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REVIEW

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Preoperative prophylactic insertion of intraaortic balloon pumps in critically ill patients undergoing coronary artery bypass surgery: a meta-analysis of RCTS

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Abstract

Background The intra-aortic balloon pump (IABP) technique plays a crucial role in providing circulatory support for patients experiencing hemodynamic instability. This study aimed to assess the effectiveness and safety of preoperative prophylactic IABP insertion in patients undergoing acute critical coronary artery bypass grafting (CABG).

Methods A comprehensive search was conducted in PubMed, Cochrane Library, and Embase databases, covering the period from January 1995 to September 2022.

Results The incidence of renal insufficiency, mechanical ventilation exceeding 24 h, and bleeding events in the IABP group did not exhibit significant differences compared to the control group (relative risk [RR] = 0.85, $P = 0.26$; RR = 0.81, $P = 0.08$; RR = 0.95, $P = 0.87$). However, the hospital mortality rate was significantly lower in the IABP group than in the control group (RR = 0.54, $P = 0.0007$), and the length of ICU stay was shorter in the IABP group (mean difference [MD] = -1.12, $P < 0.000001$). The IABP group also exhibited a lower incidence of low cardiac output syndrome (LCOS%) compared to the control group (RR = 0.61, $P < 0.0001$), and a lower incidence of major adverse cardiac and cerebrovascular events (MACCE%) (RR = 0.70, $P = 0.001$). No significant publication bias was observed in the funnel plot analysis.

Conclusion Preoperative prophylactic insertion of IABP is currently considered beneficial in improving outcomes for critically ill patients undergoing CABG. This technique reduces hospital mortality, shortens ICU stays, and lowers the incidence of LCOS% and MACCE%.

Keywords Intra-aortic balloon pump, Coronary artery bypass graft, Hospital mortality

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Background

Intra-aortic balloon counterpulsation (IABP) is a well-established and widely utilized technique in clinical practice, commonly employed in the management of acute and critically ill patients. However, there remains ongoing debate regarding the necessity of preoperative prophylactic IABP implantation in patients undergoing coronary artery bypass grafting (CABG) [1]. Given the high perioperative mortality rate associated with CABG in critically ill patients, influenced by factors such as age, comorbidities, and cardiovascular diseases, it is imperative to systematically evaluate the impact of preventive IABP implantation on post-CABG patient outcomes [2]. While chemotherapy and physical therapy are viable treatment options for perioperative heart failure support, physical therapy, including the insertion of an intra-aortic balloon pump (IABP) and other ventricular assist devices, has shown to be more effective with fewer adverse effects. Among these options, IABP serves as a versatile and economically advantageous intervention, capable of reducing ventricular afterload, enhancing coronary artery perfusion, and increasing cardiac output [3]. The use of IABP for patient treatment dates back to 1962 [4]. Research has demonstrated favorable therapeutic effects when combining IABP with pharmacological interventions in high-risk CABG patients [5]. Numerous animal studies have highlighted the benefits of prophylactic intra-aortic balloon counterpulsation (IABP) prior to CABG. However, conflicting findings have been reported, suggesting varying opinions [2]. Some studies have indicated that preoperative IABP implantation in CABG patients results in lower hospital mortality rates, reduced cardiac event incidence, shorter ICU stays, and decreased rates of major adverse cardiac and cerebrovascular events (MACCE). Conversely, other studies have presented contradictory conclusions [6]. The objective of this meta-analysis is to comprehensively evaluate the efficacy of prophylactic IABP insertion prior to coronary artery bypass grafting, incorporating recent randomized controlled trials. The primary endpoint of this study is hospitalization mortality rate, while secondary endpoints include the incidence of low cardiac output syndrome (LCOS), duration of intensive care, incidence of MACCE, incidence of renal dysfunction, incidence of mechanical ventilation exceeding 24 h, and incidence of bleeding events [7].

Methods

The protocol for this systematic review has been registered on the PROSPERO website (www.crd.york.ac.uk/PROSPERO) under the registration ID: CRD4202335690. The current study adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

A comprehensive search strategy was employed using a combination of controlled vocabulary terms and free-text keywords in PubMed, Embase, and Cochrane Library databases, encompassing the inception of the databases until September 2022. The aim was to identify all relevant randomized controlled trials investigating the effects of preoperative prophylactic insertion of IABP in patients undergoing coronary artery bypass grafting. Additionally, a manual search was conducted to include any relevant unpublished references. The selection of studies for inclusion was performed independently by two reviewers, and any discrepancies were resolved through consultation with a third reviewer. We used the following MeSH and keyword search strategies: ((((((((((Intra Aortic Balloon Pumping) OR (Intraaortic Balloon Pumping)) OR (Balloon Pumping, Intraaortic)) OR (Pumping, Intraaortic Balloon)) OR (Pumping, Intra-Aortic Balloon)) OR (Balloon Pumping, Intra-Aortic)) AND (Pumping, Intra Aortic Balloon)) OR (IABP)) OR (intraaortic counterpulsation)) AND ((((((((((((Artery Bypass, Coronary) OR (Artery Bypasses, Coronary)) OR (Bypasses, Coronary Artery)) OR (Coronary Artery Bypasses)) OR (Coronary Artery Bypass Surgery)) OR (Bypass, Coronary Artery)) OR (Aortocoronary Bypass)) OR (Aortocoronary Bypasses)) OR (Bypass, Aortocoronary)) OR (Bypasses, Aortocoronary)) OR (Bypass Surgery, Coronary Artery)) OR (Coronary Artery Bypass Grafting)) OR (CABG))) AND ((((randomized controlled trial) OR (Clinical Trials, Randomized)) OR (Trials, Randomized Clinical)) OR (Controlled Clinical Trials, Randomized)). The search process is not restricted by language, and the screening of articles typically involves an initial selection of preliminary articles based on titles or abstracts, followed by a comprehensive evaluation of the entire text to determine the final set of articles.

Inclusion criteria: This analysis exclusively includes data from randomized controlled trials involving adult participants aged≥18 years who underwent coronary artery transplantation. The selected patients had severe coronary artery stenosis, usually exceeding 70% stenosis, and required coronary artery bypass grafting surgery. The definition of critically ill patients may vary across studies depending on the study's objectives, field, and specific research design. Generally, critically ill patients are those with abnormal vital signs, organ dysfunction, or facing life-threatening conditions due to a significant illness or trauma.

Exclusion criteria: Patients with cardiogenic shock, animal studies, reviews, observational studies, duplicate reports, low-quality studies, and studies without relevant data will be excluded.

This article adheres to the principles outlined in the "Cochrane Intervention System Evaluation Manual." Two researchers independently assessed the eligibility of the included studies, compared their findings, and resolved any discrepancies through discussion. If disagreements persisted, a third researcher acted as an arbitrator. Specialized tables were used to collect detailed information from the literature, including the article's primary author, publication year, country of publication, sample size, timing of IABP placement, average European score, LVEF, average age, and whether non-pump coronary artery bypass grafting was performed. The primary outcome assessed was hospital death, with secondary outcomes including the incidence of LCOS, duration of intensive care, incidence of MACCE, incidence of renal insufficiency, incidence of mechanical ventilation lasting approximately 24 h, and incidence of bleeding events. In cases where relevant research data could not be directly obtained from the literature, efforts were made to acquire the data by directly contacting the corresponding authors or sending emails.

For statistical analysis, Review Manager version 5.4 was employed. The impact of binary variables was analyzed using relative risk, while mean difference was used to assess the impact of continuous variables. A 95% confidence interval was calculated. In case of suspected heterogeneity, the chi-square test was employed for analysis, and the I2 value was used for quantitative evaluation. If the study exhibited low heterogeneity ($P \geq 0.1$, I2≤50%), both fixed effects models and random effects models were considered for data analysis, with a preference for random effects models. However, in the presence of high heterogeneity ($P < 0.1$, I2>50%), a random effects model was mandated. Subgroups were created based on race and the performance of non-pump coronary artery bypass grafting to explore potential causes of heterogeneity. Sensitivity analysis was conducted by systematically excluding individual studies to examine the robustness of the results against various exclusion criteria. Additionally, if applicable, a funnel plot was utilized to assess publication bias. Metaregression, a statistical analysis method, was employed to evaluate the relationship between research outcomes and individual patient characteristics. It aids in determining the extent to which specific characteristics (such as age, gender, baseline disease status, etc.) influence research results. Considering these factors allows for a more accurate understanding and comparison of the research findings. Subgroup analysis involves dividing study participants into different subgroups based on specific characteristics and conducting separate analyses for each subgroup. This approach helps assess whether treatment outcomes differ among various patient subgroups. When conducting metaregression and subgroup analysis, it is crucial to ensure the reliability and quality of the data, as well as the adequacy of sample size. Additionally, attention should be paid to potential variations in other study factors. Minimizing the impact of these factors can be achieved through meticulous research design, rigorous data collection, and thorough analysis. Weighted average methods are typically used to evaluate the magnitude of effects in meta-analysis, considering factors such as sample size, research variance, and weight coefficients.

Results

We screened a total of 368 articles and identified 13 randomized controlled trials (RCTs) [8–20] for inclusion in this study, which involved a total of 1657 patients (Fig. 1).

The study population was divided into an experimental group and a control group based on the performance of preoperative intra-aortic balloon counterpulsation (IABP). The experimental group comprised 825 patients, while the control group comprised 832 patients (Tables 1 and 2).

All the articles included in this study were predominantly RCTs, and we used the Cochrane collaboration bias risk assessment tool to evaluate the methodological quality of each trial. The included studies were assessed for seven characteristics: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting (Fig. 2a).

Hospital mortality rate (Fig. 3) Thirteen RCTs were analyzed to assess the hospital mortality rate. A total of 1657 patients were included, with 825 in the experimental group and 832 in the control group. Based on the results of the fixed effects model, the preoperative mortality rate in the experimental group was significantly lower than that in the control group (relative risk: RR=0.54, 95% confidence interval: 0.38–0.77, $P=0.0007$). No significant publication bias was observed, as demonstrated by the funnel plot (Fig. 2b). Specifically, there were 42 deaths in the experimental group and 77 deaths in the control group.

ICU length of stay (Fig. 4) Twelve studies compared the ICU length of stay. The IABP group exhibited a relatively shorter ICU hospitalization time compared to the control group (mean difference: MD=1.12, 95% confidence interval: -1.48 to -0.76, $P<0.00001$). Due to heterogeneity ($P<0.0001$, I2=72%), subgroup analysis was conducted based on the race of OPCAB patients and whether they were OPCAB patients (Fig. 5). Based on race, the subgroups were divided into Asian and Caucasian patients (Fig. 6). Subgroup analysis revealed that the ICU hospitalization time in the Asian IABP group was significantly shorter than that in the control group (MD=1.42, 95% confidence interval: -1.67 to -1.16, $P<0.0001$), with low heterogeneity ($P=0.78$, I2=0%). In the Caucasian subgroup analysis, the ICU hospitalization time in the IABP group was significantly lower than that in the control group (MD=1.02, 95% confidence interval: -1.49 to -0.55,

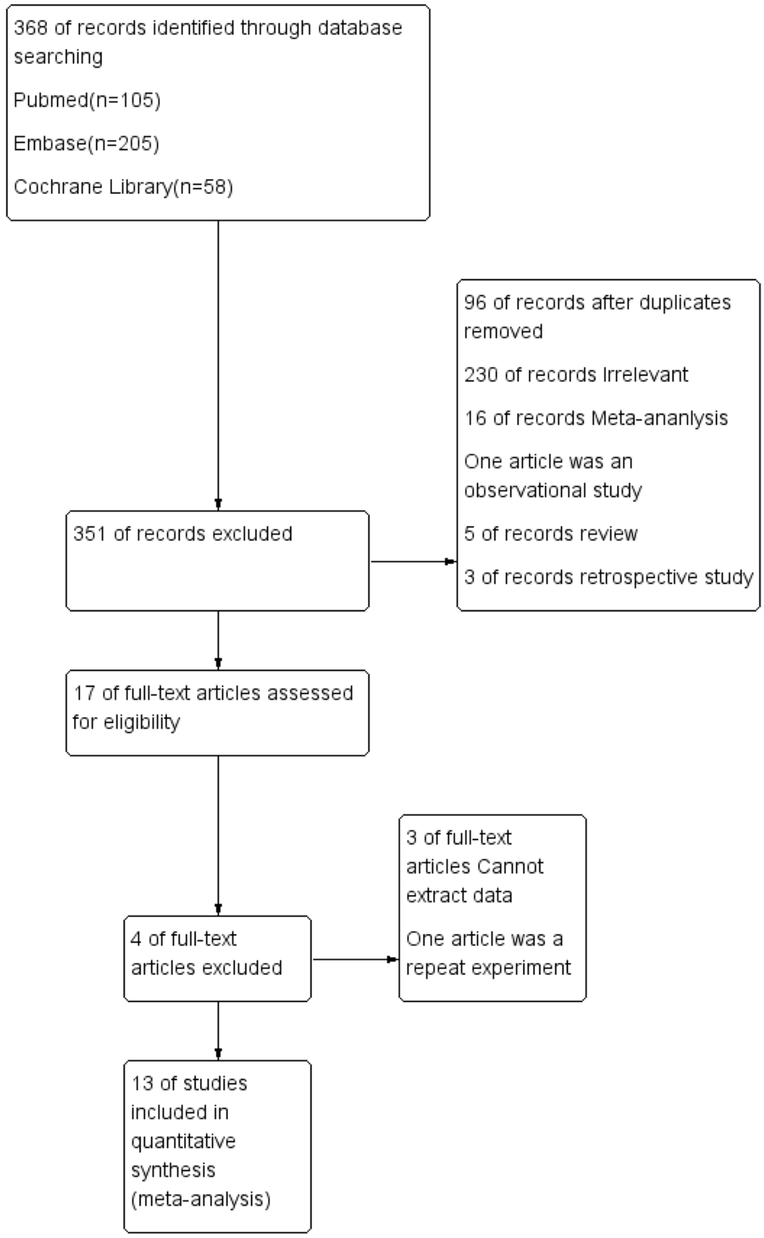


Fig. 1 Study flow diagram

P<0.001), with high heterogeneity (*P*<0.0001, I2=74%). In the subgroup analysis of OPCAB patients, the ICU hospitalization time in the IABP group was shorter than that in the control group (MD=1.44, 95% confidence interval: -1.68 to -1.21, *P*<0.00001), with low heterogeneity (*P*=0.82, I2=0%). Additionally, for patients who did not undergo OPCAB, the ICU hospitalization time in the IABP group was lower than that in the control group (MD=0.93, 95% confidence interval: -1.45 to -0.41, *P*=0.0004), with high heterogeneity (*P*=0.0001, I2=74%).

LCOS% (Fig. 7) Nine studies compared the incidence of Low Cardiac Output Syndrome (LCOS%). The analysis revealed a lower incidence of LCOS in the IABP group compared to the control group (RR=0.61, 95% confidence interval: 0.48–0.77, *P*<0.001).

MACCE% (Fig. 8) Nine studies investigated the occurrence of Major Adverse Cardiac and Cerebrovascular Events (MACCE%). The results indicated a lower incidence of MACCE in the IABP group compared to the control group (RR=0.70, 95% confidence interval: 0.56–0.87, *P*=0.001).

Renal insufficiency (%) (Fig. 9) Nine studies assessed the occurrence of renal insufficiency (%). No significant difference was observed in the incidence of renal dysfunction between the IABP group and the control group (RR=0.85, 95% confidence interval: 0.64–1.13, *P*=0.26).

Table 1 Characteristics of the included studys

Study	IABP	Control	Date	location	Timing of IABP placement Prior to surgery (hours)	Mean EuroScore (points)	LVEF (%)	Mean Age	OPCAB
Christenson 1997	32	20	1994–1996	Switzerland	≤ 24;≤2	-	34	64	No
Christenson HTN 1997	19	14	1994–1996	Switzerland	≤ 2	-	32.6	65	No
Christenson REDO 1997	24	24	1994–1996	Switzerland	≤ 5	-	32.5	65	No
Christenson 1999	30	30	1997–1998	Switzerland	≤ 24;≤12;≤2	-	26	63	No
Marra 2002	30	30	1999–2001	Italy	≤ 2	-	28.5	64	No
Christenson 2003	15	15	1994–1996	Switzerland	≤ 1.5	-	29	64	yes
Qiu, Z 2009	115	106	2000–2008	China	≤ 24	12.58	29.6	78	yes
Wilczynski 2010	243	259	2004–2008	Poland	≤ 1	7.4	37.8	65.2	No
Metz 2011	52	52	2003–2004	Germany	≤ 2	6.61	43.5	74	No
Shi 2011	107	125	1999–2010	China	≤ 1	18.4	35.3	65.2	yes
Ranucci 2013	55	55	2009–2012	Italy	≤ 1	10.2	29	66.2	No
Rocha 2018	90	91	2014–2016	Brazil	≤ 24	6	40	64.4	No
Litton 2020	13	11	2015–2016	Australia	≤ 24	4.7	30	63	No

Table 2 Results of a randomized controlled trial

Study	Hospital mortality (%)		LCOS (%)		ICU stay (days/h)		MACCE (%)		renal insufficiency (%))		ventilatory support ≥ 24 h (%))		Bleeding (%)	
	IABP	Control	IABP	Control	IABP	Control	IABP	Control	IABP	Control	IABP	Control	IABP	Control
Christenson 1997	6.25	25	28.1	60	2.4 ± 0.9	3.4 ± 1.1	3.1	5	21.9	30	21.9	20	NR	
Christenson HTN 1997	0	21.4	11	64	2.4 ± 0.9	3.4 ± 1.1	NR		26.3	28.6	NR		NR	
Christenson REDO 1997	0	16.6	16.7	54.1	2.39 ± 0.9	3.59 ± 1.1	4.2	4.2	12.5	16.7	16.7	25	4.2	4.2
Christenson 1999	3.3	20	37	83	48.4 ± 29.3	116.4 ± 67.8	NR		NR		NR		NR	
Marra 2002	6.7	23	NR		111 ± 72	139 ± 66	10	20	NR		50	59.8	NR	
Christenson 2003	0	7	40	47	27 ± 3	65 ± 28 h	0	7	0	13.3	0	33	NR	
Qiu,Z 2009	2.6	3.8	10.4	18.9	2.2 ± 0.7	3.6 ± 1.3	1.7	2.8	6.9	11.3	33	39.6	6.9	5.7
Wilczynski 2010	2.5	5.0	NR		3.51 ± 0.48	4.57 ± 2.52	30.9	44.8	2.55	3.26	NR		NR	
Metz 2011	13.4	17.3	25	26	70 h (43–144)	90 h (43–191)	NR		18	28	11.5	19	NR	
Shi 2011	1.9	4	2.8	6.4	3.8 ± 3.2	5.3 ± 1.5	2.8	3.2	10.3	15.2	NR		1.9	2.4
Ranucci 2013	7.3	14	NR.		NR		1.8	0	12	4.9	31	27	NR.	
Rocha 2018	14.4	12.1	23.6	27.8	5 (3–8)	4 (3–6)	2.2	2.2	22.4	14.3	5.6	7.7	11.2	13.3
Litton 2020	15.4	9	NR		3 (2–6)	3 (1–6)	NR		NR		NR		NR	

Abbreviations NR not reported, LCOS low cardiac output syndrome. IABP intra-aortic balloon pump, ICU intensive care unit, RCTs randomized controlled trials, MACCE major adverse cardiac or cerebrovascular event; CABG: coronary artery bypass grafting; OPCAB: Off-pump coronary artery bypass

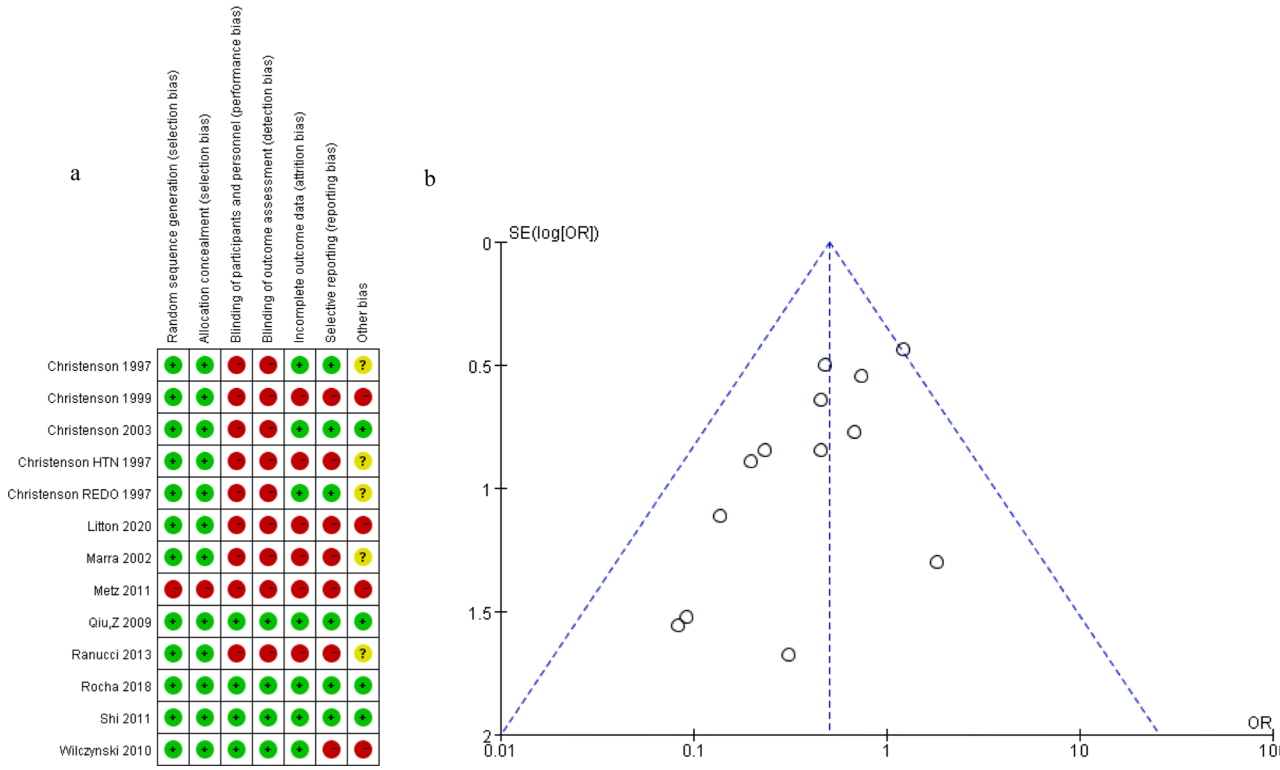


Fig. 2 **a** Risk of bias summary. **b** Bias funnel plot of published literature

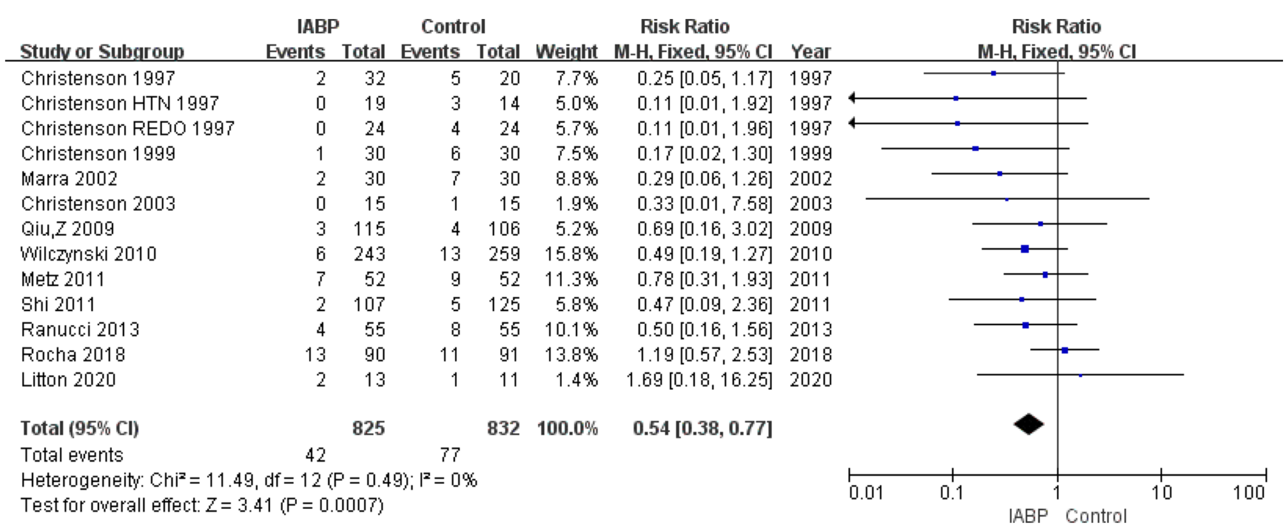


Fig. 3 Effect of intraaortic balloon pump (IABP) and control group on mortality

Ventilation support≥24 h (%) (Fig. 10) Eight studies examined the requirement for ventilation support for 24 h or more (%). The results indicated a minimal difference in ventilation time between the IABP group and the control group (RR=0.81, 95% confidence interval: 0.64–1.02,P=0.08).

Bleeding (%) (Fig. 11) Four studies compared the incidence of bleeding events (%). The findings of our study demonstrated that the occurrence of bleeding events was similar between the IABP group and the control group (RR=0.95, 95% confidence interval: 0.54–1.69, P=0.87), indicating that preoperative IABP did not exacerbate bleeding in patients.

Sensitivity analysis was conducted using a random effects model, which confirmed the robustness and stability of the meta-analysis results for mortality and low cardiac output when individual studies were excluded.

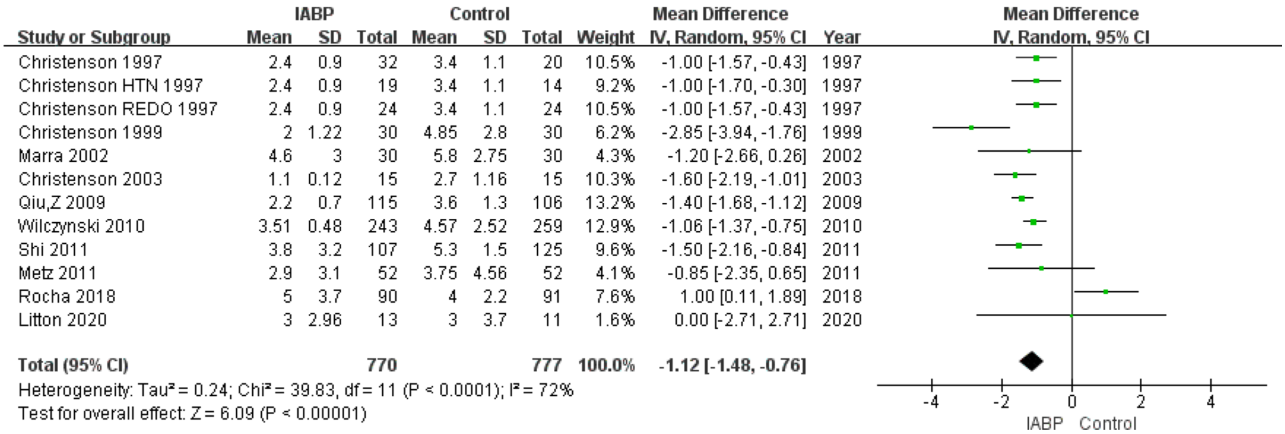


Fig. 4 Effect of intraaortic balloon pump (IABP) and control group on length of stay in ICU

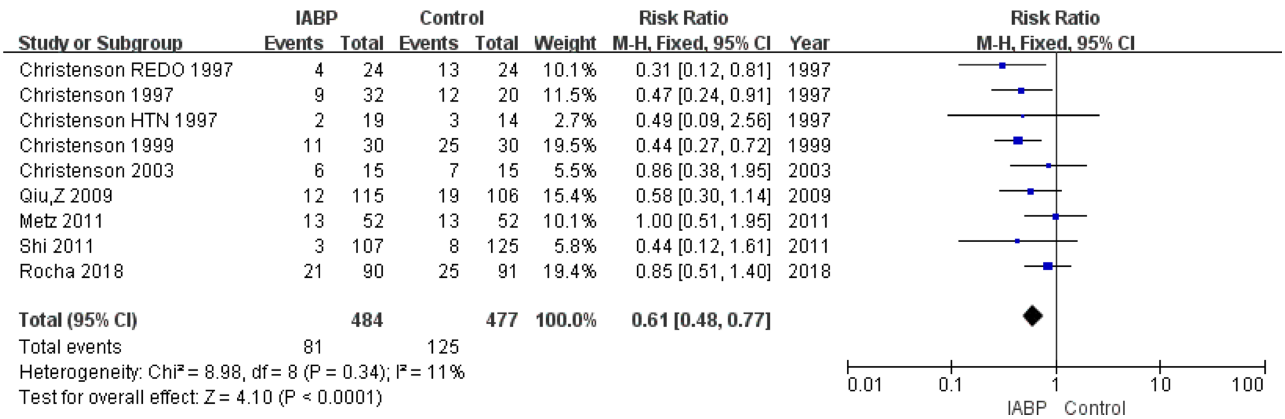


Fig. 5 Effect of Intraaortic Balloon Pump (IABP) and control group on length of stay in ICU (OPCAB and CABG subgroup analysis)

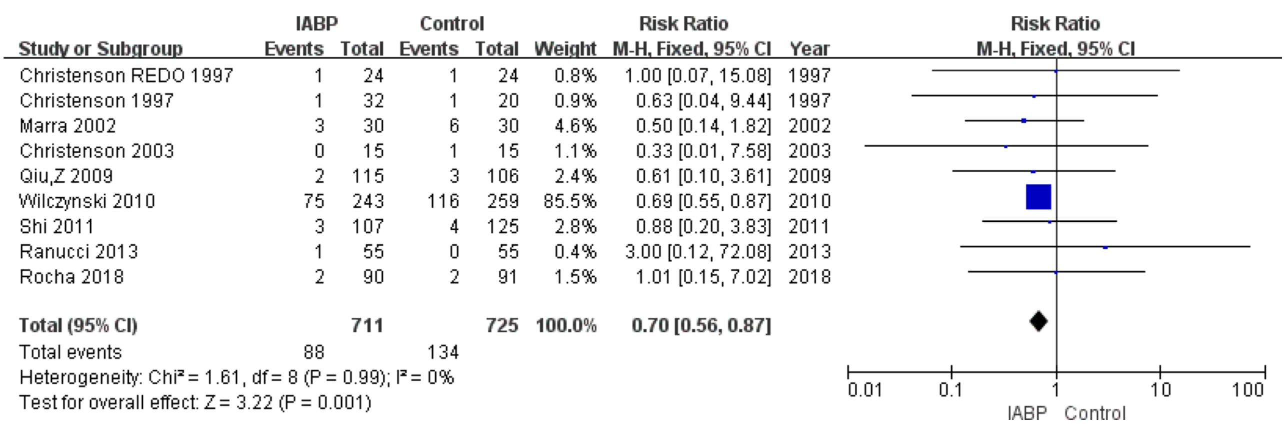
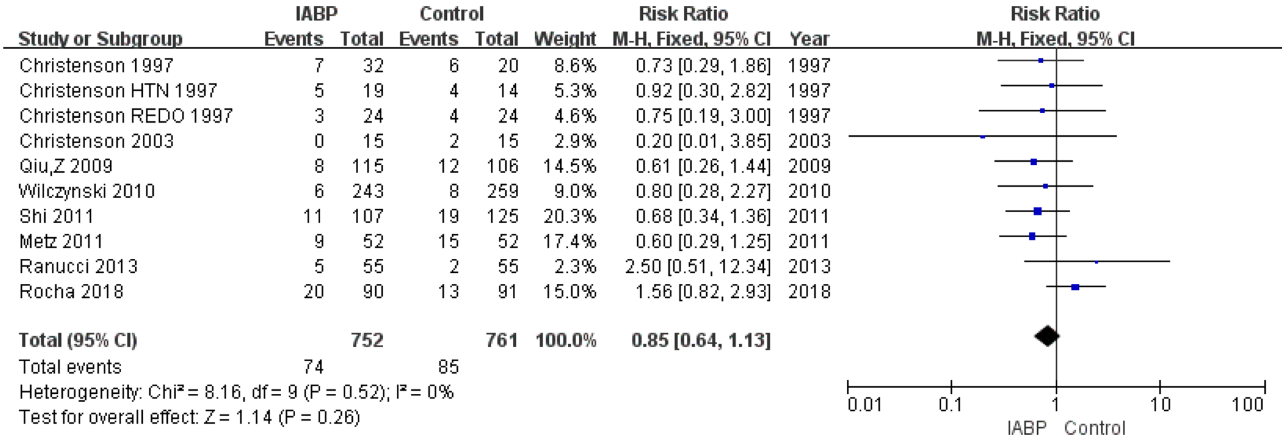


Fig. 6 Effect of Intraaortic balloon Pump (IABP) and control group on length of ICU stay (Asian and Caucasian subgroup analysis)

Discussion

Our analysis suggests that preoperative prophylactic implantation of an IABP is associated with several beneficial outcomes in patients undergoing CABG. These outcomes include a reduction in hospital mortality, shortened ICU hospitalization time, and a decrease in the incidence of LCOS% and MACCE%. However, preoperative IABP has little effect on renal dysfunction, the need for ventilation support for 24 h or more, and bleeding events.

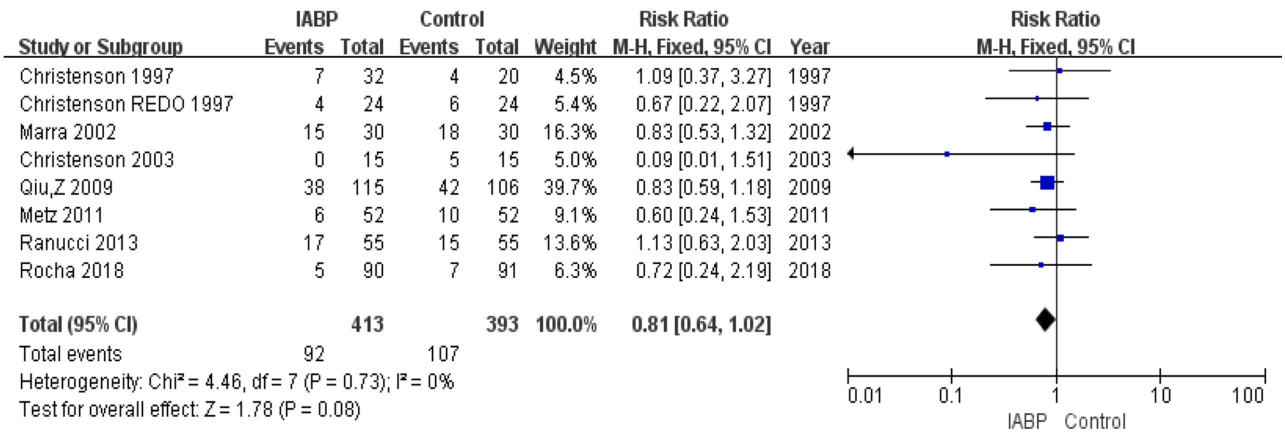
IABP has been widely used since the 1960s, particularly in high-risk patients with coronary heart disease. The technology has become well-established and mature in hospital settings. The principle of IABP involves the automatic expansion of a balloon during diastole, increasing aortic diastolic pressure and coronary artery perfusion.



Study or Subgroup	IABP Events	IABP Total	Control Events	Control Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
Christenson 1997	7	32	6	20	8.6%	0.73 [0.29, 1.86]	1997
Christenson HTN 1997	5	19	4	14	5.3%	0.92 [0.30, 2.82]	1997
Christenson REDO 1997	3	24	4	24	4.6%	0.75 [0.19, 3.00]	1997
Christenson 2003	0	15	2	15	2.9%	0.20 [0.01, 3.85]	2003
Qiu,Z 2009	8	115	12	106	14.5%	0.61 [0.26, 1.44]	2009
Wilczynski 2010	6	243	8	259	9.0%	0.80 [0.28, 2.27]	2010
Shi 2011	11	107	19	125	20.3%	0.68 [0.34, 1.36]	2011
Metz 2011	9	52	15	52	17.4%	0.60 [0.29, 1.25]	2011
Ranucci 2013	5	55	2	55	2.3%	2.50 [0.51, 12.34]	2013
Rocha 2018	20	90	13	91	15.0%	1.56 [0.82, 2.93]	2018
Total (95% CI)		**752**		**761**	**100.0%**	**0.85 [0.64, 1.13]**	
Total events	74		85				

Heterogeneity: Chi² = 8.16, df = 9 (P = 0.52); I² = 0%
Test for overall effect: Z = 1.14 (P = 0.26)

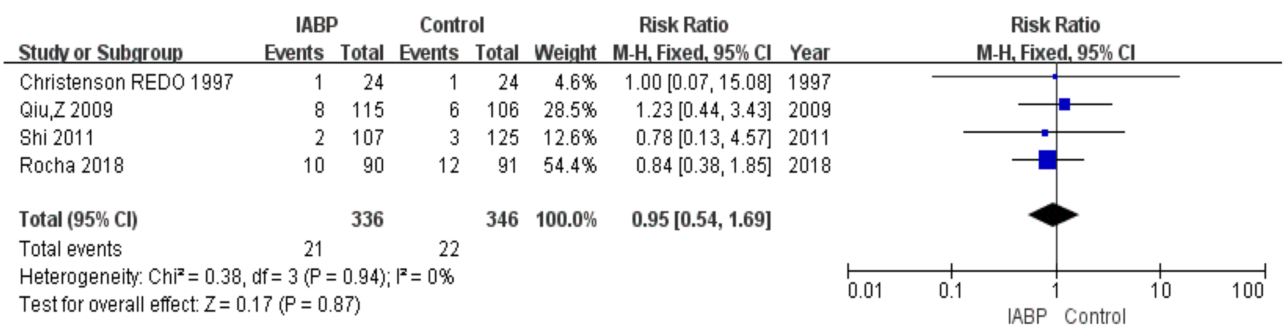
Fig. 7 Effect of intraaortic balloon pump (IABP) and control group on the incidence of low cardiac discharge syndrome



Study or Subgroup	IABP Events	IABP Total	Control Events	Control Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
Christenson 1997	7	32	4	20	4.5%	1.09 [0.37, 3.27]	1997
Christenson REDO 1997	4	24	6	24	5.4%	0.67 [0.22, 2.07]	1997
Marra 2002	15	30	18	30	16.3%	0.83 [0.53, 1.32]	2002
Christenson 2003	0	15	5	15	5.0%	0.09 [0.01, 1.51]	2003
Qiu,Z 2009	38	115	42	106	39.7%	0.83 [0.59, 1.18]	2009
Metz 2011	6	52	10	52	9.1%	0.60 [0.24, 1.53]	2011
Ranucci 2013	17	55	15	55	13.6%	1.13 [0.63, 2.03]	2013
Rocha 2018	5	90	7	91	6.3%	0.72 [0.24, 2.19]	2018
Total (95% CI)		**413**		**393**	**100.0%**	**0.81 [0.64, 1.02]**	
Total events	92		107				

Heterogeneity: Chi² = 4.46, df = 7 (P = 0.73); I² = 0%
Test for overall effect: Z = 1.78 (P = 0.08)

Fig. 8 Effect of intraaortic balloon pump (IABP) and control group on the incidence of major unscrupulous cerebrovascular events



Study or Subgroup	IABP Events	IABP Total	Control Events	Control Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
Christenson REDO 1997	1	24	1	24	4.6%	1.00 [0.07, 15.08]	1997
Qiu,Z 2009	8	115	6	106	28.5%	1.23 [0.44, 3.43]	2009
Shi 2011	2	107	3	125	12.6%	0.78 [0.13, 4.57]	2011
Rocha 2018	10	90	12	91	54.4%	0.84 [0.38, 1.85]	2018
Total (95% CI)		**336**		**346**	**100.0%**	**0.95 [0.54, 1.69]**	
Total events	21		22				

Heterogeneity: Chi² = 0.38, df = 3 (P = 0.94); I² = 0%
Test for overall effect: Z = 0.17 (P = 0.87)

Fig. 9 Effects of intraaortic balloon pump (IABP) and control group on the incidence of renal failure

During systole, the balloon automatically deflates, reducing aortic pressure and myocardial oxygen consumption. This continuous blood flow and reduced cardiac workload contribute to maintaining hemodynamic stability and improving myocardial perfusion. Additionally, preoperative IABP can minimize hemodynamic damage by improving myocardial perfusion before anesthesia induction.

Prophylactic implantation of IABP before surgery has demonstrated improved medical outcomes and potential economic benefits, particularly in patients with acute or critically ill coronary heart disease. While some studies have shown the safety and effectiveness of preoperative IABP implantation, others have suggested that it may not be beneficial in highly stable patients and could potentially have drawbacks.

This meta-analysis includes the latest randomized controlled trials and benefits from a larger sample size, enhancing the reliability of the results. Given the high postoperative mortality rate in critically ill patients,

Study or Subgroup	IABP Mean	IABP SD	IABP Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI	Year
1.2.1 Asian									
Qiu,Z 2009	2.2	0.7	115	3.6	1.3	106	13.2%	-1.40 [-1.68, -1.12]	2009
Shi 2011	3.8	3.2	107	5.3	1.5	125	9.6%	-1.50 [-2.16, -0.84]	2011
Subtotal (95% CI)			**222**			**231**	**22.8%**	**-1.42 [-1.67, -1.16]**	
Heterogeneity: Tau² = 0.00; Chi² = 0.07, df = 1 (P = 0.78); I² = 0%									
Test for overall effect: Z = 10.80 (P < 0.00001)									
1.2.2 Caucasians									
Christenson REDO 1997	2.4	0.9	24	3.4	1.1	24	10.5%	-1.00 [-1.57, -0.43]	1997
Christenson 1997	2.4	0.9	32	3.4	1.1	20	10.5%	-1.00 [-1.57, -0.43]	1997
Christenson HTN 1997	2.4	0.9	19	3.4	1.1	14	9.2%	-1.00 [-1.70, -0.30]	1997
Christenson 1999	2	1.22	30	4.85	2.8	30	6.2%	-2.85 [-3.94, -1.76]	1999
Marra 2002	4.6	3	30	5.8	2.75	30	4.3%	-1.20 [-2.66, 0.26]	2002
Christenson 2003	1.1	0.12	15	2.7	1.16	15	10.3%	-1.60 [-2.19, -1.01]	2003
Wilczynski 2010	3.51	0.48	243	4.57	2.52	259	12.9%	-1.06 [-1.37, -0.75]	2010
Metz 2011	2.9	3.1	52	3.75	4.56	52	4.1%	-0.85 [-2.35, 0.65]	2011
Rocha 2018	5	3.7	90	4	2.2	91	7.6%	1.00 [0.11, 1.89]	2018
Litton 2020	3	2.96	13	3	3.7	11	1.6%	0.00 [-2.71, 2.71]	2020
Subtotal (95% CI)			**548**			**546**	**77.2%**	**-1.02 [-1.49, -0.55]**	
Heterogeneity: Tau² = 0.36; Chi² = 34.99, df = 9 (P < 0.0001); I² = 74%									
Test for overall effect: Z = 4.22 (P < 0.0001)									
Total (95% CI)			**770**			**777**	**100.0%**	**-1.12 [-1.48, -0.76]**	
Heterogeneity: Tau² = 0.24; Chi² = 39.83, df = 11 (P < 0.0001); I² = 72%									
Test for overall effect: Z = 6.09 (P < 0.00001)									
Test for subgroup differences: Chi² = 2.08, df = 1 (P = 0.15), I² = 51.9%									

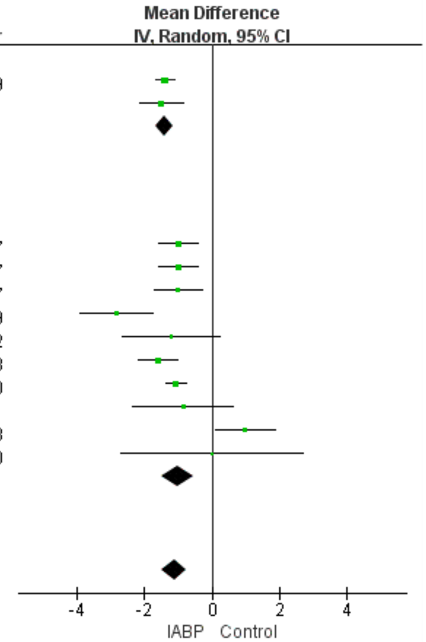


Fig. 10 Effect of intraaortic balloon pump (IABP) and control group on the incidence of mechanical ventilation for more than 24 h

Study or Subgroup	IABP Mean	IABP SD	IABP Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI	Year
1.3.1 opcabg									
Christenson 2003	1.1	0.12	15	2.7	1.16	15	10.3%	-1.60 [-2.19, -1.01]	2003
Qiu,Z 2009	2.2	0.7	115	3.6	1.3	106	13.2%	-1.40 [-1.68, -1.12]	2009
Shi 2011	3.8	3.2	107	5.3	1.5	125	9.6%	-1.50 [-2.16, -0.84]	2011
Subtotal (95% CI)			**237**			**246**	**33.1%**	**-1.44 [-1.68, -1.21]**	
Heterogeneity: Tau² = 0.00; Chi² = 0.39, df = 2 (P = 0.82); I² = 0%									
Test for overall effect: Z = 12.03 (P < 0.00001)									
1.3.2 cabg									
Christenson 1997	2.4	0.9	32	3.4	1.1	20	10.5%	-1.00 [-1.57, -0.43]	1997
Christenson HTN 1997	2.4	0.9	19	3.4	1.1	14	9.2%	-1.00 [-1.70, -0.30]	1997
Christenson REDO 1997	2.4	0.9	24	3.4	1.1	24	10.5%	-1.00 [-1.57, -0.43]	1997
Christenson 1999	2	1.22	30	4.85	2.8	30	6.2%	-2.85 [-3.94, -1.76]	1999
Marra 2002	4.6	3	30	5.8	2.75	30	4.3%	-1.20 [-2.66, 0.26]	2002
Wilczynski 2010	3.51	0.48	243	4.57	2.52	259	12.9%	-1.06 [-1.37, -0.75]	2010
Metz 2011	2.9	3.1	52	3.75	4.56	52	4.1%	-0.85 [-2.35, 0.65]	2011
Rocha 2018	5	3.7	90	4	2.2	91	7.6%	1.00 [0.11, 1.89]	2018
Litton 2020	3	2.96	13	3	3.7	11	1.6%	0.00 [-2.71, 2.71]	2020
Subtotal (95% CI)			**533**			**531**	**66.9%**	**-0.93 [-1.45, -0.41]**	
Heterogeneity: Tau² = 0.39; Chi² = 31.22, df = 8 (P = 0.0001); I² = 74%									
Test for overall effect: Z = 3.51 (P = 0.0004)									
Total (95% CI)			**770**			**777**	**100.0%**	**-1.12 [-1.48, -0.76]**	
Heterogeneity: Tau² = 0.24; Chi² = 39.83, df = 11 (P < 0.0001); I² = 72%									
Test for overall effect: Z = 6.09 (P < 0.00001)									
Test for subgroup differences: Chi² = 3.08, df = 1 (P = 0.08), I² = 67.5%									

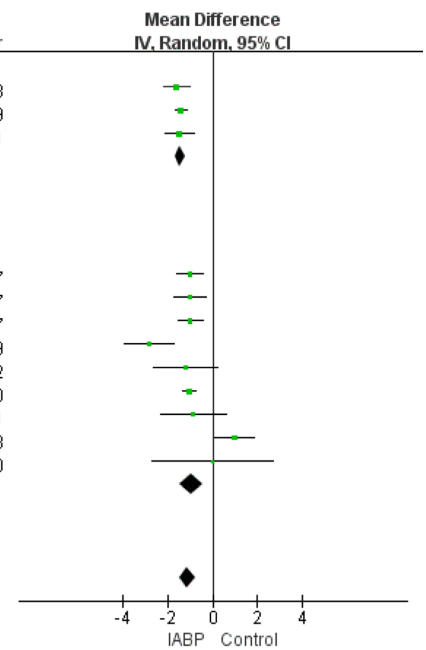


Fig. 11 The effect of intraaortic balloon pump (IABP) and control group on the incidence of bleeding events

exploring new treatment methods to further reduce preoperative mortality is crucial. Therefore, investigating the preventive implantation of IABP before surgery is important for improving the prognosis of critically ill CABG patients.

The findings of this study suggest that preoperative prophylactic placement of an IABP can reduce hospital mortality in patients with acute and critically ill CABG, which is consistent with previous scientific findings [21]. The analysis also revealed that patients in the IABP group had shorter stays in the ICU compared to the control group, aligning with previous research results [22]. To account for high heterogeneity, patients were divided into two groups based on whether they underwent off-pump CABG. Subgroup analysis indicated that patients in the IABP group who received off-pump CABG had shorter ICU hospitalization times compared to the control group. Similarly, patients in the IABP group who underwent traditional CABG surgery also had shorter hospital stays. Racial subgroup analysis demonstrated a significant reduction in ICU hospitalization time in both the Asian and Caucasus IABP groups, suggesting that the benefits of IABP are consistent and independent of race and the use of the off-pump coronary artery bypass grafting technique.

Among the 13 randomized controlled studies included in this analysis, only three utilized the off-pump CABG model. Additionally, factors such as variations in IABP insertion time, the definition of a high-risk population, and the use of preventive and treatment measures were not standardized, potentially contributing to the higher heterogeneity observed. In this meta-analysis, the incidence of low cardiac output syndrome was significantly reduced in the IABP group compared to the control group, as reported by nine studies. The meta-analysis also showed that the occurrence of MACCE% was lower in the IABP group compared to the control group, with nine studies assessing MACCE%. Previous studies have confirmed that the preoperative use of IABP has minimal effect on cerebral blood flow in high-risk patients [23], which differs from our research findings and requires further investigation for confirmation. On the other hand, other research has demonstrated that preoperative use of IABP can reduce the risk of renal failure [24]. However, our analysis results indicate that there is little difference in the incidence of renal insufficiency between the IABP and control groups, potentially due to insufficient data in the studies. More multicenter clinical trials are needed to establish definitive conclusions. We also analyzed the incidence of mechanical ventilation exceeding 24 h between the IABP group and the control group, and the research results showed no significant difference in mechanical ventilation time between patients who received preoperative IABP implantation. Additionally, some studies have suggested that preoperative IABP insertion may increase the incidence of postoperative bleeding events in patients. However, our study did not observe a significant increase in the risk of postoperative bleeding events associated with preoperative IABP insertion. Therefore, preoperative IABP placement can be considered a safe treatment method.

This study has several limitations. Firstly, five of the included studies were published by the same primary researcher, conducting experiments during overlapping time periods, which raises the possibility of duplication. Secondly, most trials did not employ blinded evaluators for the results, potentially introducing bias into the reporting. Thirdly, as all the research was funded by a specific company, there may be biases considering the relevant interests, and the majority of articles are not recently published, which could impact the results to some extent. Fourthly, due to variations in the definition of critically ill patients among the studies based on their specific research objectives, fields, and designs, as well as individual patient differences, there may be some inherent biases.

Lastly, since all the articles included in the study were single-center experiments, there is an urgent need for a large number of multicenter trials to further evaluate the effectiveness and safety of IABP. Additionally, with technological advancements, the impact of IABP may be offset by the application of new drugs and mechanical models, necessitating updated randomized controlled trials [25].

Conclusions

The findings of our investigation indicate that prophylactic preoperative IABP does not elevate the incidence of postoperative bleeding complications in patients. As such, IABP placement can be considered a highly safe intervention for critically ill CABG candidates to undergo prior to surgical revascularization. Concurrently, this preventive measure also demonstrates certain favorable therapeutic effects, including reduced in-hospital mortality, shortened intensive care unit length of stay, and decreased incidence of low cardiac output syndrome and major adverse cardiovascular events among these patients. Based on these results, we can conclude that prophylactic preoperative IABP implantation conveys beneficial outcomes for the majority of critically ill CABG surgical cohorts.

Abbreviations

IABP	Intra-aortic balloon pump
CABG	Coronary Artery Bypass Grafting
MACCE	Major Adverse Cardiovascular and Cerebrovascular Events
OPCAB	Off-Pump Coronary Artery Bypass
ICU	Intensive Care Unit
LCOS	Low Cardiac Output Syndrome
RR	Relative Risk
MD	Mean Difference
LVEF	Left Ventricular Ejection Fraction
RCT	Randomized Controlled Trial

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Author contributions

YNH conceived the study , participated in the design, collected the data, performed statistical analyses and drafted the manuscript, PRZ conceived the study , participated in the design and helped to revise the manuscript critically for important intellectual content. MMF and RL performed statistical analyses and helped to draft the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This article was approved by the Ethics Committee of Weifang Medical University Affiliated Hospital on May 20th, 2023.The ethical code is wyfy-2023-qt-024.informed consent was waived by our insitutional review board because of the retrospective nature of our study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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