tertile as reference, the adjusted OR was 0.74 (95% CI 0.44–1.25) for the middle tertile and 0.47 (95% CI 0.26–0.84, $P = 0.011$) for the highest tertile (P for trend = 0.011).

In the exploratory cutoff analysis, serum magnesium predicted POAF with an AUC of 0.612 (95% CI 0.556–0.668), and the Youden index identified 0.815 mmol/L as the optimal cutoff (sensitivity 37.8%, specificity 78.4%) (Figure S1). POAF occurred in 38.1% (51/134) of patients below this cutoff

and 21.8% (84/386) of those at or above it (Figure S2). Adjusted in the same model as Table 3A, magnesium below the cutoff remained independently associated with POAF (adjusted OR 1.94, 95% CI 1.19–3.15, P = 0.008).

For the primary association, using the adjusted OR of 1.94 (95% CI 1.19–3.15), the E-value was 2.13 for the point estimate and 1.41 for the lower confidence limit (Figure 8A). An unmeasured confounder would therefore need to be associated with both lower serum magnesium and POAF by a risk ratio of at least 2.13 to explain away the observed association, and by at least 1.41 to shift the lower confidence limit to the null. No such confounder is obvious in this clinical setting, so the association is moderately robust to unmeasured confounding. For the secondary association, using the PSM conditional logistic OR of 1.375 (95% CI 0.813–2.326), the E-value was 1.62 for the point estimate and 1.00 for the lower confidence limit (Figure 8B). Because the 95% CI crossed the null, the E-value for the confidence limit was set to 1.00 and provides no information about the robustness of a null result; unmeasured confounding of only moderate strength would suffice to explain the point estimate for drainage.

For the primary association the observed adjusted OR (1.94, 95% CI 1.19–3.15) exceeded the MDE of 1.87 at 80% power but not the MDE of 2.05 at 90% power. Because the MDE was derived post hoc from the same dataset, this comparison describes precision rather than demonstrating adequate study power. For the secondary association the observed OR (1.34, 95% CI 0.84–2.13) was below the MDE at both 80% and 90% power (1.78 and 1.94), so smaller associations cannot be excluded for the drainage comparison (Table S3).

## Discussion

This single-center retrospective cohort study had two main findings. Pleural drainage tube placement was not independently associated with POAF (adjusted OR 1.36, 95% CI 0.85–2.15), a null result that was consistent across five analytical approaches and across subgroups. Lower preoperative serum magnesium, by contrast, was independently associated with POAF in a dose-dependent manner: continuously (adjusted OR per 0.05 mmol/L increment 0.78, 95% CI 0.67–0.91), across tertiles (P for trend = 0.011) and below the internally derived cutoff of 0.815 mmol/L (adjusted OR 1.94, 95% CI 1.19–3.15). For drainage the observed OR (1.34) fell below the MDE of 1.78 at 80% power, so the null result should be read as “no moderate or larger effect detected” rather than “no association exists”.

Previous work on drainage-related interventions and POAF has focused on pericardiotomy rather than on the drain itself. Meta-analyses of RCTs consistently show that posterior pericardiotomy reduces the incidence of POAF[10-13], and the 2026 STS guidelines list it as a Class IIa recommendation[7]. Creation of a right pleuro-pericardial window before chest closure has likewise been associated with a lower incidence of POAF[14]. These findings point to an important role for pericardial effusion and pericardial inflammation in POAF[8, 9].

Pleural drainage tube placement alone showed no protective effect in our cohort. A conventional pleural drain removes pleural rather than pericardial fluid, so its influence on retained intrapericardial blood and the associated proinflammatory and pro-oxidant microenvironment is likely to be small[9, 15]. Posterior pericardiotomy reduces POAF while increasing pleural effusion[11], which suggests that the anatomical site of drainage, rather than drainage itself, determines efficacy. Our data are compatible with this interpretation, but we did not record drain position and so could not test it directly.

Serum magnesium was consistently associated with POAF in this cohort. Hypomagnesemia is common after cardiac surgery, with an incidence of up to 71% after CPB[16], and has been identified as an independent predictor of POAF[17, 18]; lower serum magnesium has also been linked to atrial fibrillation in the general population without cardiovascular disease[18]. Magnesium helps to maintain myocardial electrical stability: it acts as a physiological calcium antagonist by inhibiting L-type calcium channels, regulates sodium–potassium adenosine triphosphatase ($Na^+/K^+$-ATPase) activity and influences potassium efflux, thereby contributing to regulation of the cardiomyocyte action potential[38].

Evidence on magnesium supplementation is inconsistent. One meta-analysis reported a reduced risk of POAF (RR 0.55, 95% CI 0.41–0.74)[19], whereas another found no benefit when restricted to high-quality, double-blind, intention-to-treat trials (OR 0.94) [20]. A more recent meta-analysis found no significant reduction in new-onset atrial fibrillation[21], and a large randomized trial in which perioperative magnesium infusion maintained serum magnesium at 1.5–2.0 mmol/L did not reduce POAF[22]. Discrepancies may reflect differences in supplementation timing and dose, patient selection, and whether total or ionised magnesium was measured. In our cohort the dose-response relationship between serum magnesium and POAF (P for trend = 0.011) is compatible with a role for magnesium in the pathogenesis of POAF, but the observational design means that residual confounding cannot be excluded and no causal inference can be drawn.

The discriminatory performance of serum magnesium was moderate (AUC 0.612), consistent with a role as one of several contributing factors rather than as a standalone diagnostic marker. Even so, the dose-dependent association (P for trend = 0.011) and the roughly 1.9-fold increase in risk below the cutoff (adjusted OR 1.94, 95% CI 1.19–3.15) suggest that serum magnesium could contribute to a multimarker risk stratification model.

Two points limit the interpretation of the magnesium findings. The 0.815 mmol/L cutoff was derived from the same cohort with the Youden index and then applied to that cohort in the multivariable model, so the reported OR (1.94) and AUC (0.612) are likely to be overestimates; no split-sample, bootstrap or external validation was performed. In addition, the median serum magnesium in this cohort (0.86 mmol/L; IQR 0.81–0.92) lay well within the conventional reference range and the cutoff sits at about the 26th percentile, which is why we describe it as “lower serum magnesium” rather than “hypomagnesemia”. The cutoff-based analysis should be regarded as exploratory, and its clinical utility requires validation in independent cohorts.

Two findings have clinical relevance. First, pleural drainage tube placement did not increase the risk of POAF, which is reassuring for surgeons deciding whether to place a drain, although the study was underpowered to exclude a modest association. Second, lower serum magnesium was independently associated with POAF in a dose-dependent manner, and magnesium is easily measured and can be corrected orally or intravenously. We did not assess whether supplementation reduces POAF risk, and perioperative magnesium supplementation was not recorded; the randomized evidence remains inconsistent[19-22]. These observational findings are therefore hypothesis-generating rather than a clinical recommendation, and a prospective randomized trial is needed to determine whether preoperative magnesium optimization can prevent POAF.

The study has several limitations. The sample size was moderate and no a priori calculation was performed, so for the drainage comparison only moderate-to-large effects (OR ≥ 1.78 at 80% power) could be detected and smaller associations cannot be excluded; because the MDE was derived post hoc from the same dataset, this comparison describes precision and is not evidence of adequate power. The design was single-center and retrospective, so selection bias and unmeasured confounding are possible. POAF detection was limited to the hospital stay without uniform continuous rhythm monitoring, so transient or asymptomatic episodes may have been missed and detection may have differed between exposed and unexposed patients. Four covariates had SMD > 0.15 before matching and seven had SMD between 0.10 and 0.15; after matching, five covariates remained mildly imbalanced. All five were included in the propensity score model, and pulmonary hypertension and eGFR were additionally adjusted for in the multivariable model, but creatinine, aortic regurgitation and ARB use were not, so residual confounding cannot be excluded. Serum magnesium was measured once before surgery and postoperative changes were not assessed. Information on drain position, caliber and suction settings was not available, so differences in drainage technique could not be evaluated, which limits conclusions about the anatomical site of drainage. Finally, the proportion of patients with myocardial infarction within 90 days was high (93.5% in the no-drainage group and 94.0% in the drainage group), reflecting a referral pattern in which many patients present with acute coronary syndrome and proceed to CABG shortly afterwards; this may limit generalizability to centers with a more elective CABG population.

Larger multicenter prospective studies with sufficient power to detect small effects (OR < 1.5) and standardized continuous rhythm monitoring are needed to confirm these findings. Randomized trials are needed to determine whether preoperative magnesium optimization reduces POAF risk, and future studies should record perioperative magnesium supplementation and serial postoperative magnesium measurements. The influence of the anatomical site of drainage on POAF should also be examined.

## Conclusions

In this CABG cohort, pleural drainage tube placement was not independently associated with POAF, although the sample size was insufficient to exclude a modest association (OR < 1.78). Lower preoperative serum magnesium was independently associated with POAF in a dose-dependent manner. However, this was an observational study; perioperative magnesium supplementation was not recorded, and serum magnesium was measured only once before surgery. Therefore, the present findings do not establish that magnesium optimization would reduce POAF risk. Whether preoperative magnesium optimization can prevent POAF requires evaluation in prospective randomized controlled trials.

## Declarations

**Ethics approval and consent to participate:** The study protocol was approved by the Medical Ethics Committee of the Affiliated Hospital of Xuzhou Medical University (approval number XYFY2025-KL154-01). The requirement for written informed consent was waived owing to the retrospective nature of the study. The study was conducted in accordance with the Declaration of Helsinki.

**Consent for publication:** Not applicable.

**Availability of data and materials:** The datasets generated and analyzed during the current study are not publicly available because of institutional data protection policies but are available from the corresponding author on reasonable request.

**Competing interests:** The authors declare that they have no competing interests.

**Funding:** This study was supported by Key Project of Jiangsu Provincial Health Commission (K2024014), Construction Project of High-Level Hospital of Jiangsu Province (GSPJS202404, GSPJS202518).

**Authors' contributions:** YZ and SW contributed equally to this work. YZ, ZW, and JW conceived and designed the study. YZ and SW drafted the manuscript. HZ and YL collected and analyzed the data. ZW and JW supervised the project and critically revised the manuscript. All authors read and approved the final manuscript.

**Acknowledgements:** Not applicable.

## Figure legends

**Figure 1.** Flow diagram of patient selection and outcomes. CABG, coronary artery bypass grafting; POAF, postoperative atrial fibrillation.

**Figure 2.** Covariate balance before and after propensity score matching. Absolute standardized mean differences (SMDs) are shown; the dashed line marks the 0.10 threshold.

**Figure 3.** Incidence of POAF in patients with and without pleural drainage, in the overall cohort (left) and after propensity score matching (right). Error bars indicate 95% confidence intervals; numbers above the bars are events/total (percentage).

**Figure 4.** Multivariable logistic regression with low magnesium status (Table 3A). Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) are shown on a logarithmic scale; the dashed line marks an OR of 1. Red circles indicate $P < 0.05$, gray circles $P \geq 0.05$. The corresponding model with continuous magnesium is shown in Figure S5.

**Figure 5.** Sensitivity analyses of the association between pleural drainage and POAF. Crude and multivariable logistic regression, inverse probability of treatment weighting, overlap weighting and propensity score-matched conditional logistic regression; the dashed line marks an OR of 1.

**Figure 6.** Subgroup analyses of the association between pleural drainage and POAF. Adjusted ORs with 95% CIs were calculated within each subgroup; the dashed line marks an OR of 1.

**Figure 7.** Distribution of propensity scores before (top) and after (bottom) matching, by drainage status.

**Figure 8.** E-value analysis. (A) Lower serum magnesium and POAF. (B) Pleural drainage and POAF. The E-value is the minimum strength of association that an unmeasured confounder would need with both the exposure and the outcome to explain away the observed association.

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## Tables

Table 1. Baseline characteristics by pleural drainage status.

| Characteristic | No drainage (n=354) | Drainage (n=166) | P value | SMD |
|---|---|---|---|---|
| Age, years | 64.46 ± 7.84 | 65.46 ± 7.97 | 0.178 | 0.127 |
| Male sex, n (%) | 254 (71.8) | 118 (71.1) | 0.958 | 0.015 |
| BMI, kg/m² | 25.19 ± 3.37 | 25.08 ± 3.19 | 0.723 | 0.033 |
| Smoking, n (%) | 168 (47.5) | 78 (47.0) | 0.995 | 0.009 |
| Alcohol consumption, n (%) | 139 (39.3) | 61 (36.7) | 0.650 | 0.052 |
| Diabetes, n (%) | 127 (35.9) | 58 (34.9) | 0.913 | 0.020 |
| Hypertension, n (%) | 223 (63.0) | 106 (63.9) | 0.926 | 0.018 |
| Pulmonary hypertension, n (%) | 28 (7.9) | 12 (7.2) | 0.924 | 0.026 |
| Myocardial infarction within 90 days, n (%) | 331 (93.5) | 156 (94.0) | 0.989 | 0.020 |
| NYHA class | 2.78 ± 0.58 | 2.78 ± 0.57 | 0.908 | 0.011 |
| CCS class | 2.85 ± 0.75 | 2.82 ± 0.75 | 0.660 | 0.041 |
| LVEF, % | 58.46 ± 8.11 | 57.58 ± 9.08 | 0.290 | 0.102 |
| LAD, mm | 37.00 [35.00, 40.00] | 37.00 [34.25, 40.00] | 0.383 | 0.087 |
| LVDd, mm | 49.55 ± 5.00 | 49.54 ± 5.56 | 0.981 | 0.002 |
| Aortic stenosis, n (%) | 10 (2.8) | 0 (0.0) | 0.065 | 0.241 |
| Aortic regurgitation, n (%) | 95 (26.8) | 47 (28.3) | 0.805 | 0.033 |
| Mitral stenosis, n (%) | 6 (1.7) | 2 (1.2) | 0.967 | 0.041 |
| Mitral regurgitation, n (%) | 297 (83.9) | 138 (83.1) | 0.926 | 0.021 |
| eGFR, mL/min/1.73 m² | 115.32 [99.51, 120.00] | 115.32 [97.79, 120.00] | 0.674 | 0.048 |
| Creatinine, μmol/L | 63.00 [54.00, 73.00] | 64.00 [52.00, 75.75] | 0.621 | 0.021 |
| Albumin, g/L | 42.35 [39.30, 44.88] | 41.60 [38.85, 43.88] | 0.086 | 0.148 |
| Magnesium, mmol/L | 0.86 [0.81, 0.92] | 0.86 [0.82, 0.91] | 0.929 | 0.037 |
| Hemoglobin, g/L | 136.37 ± 14.86 | 135.04 ± 16.54 | 0.379 | 0.084 |
| BNP, pg/mL | 231.70 [100.34, 668.15] | 264.75 [111.42, 709.00] | 0.210 | 0.137 |
| Troponin T, ng/L | 14.35 [8.21, 39.77] | 14.30 [7.93, 55.43] | 0.538 | 0.103 |

| Characteristic | No drainage (n=354) | Drainage (n=166) | P value | SMD |
|---|---|---|---|---|
| WBC count, ×10⁹/L | 6.95 ± 2.77 | 6.93 ± 2.24 | 0.906 | 0.011 |
| Platelet count, ×10⁹/L | 217.98 ± 62.39 | 213.68 ± 64.43 | 0.475 | 0.068 |
| Beta-blockers, n (%) | 285 (80.5) | 135 (81.3) | 0.920 | 0.021 |
| Statins, n (%) | 327 (92.4) | 158 (95.2) | 0.316 | 0.116 |
| ACEI, n (%) | 9 (2.5) | 3 (1.8) | 0.836 | 0.050 |
| ARB, n (%) | 96 (27.1) | 40 (24.1) | 0.533 | 0.069 |
| Diuretics, n (%) | 94 (26.6) | 33 (19.9) | 0.123 | 0.159 |
| Insulin, n (%) | 36 (10.2) | 14 (8.4) | 0.641 | 0.060 |
| Oral hypoglycemic agents, n (%) | 86 (24.3) | 33 (19.9) | 0.315 | 0.107 |
| Dapagliflozin, n (%) | 90 (25.4) | 37 (22.3) | 0.505 | 0.074 |
| Concomitant surgery, n (%) | 0.06 ± 0.24 | 0.03 ± 0.17 | 0.084 | 0.153 |
| Number of diseased vessels | 3.23 ± 0.88 | 3.25 ± 0.78 | 0.781 | 0.026 |
| Cardiopulmonary bypass, n (%) | 164 (46.3) | 91 (54.8) | 0.087 | 0.170 |
| Surgery duration, min | 338.09 ± 64.14 | 342.27 ± 52.11 | 0.430 | 0.072 |
| Anesthesia duration, min | 393.89 ± 68.35 | 398.01 ± 56.89 | 0.471 | 0.066 |

Continuous variables are presented as mean ± SD or median [IQR]; categorical variables as n (%). SMD, standardized mean difference; BMI, body mass index; LVEF, left ventricular ejection fraction; LAD, left atrial diameter; LVDd, left ventricular end-diastolic diameter; eGFR, estimated glomerular filtration rate; BNP, B-type natriuretic peptide; WBC, white blood cell; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker. The high prevalence of recent myocardial infarction reflects the referral pattern at our institution, where many patients present with acute coronary syndrome and undergo CABG within 90 days of the index event.

Table 2. Univariable analysis of factors associated with POAF

| Variable | OR (95% CI) | P value |
|---|---|---|
| eGFR, per 1 mL/min/1.73 m² | 0.98 (0.97–0.99) | <0.001 |
| Albumin, per 1 g/L | 0.89 (0.84–0.93) | <0.001 |
| Concomitant surgery, per 1 procedure | 6.43 (2.88–15.36) | <0.001 |
| Magnesium, per 0.05 mmol/L | 0.76 (0.67–0.86) | <0.001 |
| Pulmonary hypertension | 3.97 (2.06–7.74) | <0.001 |

| Variable | OR (95% CI) | P value |
|---|---|---|
| LAD, per 1 mm | 1.07 (1.03–1.12) | <0.001 |
| Oral hypoglycemic agents | 2.00 (1.28–3.09) | 0.002 |
| BNP, per 100 pg/mL | 1.02 (1.01–1.03) | 0.002 |
| Diuretics | 1.94 (1.25–2.98) | 0.003 |
| LVDd, per 1 mm | 1.06 (1.02–1.10) | 0.003 |
| Insulin | 2.48 (1.36–4.50) | 0.003 |
| Hemoglobin, per 1 g/L | 0.98 (0.97–0.99) | 0.005 |
| Diabetes | 1.74 (1.16–2.59) | 0.007 |
| LVEF, per 1% | 0.97 (0.95–0.99) | 0.016 |
| Age, per 1 year | 1.03 (1.00–1.06) | 0.026 |
| Surgery duration, per 10 min | 1.04 (1.00–1.07) | 0.026 |
| Anesthesia duration, per 10 min | 1.03 (1.00–1.06) | 0.030 |
| Number of diseased vessels, per 1 vessel | 0.78 (0.62–0.98) | 0.033 |
| Dapagliflozin | 1.59 (1.02–2.46) | 0.036 |

Only variables with $P < 0.05$ are shown. OR, odds ratio; CI, confidence interval; eGFR, estimated glomerular filtration rate; LAD, left atrial diameter; LVDd, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; BNP, B-type natriuretic peptide.

Table 3A. Multivariable logistic regression with low magnesium status (< 0.815 mmol/L)

| **Variable** | **Adjusted OR** | **95% CI** | **P value** |
|---|---|---|---|
| Pleural drainage | 1.36 | 0.85–2.15 | 0.194 |
| Low magnesium (<0.815 mmol/L) | 1.94 | 1.19–3.15 | 0.008 |
| Concomitant surgery (per procedure) | 7.45 | 2.91–20.23 | <0.001 |
| Pulmonary hypertension | 2.97 | 1.33–6.63 | 0.008 |
| Diabetes | 1.79 | 1.13–2.83 | 0.013 |
| Hypertension | 1.29 | 0.80–2.11 | 0.297 |
| Male sex | 1.12 | 0.69–1.85 | 0.644 |

| Variable | Adjusted OR | 95% CI | P value |
|---|---|---|---|
| Age (per year) | 1.03 | 1.00–1.06 | 0.043 |
| LVEF (per %) | 1.00 | 0.97–1.03 | 0.974 |
| BMI (per kg/m²) | 1.00 | 0.93–1.07 | 0.925 |
| eGFR (per mL/min/1.73 m²) | 0.98 | 0.97–0.99 | <0.001 |
| Albumin (per g/L) | 0.90 | 0.85–0.96 | <0.001 |

OR, odds ratio; CI, confidence interval; LVEF, left ventricular ejection fraction; BMI, body mass index; eGFR, estimated glomerular filtration rate. Low magnesium status was defined as serum magnesium <0.815 mmol/L; this cutoff was derived from the same cohort using the Youden index and is subject to optimistic bias. Continuous magnesium was fitted in a separate model (Table 3B) because of collinearity.

Table 3B. Multivariable logistic regression with continuous magnesium (per 0.05 mmol/L)

| Variable | Adjusted OR | 95% CI | P value |
|---|---|---|---|
| Pleural drainage | 1.31 | 0.82–2.08 | 0.257 |
| Magnesium (per 0.05 mmol/L) | 0.78 | 0.67–0.91 | <0.001 |
| Concomitant surgery (per procedure) | 6.74 | 2.63–18.37 | <0.001 |
| Pulmonary hypertension | 2.83 | 1.27–6.32 | 0.011 |
| Diabetes | 1.71 | 1.08–2.71 | 0.023 |
| Hypertension | 1.26 | 0.78–2.07 | 0.347 |
| Male sex | 1.11 | 0.68–1.83 | 0.683 |
| Age (per year) | 1.04 | 1.01–1.07 | 0.020 |
| LVEF (per %) | 1.00 | 0.97–1.03 | 0.897 |
| BMI (per kg/m²) | 1.00 | 0.93–1.07 | 0.932 |
| eGFR (per mL/min/1.73 m²) | 0.98 | 0.97–0.99 | <0.001 |
| Albumin (per g/L) | 0.91 | 0.86–0.97 | 0.002 |

OR, odds ratio; CI, confidence interval; LVEF, left ventricular ejection fraction; BMI, body mass index; eGFR, estimated glomerular filtration rate. Continuous magnesium was modeled per 0.05 mmol/L increment. Low magnesium status was fitted in a separate model (Table 3A) because of collinearity.

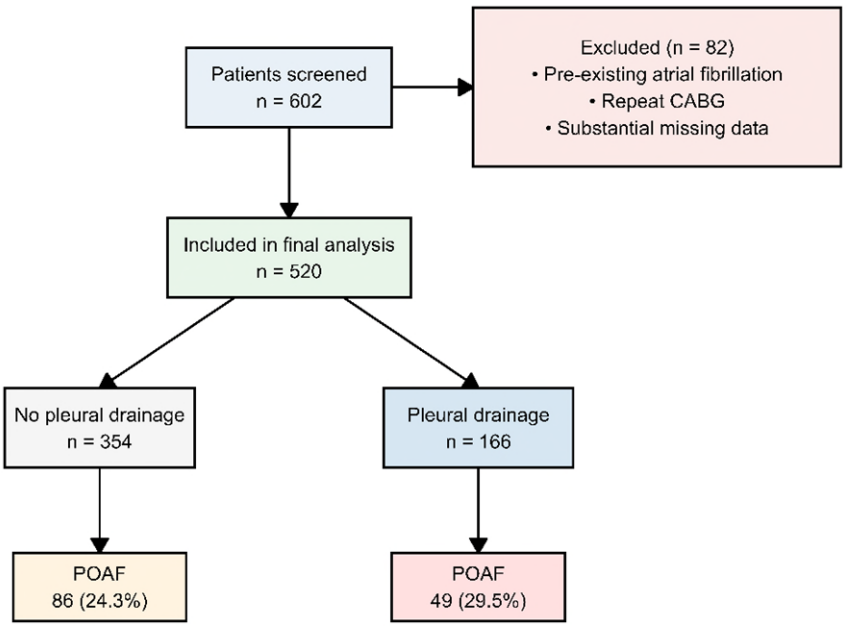



**Figure 1.** Flow diagram of patient selection and outcomes. CABG, coronary artery bypass grafting; POAF, postoperative atrial fibrillation.

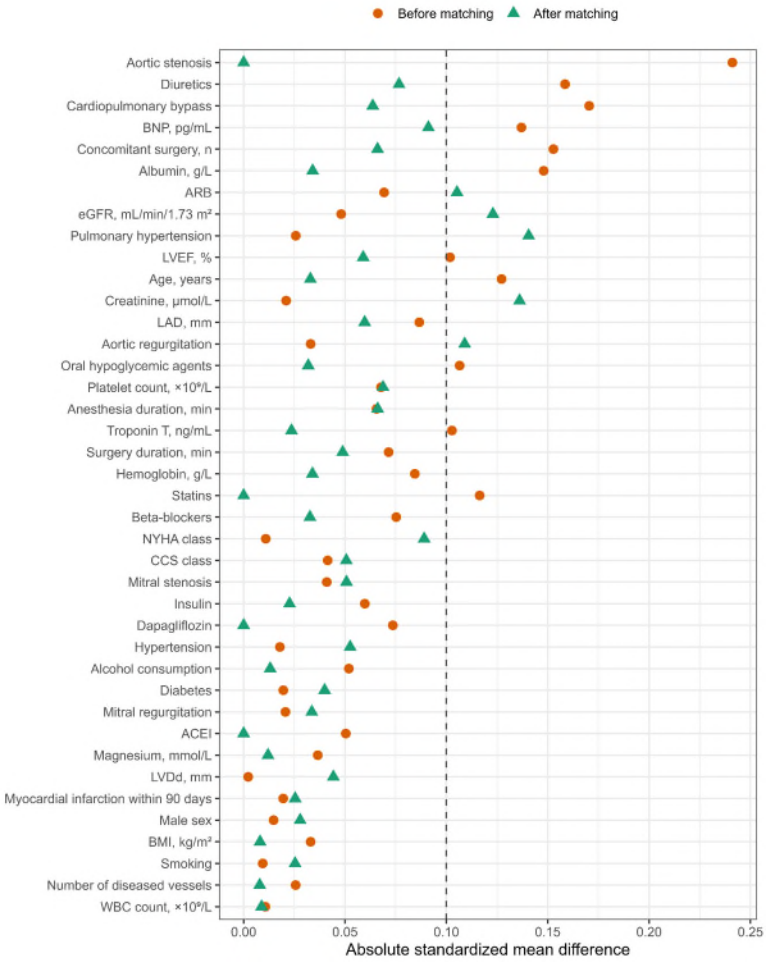



**Figure 2.** Covariate balance before and after propensity score matching. Absolute standardized mean differences (SMDs) are shown; the dashed line marks the 0.10 threshold.

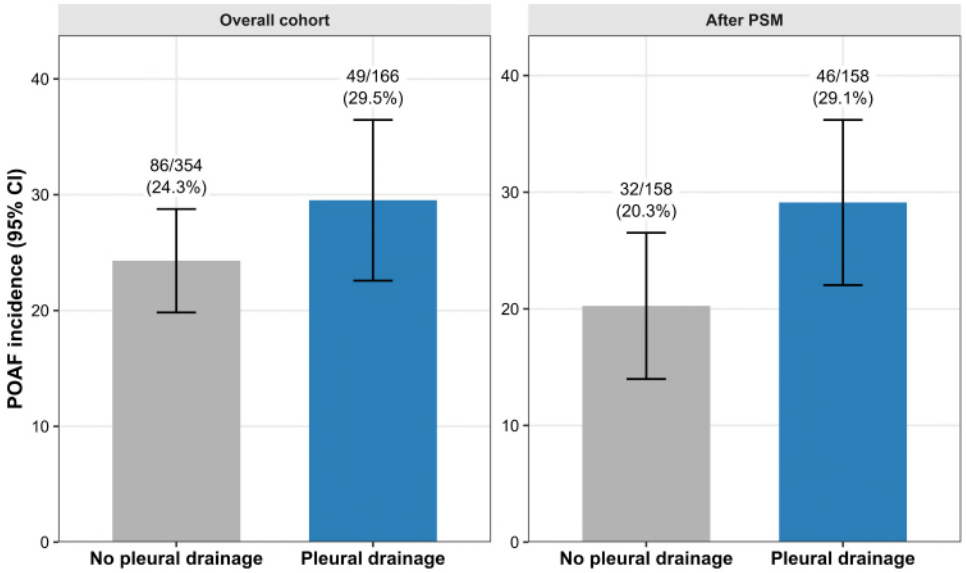



**Figure 3.** Incidence of POAF in patients with and without pleural drainage, in the overall cohort (left) and after propensity score matching (right). Error bars indicate 95% confidence intervals; numbers above the bars are events/total (percentage).

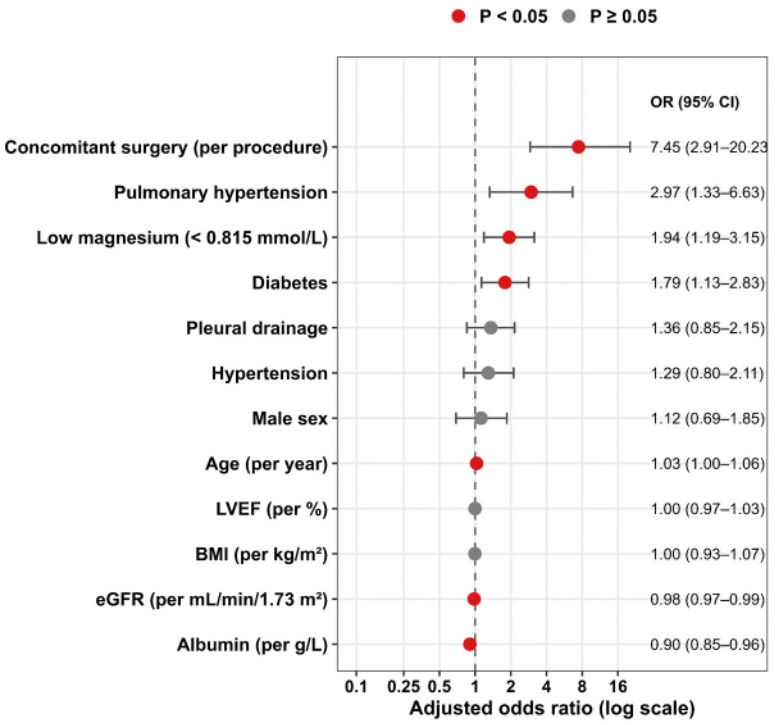



**Figure 4.** Multivariable logistic regression with low magnesium status (Table 3A). Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) are shown on a logarithmic scale; the dashed line marks an OR of 1. Red circles indicate $P < 0.05$, gray circles $P \geq 0.05$. The corresponding model with continuous magnesium is shown in Figure S5.

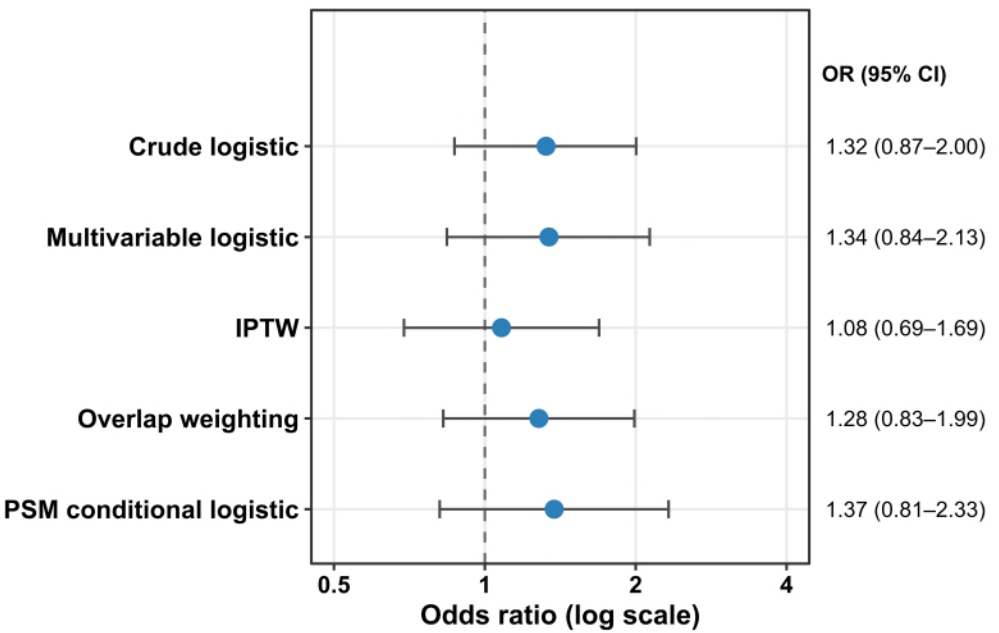



**Figure 5.** Sensitivity analyses of the association between pleural drainage and POAF. Crude and multivariable logistic regression, inverse probability of treatment weighting, overlap weighting and propensity score-matched conditional logistic regression; the dashed line marks an OR of 1.

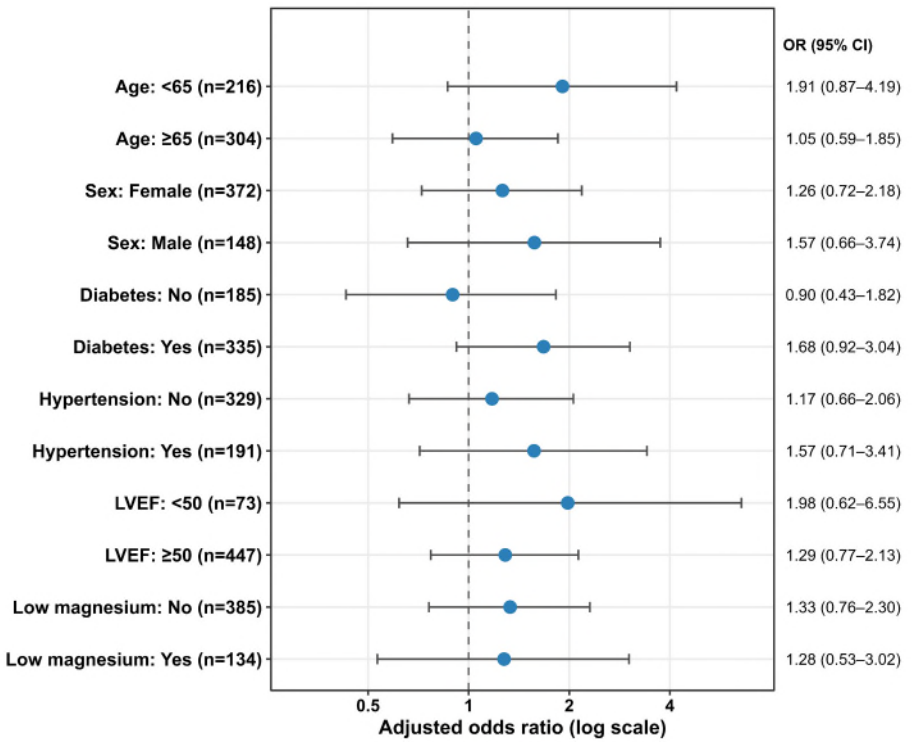



**Figure 6.** Subgroup analyses of the association between pleural drainage and POAF. Adjusted ORs with 95% CIs were calculated within each subgroup; the dashed line marks an OR of 1.

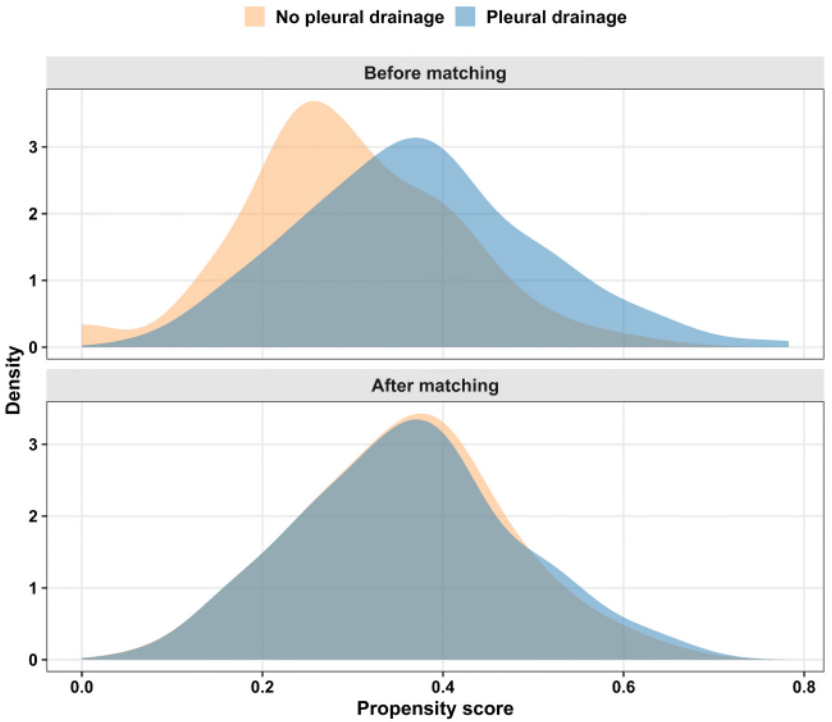



**Figure 7.** Distribution of propensity scores before (top) and after (bottom) matching, by drainage status.

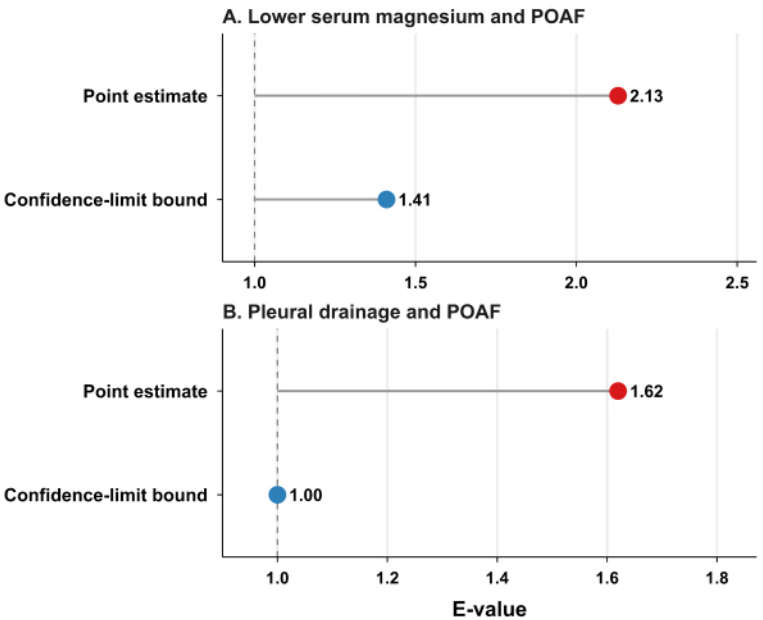



**Figure 8.** E-value analysis. (A) Lower serum magnesium and POAF. (B) Pleural drainage and POAF. The E-value is the minimum strength of association that an unmeasured confounder would need with both the exposure and the outcome to explain away the observed association.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile.pdf