

Impact of Preoperative Versus Intraoperative and Postoperative Intra-Aortic Balloon Pump Insertion on Mortality and Clinical Outcomes in High-Risk Coronary Artery Bypass Grafting Patients: A Systematic Review and Meta-Analysis

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Úvod: Optimální načasování zavedení intraaortální balonkové pumpy (intra-aortic balloon pump, IABP) při vysoce rizikovém koronárním bypassu (coronary artery bypass grafting, CABG) zůstává předmětem sporu. Zatímco předoperačně může IABP zajistit časnou stabilizaci hemodynamických poměrů, peroperační nebo pooperační zavedení se typicky provádí jako záchranná léčba při zhoršení hemodynamických poměrů. Cílem této studie bylo zhodnotit vliv předoperačního versus peroperačního/pooperačního zavedení IABP na mortalitu a výsledný klinický stav u pacientů při vysoce rizikovém CABG.

Metody: Systematický přehled a metaanalýza byly provedeny podle metodiky PRISMA 2020. V databázích PubMed a ScienceDirect byly vyhledány studie na dané téma publikované v období mezi lednem 2000 a lednem 2025. Za vhodné byly považovány studie zahrnující pacienty podstupující vysoce rizikový CABG a přímo srovnávající zavedení IABP před operací versus v průběhu operace a po ní. Primárním sledovaným parametrem byla krátkodobá mortalita (nemocniční nebo 30denní). Mezi sekundární sledované parametry patřily závažné nežádoucí kardiovaskulární příhody (major adverse cardiac events, MACE), dlouhodobá mechanická ventilace, pobyt na JIP, pobyt v nemocnici a doba podpory pomocí IABP. Údaje byly hodnoceny metaanalýzou náhodných účinků s použitím softwaru RevMan 5.4.

Výsledky: Do analýzy bylo zařazeno 10 studií s 49 557 pacienty. Předoperační zavedení IABP bylo spojeno se statisticky významně sníženou nemocniční mortalitou (OR 0,52; 95% CI 0,33–0,81; $p = 0,004$) a 30denní mortalitou (OR 0,12; 95% CI 0,05–0,31; $p < 0,001$). Statisticky významně nižší byl i výskyt MACE (OR 0,54; 95% CI 0,39–0,76; $p < 0,001$). Byl zaznamenán nižší počet případů dlouhodobé mechanické ventilace (OR 0,38; 95% CI 0,15–0,96; $p = 0,04$). Žádné statisticky významné rozdíly v délce pobytu na JIP, v nemocnici, délce mechanické ventilace i v délce podpory pomocí IABP nebyly zaznamenány.

Závěr: Předoperační zavedení IABP je spojeno s příznivějším krátkodobým přežitím a se sníženým výskytem perioperačních komplikací u pacientů podstupujících vysoce rizikový CABG; toto zjištění hovoří ve prospěch – u pečlivě vybraných jedinců – spíše aktivní než záchranné strategie.

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ABSTRACT

Introduction: The optimal timing of intra-aortic balloon pump (IABP) insertion in high-risk coronary artery bypass grafting (CABG) remains controversial. While preoperative IABP may provide early hemodynamic stabilization, intraoperative or postoperative insertion is typically performed as rescue therapy after hemodynamic deterioration. This study aimed to evaluate the impact of preoperative versus intraoperative/postoperative IABP insertion on mortality and clinical outcomes in high-risk CABG patients.

Methods: A systematic review and meta-analysis were conducted according to PRISMA 2020 guidelines. PubMed and ScienceDirect were searched for studies published between January 2000 and January 2025. Eligible studies included adult high-risk CABG patients directly comparing preoperative and delayed (intra-

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operative/postoperative) IABP insertion. The primary endpoint was short-term mortality (in-hospital or 30-day). Secondary outcomes included major adverse cardiac events (MACE), prolonged mechanical ventilation, ICU stay, hospital stay, and duration of IABP support. Random-effects meta-analysis was performed using RevMan 5.4.

Results: Ten studies comprising 49,557 patients were included. Preoperative IABP insertion was associated with significantly reduced in-hospital mortality (OR 0.52; 95% CI 0.33–0.81; $p = 0.004$) and 30-day mortality (OR 0.12; 95% CI 0.05–0.31; $p < 0.001$). Major adverse cardiac events were also significantly lower (OR 0.54; 95% CI 0.39–0.76; $p < 0.001$). Prolonged mechanical ventilation was reduced (OR 0.38; 95% CI 0.15–0.96; $p = 0.04$). No significant differences were observed in ICU stay, hospital stay, ventilation duration, or IABP support duration.

Conclusion: Preoperative IABP insertion is associated with improved short-term survival and reduced perioperative complications in high-risk CABG patients, supporting a proactive rather than rescue strategy in carefully selected individuals.

Introduction

Coronary artery bypass grafting (CABG) remains the standard revascularization strategy for patients with multivessel coronary artery disease, significant left main stenosis, or advanced left ventricular dysfunction.¹ Contemporary surgical techniques and perioperative care have substantially improved outcomes; however, patients classified as high risk, particularly those with reduced left ventricular ejection fraction (LVEF), recent myocardial infarction, cardiogenic shock, or complex coronary anatomy, continue to experience considerable perioperative morbidity and mortality.^{2,3} Operative mortality in this subgroup remains clinically significant despite advances in risk stratification models such as the Society of Thoracic Surgeons (STS) scoring system.⁴ Optimizing perioperative hemodynamic stability is therefore a critical component of management in high-risk CABG.

Mechanical circulatory support devices are frequently employed to stabilize these vulnerable patients. The intra-aortic balloon pump (IABP) remains the most widely used temporary support device in cardiac surgery due to its relative simplicity, safety profile, and physiologic mechanism of action.⁵ Through diastolic counterpulsation, IABP augments coronary perfusion pressure and reduces left ventricular afterload, thereby improving myocardial oxygen supply-demand balance and systemic perfusion.⁶ Although its role in cardiogenic shock has evolved with the emergence of alternative support devices, IABP continues to be commonly used in high-risk surgical populations.⁷

The optimal timing of IABP insertion in high-risk CABG remains controversial. Preoperative insertion may provide hemodynamic stabilization before induction of anesthesia and initiation of cardiopulmonary bypass, potentially reducing the incidence of low-cardiac-output syndrome and major adverse cardiovascular events.^{8,9} Conversely, intraoperative or postoperative insertion is typically reserved for patients who develop hemodynamic compromise, raising concerns regarding confounding by indication and delayed intervention. Contemporary studies and meta-analyses report heterogeneous findings, with some demonstrating survival benefit and others suggesting neutral outcomes while highlighting device-related complications.^{9–13} Given evolving perioperative strategies and variability in defining “high-risk” CABG, an updated systematic review and meta-analysis is warranted to clarify

the impact of IABP timing on mortality and major clinical outcomes in contemporary practice.

Materials and methods

Search strategy and data sources

This study was conducted as a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The study protocol was developed prior to data extraction to minimize selection and analytical bias.

A comprehensive literature search was performed in PubMed and ScienceDirect for studies published between January 1, 2000 and January 31, 2025. The following keywords and Boolean operators were applied: (“intra-aortic balloon pump” OR “IABP”) AND (“coronary artery bypass grafting” OR “CABG”) AND (“preoperative” OR “intraoperative” OR “postoperative”) AND (“mortality” OR “clinical outcomes”).

Only studies published in English were considered. Reference lists of eligible articles and relevant reviews were manually screened to identify additional studies.

Eligibility criteria

Studies were included if they met the following criteria: (1) Adult patients undergoing isolated CABG. (2) Classified as high-risk according to study-defined criteria (e.g., reduced LVEF $\leq 40\%$, cardiogenic shock, left main disease, recent myocardial infarction, or hemodynamic instability). (3) Direct comparison between preoperative IABP insertion and intraoperative or postoperative insertion. (4) Reported at least one relevant clinical outcome (in-hospital mortality, 30-day mortality, major adverse cardiovascular events, duration of mechanical ventilation, ICU stay, or hospital stay). (5) Observational cohort studies or randomized controlled trials. Exclusion criteria were case reports, editorials, reviews, conference abstracts without full text, pediatric populations, studies without timing comparison, and studies lacking extractable outcome data.

Study selection

Two independent reviewers screened titles and abstracts for eligibility. Full-text review was performed for po-

tentially relevant studies. Disagreements were resolved through discussion and consensus. The following data were extracted using a standardized form: study design, country of origin, publication year, sample size, patient demographics, definition of high-risk status, timing of IABP insertion, operative characteristics, and reported clinical outcomes.

Quality assessment

Methodological quality of observational studies was assessed using the Newcastle–Ottawa Scale (NOS). Studies scoring ≥ 7 were considered high quality. Risk of bias was independently evaluated by two reviewers.

Outcome measures

The primary endpoint was short-term mortality, defined as in-hospital mortality or 30-day mortality. Secondary endpoints included: Major adverse cardiovascular events (MACE), Prolonged mechanical ventilation, Duration of mechanical ventilation, Length of intensive care unit (ICU) stay, and Length of hospital stay.

Statistical analysis

Meta-analysis was performed using Review Manager (RevMan) version 5.4. Dichotomous outcomes were analysed using risk ratios (RR) with 95% confidence intervals (CI). Continuous variables were pooled using mean differences (MD) with 95% CI.

A random-effects model (DerSimonian–Laird method) was applied due to expected clinical heterogeneity across

studies. Statistical heterogeneity was assessed using the I^2 statistic, with values $>50\%$ considered indicative of substantial heterogeneity.

Sensitivity analyses were performed by sequential exclusion of individual studies. Publication bias was evaluated using funnel plot inspection when ≥ 10 studies were available for a given outcome. A p -value <0.05 was considered statistically significant.

Results

Study selection

The systematic search identified 3,606 records from electronic databases, including 3,007 from ScienceDirect and 599 from PubMed. After removal of 360 duplicate records, 3,246 studies remained for title and abstract screening. During initial screening, 3,182 records were excluded due to non-human studies ($n = 811$), irrelevant topics ($n = 1,305$), review articles ($n = 1,021$), and non-English publications ($n = 45$). A total of 64 full-text articles were retrieved and assessed for eligibility. Of these, 54 studies were excluded for the following reasons: inappropriate study design ($n = 2$), irrelevant outcomes ($n = 2$), lack of full-text availability ($n = 14$), and absence of clearly defined timing of IABP insertion ($n = 36$). Ultimately, 10 studies met the inclusion criteria and were included in the systematic review and meta-analysis. The study selection process is summarized in **Figures 1 and 2**.

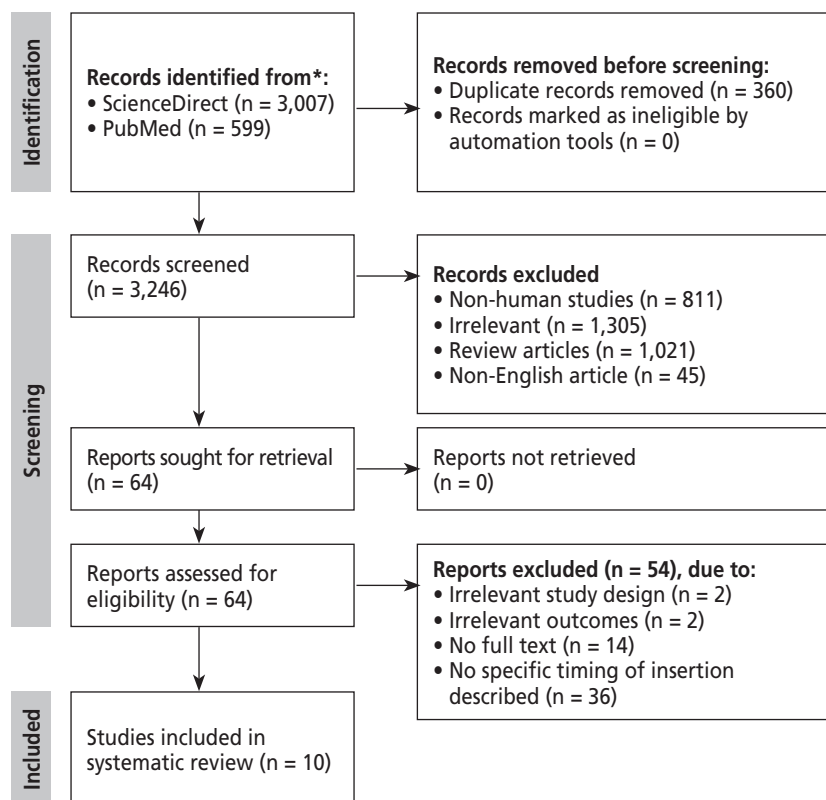


Fig. 1 – PRISMA 2020 flow diagram for included studies.
Identification of studies via databases and registers

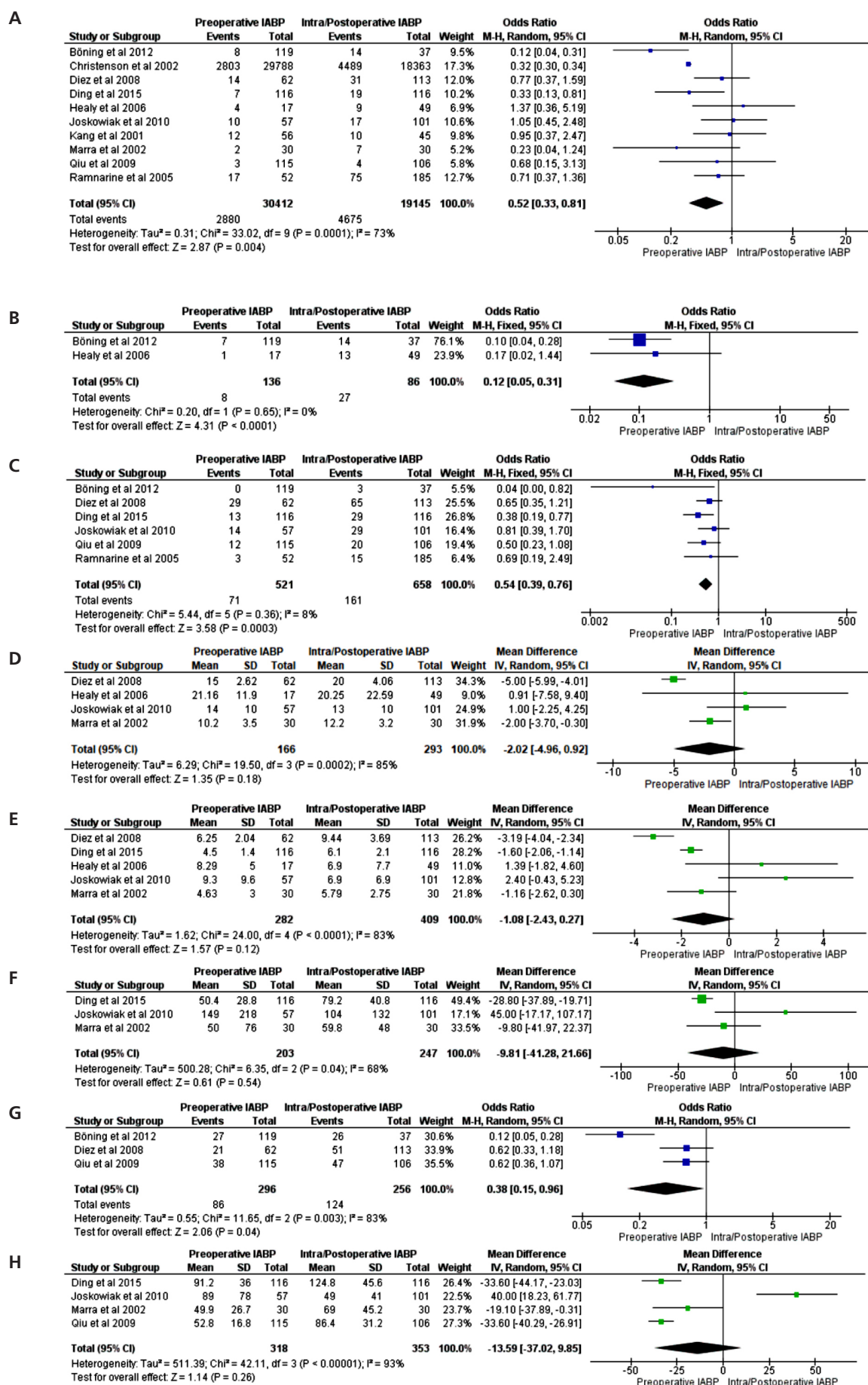


Fig. 2 – Forest plot of the meta-analysis. (A) Inhospital mortality. (B) 30-day mortality. (C) Major adverse cardiac events (MACE). (D) Length of hospital stay. (E) Length of ICU stay. (F) Duration of mechanical ventilation. (G) Prolonged of mechanical ventilation. (H) Duration of IABP support.

Study characteristics

A total of 10 studies met the inclusion criteria and were included in the final analysis. Nine studies were retrospective cohort designs,^{14–19,21–23} while one study was a prospective randomized trial.²⁰ The studies were conducted across Europe, Asia, and Australia. Definitions of high-risk CABG varied among studies but commonly included reduced left ventricular ejection fraction (LVEF ≤ 30 –40%),^{19–21} elevated operative risk scores such as EuroSCORE,^{16,18} or clinical instability and emergent presentation.^{14,23} Preoperative IABP was generally inserted prophylactically in high-risk or hemodynamically unstable patients,^{14,16,17,20,23} whereas intraoperative or postoperative IABP was typically initiated in response to failure to wean from cardiopulmonary bypass or development of postoperative low cardiac output syndrome.^{18,19,22} Despite heterogeneity in study design and risk stratification, all studies directly compared outcomes between preoperative and delayed IABP insertion strategies.^{14–23}

Baseline demographics and clinical characteristics

Most cohorts included high-risk CABG populations defined by reduced LVEF, hemodynamic instability, emergent status, or elevated operative risk scores.^{16–19,22,23} The proportion of female patients ranged from 14% to 40% in preoperative IABP groups and from 22% to 37% in intraoperative/postoperative groups.^{14,19,23} Mean age was generally comparable across intervention arms, ranging between 63 and 72 years.

Comorbidity burden was substantial across studies. Diabetes mellitus prevalence ranged from approximately 19% to 43% when reported, and hypertension was present in up to 90% of patients in certain cohorts. Prior cerebrovascular accident was reported in a minority of patients, generally below 20%. Left ventricular dysfunction was a defining feature in several studies, particularly in Marra et al.²⁰ and Qiu et al.,²¹ both of which specifically enrolled patients with severe LVEF impairment. Joskowiak et al.¹⁹ reported impaired LV function (EF $< 40\%$) in 68% of preoperative IABP patients. Left main disease and triple-vessel disease were common across multiple cohorts, particularly in Kang et al.²³ and Ramnarine et al.²²

Overall, baseline characteristics were broadly comparable between preoperative and intraoperative/postoperative IABP groups within individual studies, without consistent systematic imbalance across cohorts.^{14–23}

In-hospital mortality

All ten studies reported in-hospital mortality. Preoperative IABP insertion was associated with lower mortality in several cohorts, including Böning et al.¹⁴ (6.7% vs 37.8%), Ding et al.¹⁷ (6.0% vs 16.4%), Marra et al.²⁰ (6.7% vs 23.3%), Qiu et al.²¹ (2.6% vs 3.8%), and Christenson et al.¹⁵ (9.4% vs 24.4%). Comparable mortality rates were reported in Healy et al.¹⁸ and Joskowiak et al.,¹⁹ while Kang et al.²³ demonstrated similar outcomes between groups. Ramnarine et al.²² reported higher mortality in patients requiring delayed IABP insertion.

Pooled meta-analysis (10 studies; $n = 49,557$) demonstrated significantly reduced in-hospital mortality with preoperative IABP (OR 0.52; 95% CI 0.33–0.81; $p = 0.004$; $I^2 = 73\%$).

30-day mortality

Thirty-day mortality was reported in selected studies. Healy et al.¹⁸ demonstrated significantly lower 30-day mortality in the preoperative group (5.8% vs 26.5%). Meta-analysis confirmed significant reduction in 30-day mortality (OR 0.12; 95% CI 0.05–0.31; $p < 0.001$; $I^2 = 0\%$).

Major adverse cardiac events (MACE)

Reduced MACE rates with preoperative IABP were observed in Diez et al.¹⁶ (46.8% vs 57.5%), Ding et al.¹⁷ (11.2% vs 25.0%), Qiu et al.²¹ (10.4% vs 18.9%), and Ramnarine et al.²² (5.8% vs 8.1%). Meta-analysis confirmed significant reduction in MACE (OR 0.54; 95% CI 0.39–0.76; $p < 0.001$; $I^2 = 8\%$).

Length of hospital stay

Diez et al.¹⁶ reported shorter hospitalization in the preoperative group (15 ± 2.6 vs 20 ± 4.1 days), whereas Healy et al.¹⁸ reported comparable durations. Pooled analysis did not demonstrate statistical significance (MD -2.02 days; 95% CI -4.96 to 0.92 ; $p = 0.18$; $I^2 = 85\%$).

Length of ICU stay

Shorter ICU stay with preoperative IABP was reported in Diez et al.¹⁶ and Marra et al.,²⁰ while Joskowiak et al.¹⁹ demonstrated similar durations between groups. Meta-analysis showed no statistically significant difference (MD -1.08 days; 95% CI -4.23 to 2.07 ; $p = 0.12$; $I^2 = 83\%$).

Duration of mechanical ventilation

Ding et al.¹⁷ and Marra et al.²⁰ reported shorter ventilation duration in the preoperative group, whereas Joskowiak et al.¹⁹ observed longer duration in early IABP patients. Meta-analysis showed no significant difference (MD -9.81 hours; 95% CI -41.28 to 21.66 ; $p = 0.54$; $I^2 = 68\%$).

Prolonged mechanical ventilation

Lower prolonged ventilation rates were reported in Böning et al.,¹⁴ Diez et al.,¹⁶ and Qiu et al.²¹ in the preoperative groups. Pooled analysis demonstrated significant reduction (OR 0.38; 95% CI 0.15–0.96; $p = 0.04$; $I^2 = 83\%$).

Duration of IABP support

Shorter IABP duration in preoperative groups was reported in Ding et al.,¹⁷ Marra et al.,²⁰ and Qiu et al.²¹ Meta-analysis did not show statistical significance (MD -13.59 hours; 95% CI -37.02 to 9.85 ; $p = 0.26$; $I^2 = 93\%$).

Discussion

This meta-analysis demonstrates that preoperative intra-aortic balloon pump (IABP) insertion in high-risk CABG patients is associated with significant reductions in in-hospital and 30-day mortality, as well as lower incidence of major adverse cardiac events and prolonged mechanical ventilation. These findings are consistent with several earlier observational studies^{16,20,23} and align with prior meta-analyses suggesting benefit of prophylactic IABP in high-risk surgical populations.^{9,10} However, unlike earlier analyses conducted in the pre-modern surgical era, the present study includes contemporary cohorts, thereby

Table 1 – Study characteristics

No	Author	Study type	Country	Sample (n)	Participant	Intervention	Control	Gender (female)	Mean Age	Comorbidity			CVA			Heart failure	Renal Failure	Low EF	Left main disease	TVD
										Hypertension	Diabetes									
1	Böning et al., 2012	Retrospective cohort	Germany	156	Patients undergoing coronary surgery with IABP support	Preoperative IABP = 119 IABP = 29788, Benchmark = 5721, 26067 S15 = 14983	Intraoperative IABP = 37	Pre-operative IABP: 37 (31.1%), intra-operative IABP: 10 (27%)	Pre-operative IABP: 70 (63-76), intraoperative IABP: 72 (64-78)	N/A	N/A	Pre-operative IABP: 39.5%, intraoperative IABP: 51.4%	N/A	N/A	N/A	N/A	N/A	<30% Pre-operative IABP: 30.3%, intraoperative IABP: 29.7%	N/A	Pre-operative IABP: 87.4%, intraoperative IABP: 91.9%
2	Christenson et al., 2002	Retrospective cohort	Switzerland	119	Patients undergoing cardiac surgery with IABP support	Preoperative IABP = 62 Benchmark = 5721, 26067 S15 = 14983	Intra-postoperative IABP = 113	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Diez et al., 2008	Retrospective cohort	Germany	175	Patients undergoing cardiac surgery with IABP support	Preoperative IABP = 62	Intra-postoperative IABP = 113	Preoperative IABP = 21, intra-postoperative IABP = 40	Preoperative IABP = 69 (62-74), intra-postoperative IABP = 67 (60-72)	N/A	N/A	N/A	N/A	N/A	Preoperative IABP = 51, intra-postoperative IABP = 81	N/A	N/A	N/A	Preoperative IABP = 67, intra-postoperative IABP = 48	
4	Ding et al., 2015	Cohort	China	232	High-risk patients (based on EuroSCORE) undergoing off-pump coronary artery bypass grafting	Preoperative IABP = 116	Intra-postoperative IABP = 113	Preoperative IABP = 21, intra-postoperative IABP = 40	Preoperative IABP = 63.0 ± 8.2, post-operative IABP = 64.1 ± 9.5	Preoperative IABP = 92, intra-postoperative IABP = 89	Preoperative IABP = 24, intra-postoperative IABP = 18	Preoperative IABP = 59, intra-postoperative IABP = 46	Preoperative IABP = 6, intra-postoperative IABP = 4	Preoperative IABP = 37, intra-postoperative IABP = 28	Preoperative IABP = 39, intra-postoperative IABP = 28	Preoperative IABP = 112, intra-postoperative IABP = 114				
5	Healy et al., 2006	Cohort retrospective	Ireland	66	Patients undergoing CABG and CABG procedures from January 2000 to December 2001 who required an IABP	Group 1A (low EuroSCORE/pre-operative IABP: 4, EuroSCORE/pre-operative IABP: 24 (high EuroSCORE/pre-operative IABP: group 2B (high EuroSCORE/postoperative IABP: 1A + 2A): 17, post-operative (1B + 2B): 49	Group 1A (low EuroSCORE/pre-operative IABP: 4, EuroSCORE/pre-operative IABP: 24 (high EuroSCORE/pre-operative IABP: group 2B (high EuroSCORE/postoperative IABP: 1A + 2A): 17, post-operative (1B + 2B): 49	Preoperative IABP: 4 (23.5%), postoperative IABP: 9 (22.5%)	Preoperative IABP = 64.35 ± 10, postoperative IABP: 66.9 ± 8.5	N/A	N/A	Preoperative IABP: 4, post-operative IABP: 8 (16.3%)	N/A	N/A	Preoperative IABP = 38 (77.5%), post-operative IABP: 38 (77.5%)	N/A	N/A	N/A	N/A	
6	Joskowiak et al., 2010	Retrospective cohort	Germany	158	Patients with AMI (NSTEMI and STEMI) who underwent emergency CABG	Preoperative IABP	Intraoperative IABP	Preoperative IABP = 8 (14.03%), postoperative IABP = 28 (27.7%)	Preoperative IABP = 65 ± 11, postoperative IABP = 68 ± 9	Preoperative IABP = 23 (43%), postoperative IABP = 39 (39%)	Preoperative IABP = 49 (86%), postoperative IABP = 91 (31%)	N/A	Preoperative IABP = 23 (40%), post-operative IABP = 23 (23%)	Impaired LV function (EF < 40%), post-operative IABP = 32 (68%), intraoperative IABP = 39 (38%)	Left main stem stenosis > 70%, preoperative IABP = 27 (52%), intraoperative IABP = 37 (37%)	Number of diseased vessels: preoperative IABP = 2.8 ± 0.4, postoperative IABP = 2.8 ± 0.4				
7	Kang et al., 2001	Retrospective cohort	Australia	101	Patients having open heart surgery from January 1998 to October 1999	Group A (preoperative IABP for high-risk nonemergent cases), group B (preoperative IABP for emergent cases), and group C (intra/postoperative IABP); group A (35) + B (21) = 56; group C = 45	Group A + B = 7 + 4 = 11 (19.64%), low risk (63.6), intra/postoperative (64.2)	Group A + B = 7 + 4 = 11 (19.64%), low risk (63.6), intra/postoperative (64.2)	Preoperative IABP = 65 ± 11, postoperative IABP = 68 ± 9	N/A	N/A	Group A + B = 15 (26.79%), group C: 8 (18.6%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
8	Marra et al., 2002	Prospective randomised study	Italy	60	Coronary artery bypass graft (CABG) patients with low left ventricular ejection fraction (LVEF)	Preoperative IABP (just before induction)	Intra-operative IABP	Preoperative IABP = 12 (40%), intraoperative IABP = 11 (36.6%)	Preoperative IABP = 63.8 ± 1.5, intraoperative IABP = 64.1 ± 2.3	Preoperative IABP = 12 (40), intraoperative IABP = 15 (50)	Preoperative IABP = 5 (16.6), intraoperative IABP = 3 (10)	Preoperative IABP = 13 (43.3), intraoperative IABP = 12 (40)	N/A	Preoperative IABP = 30 (100%), intraoperative IABP = 30 (100%)	N/A	N/A	N/A	N/A	N/A	
9	Qiu et al., 2009	Cohort observational	China	221		Preoperative IABP insertion	Post-operative IABP insertion	Early IABP 42 (36.5%), post-operative IABP 32 (30.2%)	N/A	Early IABP 70 (60.9%), post-operative IABP 79 (74.5%)	Early IABP 5 (4.3%), post-operative IABP 3 (2.8%)	Early IABP 35 (30.4%), post-operative IABP 36 (34.0%)	Early IABP 4 (3.5%), post-operative IABP 3 (2.8%)	N/A	Early IABP 20 (17.2%), post-operative IABP 21 (19.8%)	N/A	N/A	N/A		
10	Ramnarine et al., 2005	Retrospective observational	UK	237		(Group B: preoperative IABP in high risk patients, group C: preoperative IABP in stable haemodynamic), post-operative IABP 52	(Group D: intraoperative IABP, group E: postoperative IABP, intraoperative IABP 185	Preoperative IABP = 12 (23.1%), intraoperative IABP = 56 (30.2%)	Preoperative IABP = 67.05, intraoperative IABP = 68.05	Preoperative IABP = 27 (51.92%), intraoperative IABP = 99 (53.51%)	Preoperative IABP = 17 (30.3%), post-operative IABP = 25 (13.51%)	N/A	Preoperative IABP = 10 (19.23%), intraoperative IABP = 69 (14.22%)	Preoperative IABP = 18 (34.61%), intraoperative IABP = 49 (26.48%)	Preoperative IABP = 21 (34.61%), intraoperative IABP = 39 (21.08%)	Preoperative IABP = 33 (34.61%), intraoperative IABP = 143 (77.29%)				

Table 2 – Clinical outcomes

No	Study Group 1	In-hospital mortality		30-day mortality		Major adverse cardiac events (MACE)		Length of hospital stay (d)		Length of ICU stay (d)		Duration of mechanical ventilation (h) (mean ± SD)		Prolonged mechanical ventilation (percentage)		Duration of IABP used (h)		
		Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2		
1	Böning et al., 2012	Overall = 156	119	37	119	37	119	37	N/A	N/A	N/A	N/A	N/A	119	37	N/A	N/A	
		Yes	8 (6.7%)	14 (37.8%)	7 (5.9%)	14 (37.8%)	0 (0%)	3 (8.3%)	N/A	N/A	N/A	N/A	N/A	27 (22.7%)	26 (72.2%)	N/A	N/A	
		No	111 (93.3%)	23 (62.2%)	112 (94.1%)	23 (62.2%)	N/A	34 (91.7%)	N/A	N/A	N/A	N/A	N/A	92 (77.3%)	11 (27.8%)	N/A	N/A	
2	Christenson et al., 2002	Overall = 48151	29788	18363	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		Yes	2803 (9.4%)	4489 (24.4%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		No	26985 (90.6%)	13874 (75.6%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Diez et al., 2008	Overall = 175	62	113	N/A	N/A	62	113	62	113	62	N/A	N/A	62	113	N/A	N/A	
		Yes	14 (22.6%)	31 (27.4%)	N/A	N/A	29 (46.77%)	65 (57.52%)	20 ± 4.06 ^a	6.25 ± 2.04 ^a	N/A	N/A	N/A	21 (33.87%)	51 (45.13%)	N/A	N/A	
		No	48 (77.4%)	82 (72.6%)	N/A	N/A	33 (53.23%)	48 (42.48%)	15 ± 2.62 ^a	9.44 ± 3.69 ^a	N/A	N/A	41 (66.13%)	62 (54.67%)	N/A	N/A		
4	Ding et al., 2015	Overall = 232	116	116	N/A	N/A	116	116	N/A	N/A	116	116	N/A	N/A	N/A	116	116	
		Yes	7 (6.0%)	19 (16.4%)	N/A	N/A	13 (11.2%)	29 (25.0%)	N/A	4.5 ± 1.4	6.1 ± 2.1	50.4 ± 28.8	79.2 ± 40.8	N/A	N/A	91.2 ± 36	124.8 ± 45.6	
		No	109 (94.0%)	97 (83.6%)	N/A	N/A	103 (88.8%)	87 (75.0%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Healy et al., 2006	Overall = 66	17	49	17	49	N/A	N/A	17	49	17	N/A	N/A	N/A	N/A	N/A	N/A	
		Yes	4 (23.5%)	9 (22.5%)	1 (5.8%)	13 (26.5%)	N/A	N/A	21.16 ± 11.9	20.25 ± 22.59	8.29 ± 5	6.9 ± 7.7	N/A	N/A	N/A	N/A	N/A	N/A
		No	13 (76.5%)	40 (77.5%)	16 (94.2%)	36 (73.5%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Jaskowiak et al., 2010	Overall = 158	57	101	N/A	N/A	57	101	57	101	57	57	101	N/A	N/A	57	101	
		Yes	10 (17.6%)	17 (16.8%)	N/A	N/A	14 (25.0%)	29 (30.5%)	13 ± 10	9.3 ± 9.6	6.9 ± 6.9	149 ± 218 (h)	104 ± 132 (h)	N/A	N/A	89 ± 78	49 ± 41	
		No	47 (82.4%)	84 (83.2%)	N/A	N/A	43 (75.0%)	72 (69.5%)	14 ± 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	Kang et al., 2001	Overall = 101	56	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		Yes	12 (21.43%)	10 (22.2%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		No	44 (78.57%)	35 (77.78%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Marra et al., 2002	Overall = 60	30	30	N/A	N/A	N/A	N/A	30	30	30	30	30	N/A	N/A	30	30	
		Yes	2 (6.67%)	7 (23.33%)	N/A	N/A	N/A	N/A	10.2 ± 3.5	12.2 ± 3.2	4.63±3	5.79 ± 2.75	50 ± 76 (h)	59.8 ± 48 (h)	N/A	N/A	49.9 ± 26.7	69 ± 45.2
		No	28 (93.3%)	23 (76.6%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	Qiu et al., 2009	Overall = 221	115	106	N/A	N/A	115	106	N/A	N/A	N/A	N/A	N/A	115	106	115	106	
		Yes	3 (2.6%)	4 (3.8%)	N/A	N/A	12 (10.4%)	20 (18.9%)	N/A	N/A	N/A	N/A	N/A	38 (33.0%)	47 (44.3%)	52.8 ± 16.8	86.4 ± 31.2	
		No	112 (97.4%)	102 (96.2%)	N/A	N/A	103 (89.6%)	86 (81.1%)	N/A	N/A	N/A	N/A	N/A	77 (67.0%)	59 (55.7%)	N/A	N/A	
10	Ramarine et al., 2005	Overall 237	52	185	N/A	N/A	52	185	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		Yes	17 (32.69%)	75 (40.54%)	N/A	N/A	3 (5.77%)	15 (8.10%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		No	35 (67.31%)	110 (59.46%)	N/A	N/A	49 (94.23%)	170 (91.90%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

strengthening the external validity of the mortality signal in current practice.

The biological plausibility of early IABP support is supported by well-established hemodynamic principles. Counterpulsation augments diastolic coronary perfusion and reduces left ventricular afterload, thereby improving myocardial oxygen supply-demand balance.^{5,6} In patients with severely impaired ventricular function, surgical stress and cardiopulmonary bypass may precipitate further myocardial injury and low cardiac output syndrome.²⁴ Early hemodynamic unloading before anesthetic induction may attenuate ischemia-reperfusion injury and reduce subendocardial hypoperfusion. This is particularly relevant in patients with severe left ventricular dysfunction, a population shown in the STICH and STICHES trials to derive long-term survival benefit from surgical revascularization,^{3,25} but who remain at high perioperative risk.

Importantly, the timing of IABP insertion appears to be a critical determinant of outcome. Intraoperative or postoperative IABP deployment often reflects failure to wean from bypass or established hemodynamic collapse,²² a scenario associated with worse prognosis independent of support strategy.²⁶ The IABP-SHOCK II trial demonstrated no mortality benefit of routine IABP use in acute myocardial infarction complicated by cardiogenic shock,²⁷ however, extrapolation of these findings to elective or urgent CABG populations is inappropriate. Cardiogenic shock represents a distinct pathophysiologic entity characterized by systemic inflammatory response and microvascular dysfunction,²⁸ whereas perioperative CABG patients experience controlled ischemia-reperfusion injury under cardioplegic protection. Thus, the absence of benefit in shock trials does not negate potential benefit in prophylactic surgical settings.

Although mortality and MACE outcomes demonstrated consistent benefit, resource-utilization outcomes such as ICU stay and hospital length of stay did not reach statistical significance and were characterized by substantial heterogeneity. Similar variability has been reported in prior surgical meta-analyses of mechanical circulatory support.²⁹ This heterogeneity likely reflects institutional differences in extubation protocols, enhanced recovery pathways, and criteria for IABP weaning rather than absence of clinical effect. Furthermore, improvements in myocardial protection, anesthetic management, and perioperative critical care over the past two decades,^{1,2} may attenuate measurable differences in length-of-stay metrics despite persistent survival benefit.

The predominance of observational studies remains an important limitation and introduces the possibility of confounding by indication. However, consistent directionality of effect across geographically diverse cohorts^{14–23} and the strong pooled reduction in 30-day mortality support the robustness of the findings. Moreover, contemporary revascularization guidelines emphasize individualized risk stratification and multidisciplinary decision-making in complex coronary disease.^{1,30} Within this framework, selective prophylactic IABP use in patients with severe ventricular dysfunction, left main disease, or elevated operative risk scores may represent a rational adjunct to surgical strategy rather than routine application.

In summary, this analysis supports a proactive approach to mechanical circulatory support in carefully selected high-risk CABG patients. Preoperative IABP insertion appears to mitigate perioperative risk and improve early survival, whereas delayed insertion may reflect irreversible hemodynamic deterioration. Future multicenter randomized trials in the era of modern myocardial protection and enhanced recovery protocols are warranted to further refine patient selection and confirm causality.

Conclusion

In high-risk patients undergoing coronary artery bypass grafting, preoperative intra-aortic balloon pump insertion is associated with significantly reduced in-hospital and 30-day mortality, as well as lower incidence of major adverse cardiac events and prolonged mechanical ventilation compared with intraoperative or postoperative deployment. These findings support the concept that early hemodynamic stabilization before surgical stress and cardiopulmonary bypass may mitigate perioperative myocardial injury and improve short-term survival.

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