

Impact of Intraoperative Intra-Aortic Balloon Pump Use on Mortality rate Following Coronary Artery Bypass Grafting

Minoo Momenzadeh ¹, Mohammad Amin Talebpour ¹, Mahdi Kahrom ², Behrooz Mottahedi ^{2 *}

¹ Innovative Medical Research Center, Faculty of Medicine, Mashhad Medical Sciences, Islamic Azad University, Mashhad, Iran.

² Department of Cardiovascular Surgery, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.

ARTICLE INFO

Article type:
Original Article

Article history:
Received: 16 August 2026
Accepted: 14 September 2026

Keywords:
Coronary artery bypass
grafting
Intra-aortic balloon pump
Mortality
Shock

ABSTRACT

Introduction: Use of an intra-aortic balloon pump (IABP) during coronary artery bypass grafting (CABG) identifies a high-risk subgroup with substantial perioperative mortality. Determinants of outcome in this setting remain incompletely defined, particularly regarding hemodynamic severity and intraoperative timing of IABP insertion relative to cardiopulmonary bypass (CPB). We aimed to identify independent predictors of in-hospital mortality among CABG patients requiring IABP support and to evaluate whether the intraoperative interval between CPB separation and IABP insertion influences outcome.

Methods: A retrospective analysis of CABG patients supported with IABP was performed. 113 patients who underwent on-pump CABG with IABP between March 2020 and March 2025 were included. Baseline characteristics, operative variables—including CPB time and precise intraoperative IABP timing—and postoperative outcomes were recorded. Multivariate logistic regression was used to identify independent predictors of mortality.

Results: In-hospital mortality was high and consistent with previously reported surgical IABP cohorts. Lower preoperative ejection fraction, prolonged CPB duration, and higher inotrope requirement independently predicted mortality, indicating that outcome was primarily driven by myocardial dysfunction, bypass-related stress, and persistent hemodynamic instability. Sex was associated with mortality but was not a primary determinant of risk. The interval between CPB weaning and IABP initiation did not show statistical significance; however, interpretation was limited by substantial missing data and restricted variability in recorded timings.

Conclusion: Among CABG patients requiring IABP, early mortality is determined mainly by the severity of ventricular dysfunction, operative complexity, and residual circulatory failure rather than by IABP use itself. Although the intraoperative timing of IABP relative to CPB separation was not statistically significant in this study, methodological limitations prevent ruling out a clinically significant effect. Prospective studies with precise, complete intraoperative timing data are needed to define optimal timing and refine risk stratification.

► Momenzadeh, M., Talebpour, M.A., Kahrom, M., Mottahedi, B. Impact of Intraoperative Intra-Aortic Balloon Pump Use on Mortality rate Following Coronary Artery Bypass Grafting. *J Cardiothorac Med.* 2026; 14(3): 1734-1741. Doi : 10.22038/jctm.2026.98189.1537

* Corresponding authors: Behrooz Mottahedi, Ghaem Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran. Tel: +98513-8012806, Fax: +98-513-8402972 ; E-mail: motahedib@mums.ac.ir

© 2016 mums.ac.ir All rights reserved.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Introduction

Coronary artery disease (CAD), caused by atherosclerotic plaque formation, is a leading cause of mortality globally and in Iran (1, 2). With the increasing prevalence of CAD in developing countries, including Iran, the World Health Organization (WHO) has prioritized the prevention and treatment of cardiovascular diseases in global health programs (3).

Clinical manifestations of CAD include chest pain, dyspnea, palpitations, irregular heart rhythm, weakness or dizziness, nausea, and diaphoresis (4). Several risk factors are well-established contributors to its pathogenesis, including hypertension, cigarette smoking, hyperlipidemia, diabetes mellitus, and obesity (5).

Various therapeutic strategies are used in the management of CAD, including pharmacological therapy, percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG) (6). Numerous studies have reported encouraging survival outcomes in CAD patients undergoing surgical treatment (7, 8). High-risk patients with CAD who are candidates for CABG frequently present with left ventricular (LV) dysfunction (9). Severe LV dysfunction (ejection fraction $\leq 35\%$) has been identified as a predictor of low cardiac output syndrome and increased mortality following CABG (10).

Despite therapeutic advances, managing severe LV dysfunction during cardiac surgery remains challenging, necessitating mechanical circulatory support devices (11). One such mechanical support device is the intra-aortic balloon pump (IABP), which has been shown to be clinically beneficial in patients with moderate to severe reductions in ejection fraction following CABG (12). According to a survey of cardiothoracic surgeons in New York, the use of IABP after CABG is favored in practice over other mechanical support strategies such as Impella and extracorporeal membrane oxygenation (ECMO) (13,14).

Typically inserted via the femoral artery, the IABP improves hemodynamics by increasing coronary perfusion and reducing afterload through synchronous diastolic inflation and systolic deflation. Its affordability and ease of use make it a widely

utilized post-surgical support device. Although complications such as limb ischemia, bleeding, and emboli can occur, direct IABP-related mortality is extremely low ($\sim 0.05\%$) (15).

In recent years, numerous studies have investigated the effectiveness of IABP in patients undergoing angiography and/or PCI, as well as the impact of preoperative or intraoperative IABP use in CABG surgery. However, there remains limited evidence regarding the effectiveness of IABP with respect to the postoperative timing of its insertion following CABG in improving survival among patients with CAD. Therefore, the aim of the present study is to identify predictors of mortality in CAD patients with cardiogenic shock who receive IABP following CABG.

Methods

Study Design and Setting

This retrospective study was conducted to evaluate the impact of IABP support on postoperative mortality among patients undergoing CABG. The study was performed at Ghaem Hospital, a tertiary referral teaching hospital affiliated with Mashhad University of Medical Sciences, Mashhad, Iran. 113 Patients who underwent CABG with IABP between March 2020 and March 2025 were included.

Participants

All adult patients with coronary artery disease who underwent isolated on-pump CABG and required IABP support during or after surgery at Ghaem Hospital during the study period were considered eligible for inclusion. Only patients aged 18 years or older were included in the study. Patients were excluded if they had contraindications to IABP insertion, were in the acute phase of intracranial hemorrhage, underwent cardiac surgical procedures other than isolated CABG, or had received any form of mechanical circulatory support prior to surgery.

Data Collection and Variables

Clinical and demographic data were retrospectively extracted from hospital medical records using a standardized data collection form. Collected variables included

age, sex, body mass index (BMI), and medical history of diabetes mellitus (DM), hypertension (HTN), smoking, and history of myocardial infarction. Preoperative cardiac variables included left ventricular ejection fraction (LVEF).

Operative variables included surgical priority (elective vs. emergency surgery), cardiopulmonary bypass (CPB) time, surgery duration, interval from CPB discontinuation to IABP insertion, types of inotropes (dobutamine, epinephrine, norepinephrine) with their doses, and in-hospital 30-day mortality.

Surgical Procedure and Myocardial Protection

All patients underwent CABG using standard surgical techniques, which included on-pump arrest, and on-pump beating. In cases utilizing cardioplegic on-pump arrest myocardial protection was achieved through intermittent antegrade administration of cardioplegia solution every 20 minutes during cardiopulmonary bypass.

Indications for IABP Support

IABP support was used in the following clinical situations: failure to wean from cardiopulmonary bypass despite maximal inotropic support; low cardiac output syndrome following difficult separation from CPB requiring high-dose inotropic agents; occurrence of significant ventricular arrhythmias (premature ventricular contractions or ventricular tachycardia) unresponsive to continuous antiarrhythmic therapy during separation from CPB; and postcardiotomy low cardiac output syndrome. Prophylactic use of IABP was not routinely performed.

IABP Insertion and Management

The intra-aortic balloon pump was inserted percutaneously via the common femoral artery using a Datascope IABP system (Datascope Corp., Paramus, NJ, USA). Correct positioning of the device was routinely confirmed by chest radiography in the intensive care unit (ICU). When mediastinal drainage decreased to less than 50 mL/h, anticoagulation therapy with intravenous heparin infusion was initiated to maintain an activated clotting time (ACT) between 180

and 200 seconds. First-generation cephalosporins were routinely administered as prophylactic antibiotics during the period of IABP support.

Outcome Measures

The primary outcome of the study was postoperative mortality. Operative mortality was defined as death occurring within 30 days after surgery or during the same hospitalization.

Due to the retrospective nature of the study and a high rate of missing the time interval from CPB discontinuation to IABP insertion in the medical records, analyzing the exact timing as a continuous variable was not feasible. Due to the profound significance of this concept in our current study, our team has investigated it further in a separate manuscript that is currently pending publication. To evaluate the impact of treatment strategy, 248 patients (admitted between April 2016 and October 2024) were dichotomized into two qualitative groups based on their primary clinical approach: (1) early IABP insertion, and (2) preference for higher doses of inotropic agents.

Ethical Considerations

The study protocol was approved by the Ethics Committee of Mashhad Medical Science Islamic Azad University. All patient information was handled confidentially and analyzed anonymously in accordance with institutional and ethical guidelines. Ethics Code: IR.IAU.MSHD.REC.1403.031.

Statistical Analysis

Statistical analyses were performed using SPSS v20. Continuous variables were expressed as mean $\pm$ SD or median (IQR) based on Shapiro-Wilk normality testing and compared using independent t-tests or Mann-Whitney U tests, respectively. Categorical variables were reported as frequencies (%) and compared via Chi-square. Variables demonstrating clinical relevance or $P < 0.20$ in univariate analysis were evaluated using univariate logistic regression. Finally, the four most clinically relevant variables were included in a multivariable logistic regression model to identify independent predictors of mortality. Statistical significance was set at $P < 0.05$.

Results

A total of 113 patients were included in the study, of whom 46 (40.7%) died and 67 (59.3%) survived.

The mean age of the patients was 63.7 ± 10.5 years, with no significant difference between the deceased and alive groups (66.1 ± 9.2 vs. 62.1 ± 11.2 years, $P=0.17$). Overall, 71 patients were male and 42 were female. Death occurred in 23 of 42 females (54.8%) and 23 of 71 males (32.4%), demonstrating a significant association between sex and mortality ($P=0.02$). The median BMI was 25.60 (6.93), with no significant difference between groups [25.78 (7.7) vs. 25.49 (7), $P=0.11$] (Table 1).

Among clinical risk factors, prior myocardial infarction ($n=76$), smoking ($n=38$), hypertension ($n=85$), and diabetes mellitus ($n=48$) were not significantly associated with mortality (all $P>0.05$). Preoperative ejection fraction (EF) was

significantly associated with mortality ($P=0.005$), with mortality rates of 57.1% in patients with EF 10–30%, 27.5% in those with EF 30–50%, and 25.0% in those with EF 50–70%. Emergency surgery was performed in 68 patients and showed no significant association with mortality ($P=0.75$) (Table 1).

The median CABG duration was 240 (50) minutes and did not differ significantly between groups [245 (75) vs. 235 (55), $P=0.18$]. In contrast, CPB time was significantly longer in the deceased group [81 (68) vs. 66.5 (30), $P=0.001$]. The interval to IABP insertion did not differ significantly between groups [9.5 (16) vs. 6 (12), $P=0.71$] (Table 1).

Regarding inotropic support, patients who died received higher median doses of dobutamine [100 (50) vs. 50 (50), $P=0.03$] and a greater number of epinephrine ampoules [5 (9) vs. 2 (3), $P=0.001$], whereas norepinephrine use was not significantly different ($P=0.22$) (Table 1).

Table 1. Baseline clinical and intraoperative characteristics of the patients.

	Total (n=113)	Deceased (n=46)	Alive (n=67)	P-value
Demographic variables				
Age (years)	63.7 ± 10.5	66.1 ± 9.2	62.1 ± 11.2	0.17
Male, n(%)	71(62.8%)	23(50.0%)	48(71.6%)	0.02*
BMI(Kg/m ²), Median (IQR)	25.6(6.9)	25.8(7.7)	25.5(7.0)	0.11
Clinical risk factors				
History of MI, n(%)	76(67.3%)	31(67.4%)	45(67.2%)	0.97
Smoking, n(%)	38(33.6%)	14(30.4%)	24(35.8%)	0.67
Hypertension, n(%)	85(75.2%)	36(78.3%)	49(73.1%)	0.69
Diabetes mellitus, n(%)	48(42.5%)	19(41.3%)	29(43.3%)	0.99
Preoperative EF(%)				
10-30	49(43.4%)	28(60.9%)	21(31.3%)	0.005*
30-50	51(45.1%)	14(30.4%)	37(55.2%)	
50-70	12(10.6%)	3(6.5%)	9(13.4%)	
Emergency Surgery, n(%)	68(60.2%)	29(63.0%)	39(58.2%)	0.75
Operative variables				
CABG duration(min), Median (IQR)	240(50)	245(75)	235(55)	0.18
CPB Time(min), Median (IQR)	69.5(39.7)	81.0(68.0)	66.5(30)	0.001*
Interval to IABP(min), Median (IQR)	6.5(13)	9.5(16)	6.0(12)	0.71
Inotropes				
Inotrope Types				0.28
One Type	17(15.0%)	4(8.7%)	13(19.4%)	
Two Types	34(30.1%)	14(30.4%)	20(29.9%)	
Three Types	59(52.2%)	26(56.5%)	33(49.3%)	
Dobutamine(mg), Median (IQR)	50(50)	100(50)	50(50)	0.03*
Epinephrine(n), Median (IQR)	2(5)	5(9)	2(3)	0.001*
Norepinephrine(n), Median (IQR)	1(1)	1(1)	1(1)	0.22

Note. * Statistically significant

Abbreviations: BMI: Body mass index, EF: Ejection fraction, CABG: Coronary Artery Bypass Grafting, CPB: Cardiopulmonary Bypass, IABP: Intraoperative Balloon Pump, OR: Odd ratio, CI: Confidence Interval.

In univariate logistic regression analysis, sex (OR=2.526, 95% CI: 1.152–5.539, P=0.021), BMI (OR=1.083, 95% CI: 1.001–1.172, P=0.048), preoperative EF (OR=0.951, 95% CI: 0.919–0.985, P=0.005), CPB time (OR=1.022, 95% CI: 1.009–1.035, P=0.001), and epinephrine use (OR=1.161, 95% CI: 1.059–1.273, P=0.001) were significantly associated with mortality, while age, CABG duration, dobutamine dose, and interval to IABP insertion were not (Table 2).

Multivariate logistic regression identified sex (OR=3.605, 95% CI: 1.413–9.198, P=0.007), preoperative EF (OR=0.950, 95% CI: 0.914–0.987, P=0.009), CPB time (OR=1.016, 95% CI: 1.000–1.032, P=0.045), and the number of epinephrine ampoules administered (OR=1.139, 95% CI: 1.021–1.270, P=0.020) as independent predictors of in-hospital mortality (Table 3).

Table 2. Univariate regression analysis for clinical, and intraoperative variables.

Variable	OR	CI 95%	P-value
Age	1.038	1.000-1.079	0.053
Sex (Female)	2.526	1.152-5.539	0.021*
BMI	1.083	1.001-1.172	0.048*
Preoperative EF (%)	0.951	0.919-0.985	0.005*
CABG duration (min)	1.006	1.000-1.011	0.062
CPB Time (min)	1.022	1.009-1.035	0.001*
Interval to IABP (min)	1.025	0.953-1.103	0.508
Dobutamine (mg)	1.005	0.999-1.011	0.083
Epinephrine (n)	1.161	1.059-1.273	0.001*

Note. * Statistically significant

Abbreviations: BMI: Body mass index, EF: Ejection fraction, CABG: Coronary Artery Bypass Grafting, CPB: Cardiopulmonary Bypass, IABP: Intraoperative Balloon Pump, OR: Odd ratio, CI: Confidence Interval.

Table 3. Multivariate regression analysis for clinical, and intraoperative variables.

Variable	OR	CI 95%	P-value
Sex (Female)	3.605	1.413-9.198	0.007*
Preoperative EF (%)	0.950	0.914-0.987	0.009*
CPB Time (min)	1.016	1.000-1.032	0.045*
Epinephrine (n)	1.139	1.021-1.270	0.020*

Note. * Statistically significant

Abbreviations: EF: Ejection fraction, CPB: Cardiopulmonary Bypass, OR: Odd ratio, CI: Confidence Interval.

Discussion

This study identified key determinants of in-hospital mortality among CABG patients requiring IABP support. Reduced preoperative ejection fraction, prolonged CPB duration, and higher epinephrine requirement independently predicted mortality, underscoring that the outcome in this population is primarily driven by the severity of perioperative myocardial dysfunction and hemodynamic compromise rather than the use of IABP per se.

The mortality rate in our study (40.7%) is in line with previous reports in high-risk CABG populations requiring IABP. Mottahedi et al. reported 41.7% mortality (16), and Muhammad Aasim et al. observed 38.2% mortality (17). Ahmad et al. described mortality of 35.7% in the IABP subgroup (18).

These figures are higher than those reported in elective low-EF prophylactic IABP cohorts, such as Kraleev et al. (19), and lower than critically ill non-surgical or mixed PCI/angiography populations, such as Bochenek et al. (20). Thus, IABP use during CABG identifies a very high-risk subgroup with substantial perioperative mortality.

Left ventricular dysfunction consistently emerges as a central theme. Lower preoperative ejection fraction was independently associated with mortality, concordant with Sohail et al., Bochenek et al., Mottahedi et al., and Aasim et al. (16, 17, 20, 21). Ahmad et al. and Gao et al. showed that reduced LVEF strongly predicts perioperative IABP insertion (18, 22). Gao et al. demonstrated that LVEF <50% was independently associated with IABP use across all age and sex strata, and combining

LVEF with other clinical and biochemical markers improved prediction performance compared with LVEF alone (22). Therefore, impaired ventricular reserve drives the need for mechanical support and strongly influences prognosis.

Operative complexity and bypass-related injury were also important. Prolonged CPB time independently predicted mortality, in agreement with Mottahedi et al. (16). Extended CPB reflects more complex surgery and contributes to greater myocardial ischemia-reperfusion and inflammatory stress, predisposing to refractory low cardiac output despite IABP support.

The independent association between mortality and epinephrine requirement highlights the prognostic importance of persistent circulatory failure. Expressing inotropic burden as the epinephrine ampoules used emphasizes that, beyond the presence of IABP, the intensity of pharmacologic support required to maintain perfusion is a powerful marker of risk. Although most previous CABG/IABP studies did not quantify inotropic exposure in detail, lower vasoactive-inotropic requirements in prophylactic IABP series such as Krlev et al. are consistent with the concept that catecholamine dependence reflects more advanced hemodynamic derangement (19). Studies indicate that the use of high doses, specifically epinephrine, in patients with cardiogenic shock is associated with a significant increase in 30-day mortality (23). Therefore, clinical guidelines emphasize that these medications should be administered at the lowest effective dose for the shortest possible duration solely to maintain vital organ perfusion.

Regarding sex, mortality was higher among women; however, most IABP cases were male, mirroring the male predominance in IABP cohorts reported by Ahmad et al., Aasim et al., and Gao et al. (17, 18, 22). Gao et al. found that IABP application rates were similar between men and women, with LVEF remaining the dominant predictor (22).

The timing of IABP insertion deserves special consideration. Previous studies generally reported better outcomes with preoperative insertion. For example, Lavana et al., Pieri et al., and other series have demonstrated higher mortality with later

IABP deployment (10, 24), and Aasim et al. observed high mortality associated with intraoperative insertion (17). While the exact minute-by-minute interval between CPB weaning and IABP initiation did not reach statistical significance in our dataset due to missing data, shifting to a categorical approach in our other study yet to be published with 248 patients demonstrated that an early IABP insertion strategy yielded significantly better recovery rates than relying on higher inotrope doses ($P=0.04$). This highlights the survival benefit of earlier mechanical support. Further prospective work with complete timing documentation is warranted.

Finally, traditional comorbidities (diabetes, hypertension, and prior MI) were not independent mortality predictors, broadly consistent with Mottahedi et al. (16). In contrast, Ahmad et al. and Gao et al. showed these comorbidities are associated with IABP insertion (18, 22). Thus, chronic risk factors may identify patients needing IABP, but once mechanical support is needed, short-term survival is predominantly driven by acute physiological variables—ventricular function, CPB duration, and inotropic burden. Taken together, IABP in CABG marks advanced perioperative risk. Mortality is largely determined by the underlying severity of myocardial dysfunction and operative injury, while the impact of very early intraoperative IABP deployment relative to CPB remains an important clinical question.

Limitation

This retrospective, single-center study has several limitations, including unmeasured confounding and limited generalizability. The modest sample size of IABP patients reduces statistical power for subgroup analyses. Crucially, missing data and limited variability regarding the precise timing of IABP initiation relative to CPB restricted our analysis to qualitative categories rather than continuous variables; thus, the lack of a significant timing effect may represent a type II error. Finally, only early, in-hospital outcomes were evaluated. Future prospective, multicenter studies with standardized intraoperative recording and long-term follow-up are required.

Conclusion

In CABG patients requiring IABP, in-hospital mortality is primarily driven by myocardial dysfunction and operative complexity. Reduced preoperative ejection fraction, prolonged CPB time, and increased epinephrine requirements independently predicted death. Although IABP timing relative to CPB weaning was not statistically significant—largely due to data limitations—these patients represent a high-risk cohort. Our findings emphasize optimizing myocardial protection, minimizing CPB duration, and considering early hemodynamic support, while highlighting the need for rigorous prospective trials to determine optimal IABP timing and patient selection.

Funding

The authors have no financial interests related to the material in this manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

1. Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, et al. Heart disease and stroke statistics—2020 update: a report from the American Heart Association. *Circulation*. 2020 Mar 3;141(9):e139-596.
2. Hatmi ZN, Tahvildari S, Gafarzadeh Motlag A, Sabouri Kashani A. Prevalence of coronary artery disease risk factors in Iran: a population based survey. *BMC cardiovascular disorders*. 2007 Oct 30;7(1):32.
3. Sarrafzadegan N, Mohammadifard N. Cardiovascular disease in Iran in the last 40 years: prevalence, mortality, morbidity, challenges and strategies for cardiovascular prevention. *Archives of Iranian medicine*. 2019;22(4):204-10.
4. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *circulation*. 2019 Sep 10;140(11):e596-646.
5. Zeinali-Nezhad N, Najafipour H, Shadkam M, Pourhamidi R. Prevalence and trend of multiple coronary artery disease risk factors and their 5-year incidence rate among adult population of Kerman: results from KERCADR study. *BMC public health*. 2024 Jan 2;24(1):25.
6. Bergmark BA, Mathenge N, Merlini PA, Lawrence-Wright MB, Giugliano RP. Acute coronary syndromes. *The Lancet*. 2022 Apr 2;399(10332):1347-58.
7. Velazquez EJ, Lee KL, Deja MA, Jain A, Sopko G, Marchenko A, et al. Coronary-artery bypass surgery in patients with left ventricular dysfunction. *New England Journal of Medicine*. 2011 Apr 28;364(17):1607-16.
8. Authors/Task Force members, Kolh P, Windecker S, Alfonso F, Collet JP, Cremer J, et al. 2014 ESC/EACTS guidelines on myocardial revascularization: the Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). *European journal of cardio-thoracic surgery*. 2014 Oct 1;46(4):517-92.
9. Sun LY, Gaudino M, Chen RJ, Bader Eddeen A, Ruel M. Long-term outcomes in patients with severely reduced left ventricular ejection fraction undergoing percutaneous coronary intervention vs coronary artery bypass grafting. *JAMA cardiology*. 2020 Jun;5(6):631-41.
10. Pieri M, Belletti A, Monaco F, Pisano A, Musu M, Dalessandro V, et al. Outcome of cardiac surgery in patients with low preoperative ejection fraction. *BMC anesthesiology*. 2016 Oct 18;16(1):97.
11. Werdan K, Gielen S, Ebelt H, Hochman JS. Mechanical circulatory support in cardiogenic shock. *European heart journal*. 2014 Jan 14;35(3):156-67.
12. Nakamura K, Hamasaki A, Uchida T, Kobayashi K, Sho R, Kim C, et al. The use of prophylactic intra-aortic balloon pump in high-risk patients undergoing coronary artery bypass grafting. *PLoS One*. 2019 Oct 28;14(10):e0224273.
13. Del Carmen GA, Axtell A, Chang D, Melnitchouk S, Sundt III TM, Fiedler AG. Intra-aortic balloon pump placement in coronary artery bypass grafting patients by day of admission. *Journal of Cardiothoracic Surgery*. 2020 Aug 14;15(1):219.
14. Smilowitz NR, Galloway AC, Ohman EM, Rao SV, Bangalore S, Katz SD, et al. Coronary revascularization and circulatory support strategies in patients with myocardial infarction, multi-vessel coronary artery disease, and cardiogenic shock: Insights from an international survey. *American heart journal*. 2020 Jul 1;225:55-9.
15. Nwaejike N, Daneshmand MA. Intra-aortic Balloon Pump. In *Cardiac Surgery: A Complete Guide* 2020 Feb 12 (pp. 613-621). Cham: Springer International Publishing.

16. Mottahedi B, Esfehanizadeh J, Alizadeh K, Shaye ZA. The Evaluation of Survival in Patients Who Need Intra-Aortic Balloon Pump (IABP) after Cardiac Surgery. *J Cardiothorac Med*. 2014 Jan 1;2(4):227-30.
17. Aasim M, Mohsin A, Khan R, Aziz R, Mankani MH, Ali A, et al. Use of Intra-aortic balloon pump in Ischemic Heart Disease Patients with Impaired Left Ventricle: 7 Years' Experience in MTI-HMC, Peshawar, Pakistan. *World Journal of Advanced Research and Reviews*, 2025, 28(2), 1053-1060.
18. Ahmad I, Islam MU, Rehman MU, Khan B. Frequency of intra-aortic balloon pump insertion and associated factors in coronary artery bypass grafting in a tertiary care hospital. *Pakistan Journal of Medical Sciences*. 2021 Mar;37(2):393.
19. KraleV A, Kalisnik JM, Bauer A, Sirch J, Fittkau M, Fischlein T. Impact of prophylactic intra-aortic balloon pump on early outcomes in patients with severe left ventricular dysfunction undergoing elective coronary artery bypass grafting with cardiopulmonary bypass. *International Journal of Cardiology*. 2023 Aug 15;385:8-15.
20. Bochenek T, Sowula P, Rodak M, Rybicka-Musialik A, Gruchlik B, Mizia-Stec K. Retrospective Analysis of Intra-Aortic Balloon Pump Use in Cardiology Ward Patients Undergoing Coronary Angiography between 2012 and 2020. *Journal of Clinical Medicine*. 2023 Feb 16;12(4):1567.
21. Sohail AA, Samejo A, Bajwa H, Wahab R, Asif N, Inam H, et al. Effect of peri-operative intra-aortic balloon pump in patients undergoing coronary artery bypass grafting on outcomes in a resource limited setting. *Perfusion*. 2024 Oct;39(7):1396-404.
22. Gao J, Zhao Q, Cheng Y. Age-and sex-related differences in risk factors for perioperative intra-aortic balloon pump application in patients undergoing coronary artery bypass grafting. *Frontiers in Surgery*. 2024 Sep 3;11:1395518..
23. Tarvasmäki T, Lassus J, Varpula M, Sionis A, Sund R, Køber L, et al. Current real-life use of vasopressors and inotropes in cardiogenic shock-adrenaline use is associated with excess organ injury and mortality. *Critical care*. 2016 Jul 4;20(1):208.
24. Lavana JD, Fraser JF, Smith SE, Drake L, Tesar P, Mullany DV. Influence of timing of intraaortic balloon placement in cardiac surgical patients. *The Journal of thoracic and cardiovascular surgery*. 2010 Jul 1;140(1):80-5.