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*Original Article*

# Preoperative intra-aortic balloon pump use and clinical outcomes in patients undergoing surgery for mitral regurgitation

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**Abstract:** Background: Mitral regurgitation (MR) requiring surgical correction poses significant perioperative challenges, particularly in hemodynamically compromised patients. Evidence supporting preoperative intra-aortic balloon pump (IABP) use in this setting remains scarce. This study evaluated the association between preoperative IABP use and clinical outcomes in patients undergoing surgical MR correction. Methods: We conducted a retrospective cohort study utilizing the Nationwide Readmissions Database (NRD) from 2016 through 2020. Adult patients undergoing surgical mitral valve repair or replacement were identified using validated ICD-10-CM and ICD-10-PCS codes. Patients who received preoperative IABP were compared with those who did not through 1:1 propensity score matching, accounting for baseline clinical characteristics and illness severity. The primary outcome was major adverse cardiac and cerebrovascular events (MACCE). Secondary outcomes included in-hospital mortality, perioperative complications, 30-day readmissions, and length of stay. Results: Among 33,644 hospitalizations for surgical MR correction, 1,691 (5.0%) involved preoperative IABP use. Following propensity score matching, 964 pairs were analyzed. Preoperative IABP use was associated with significantly lower rates of MACCE (16.8% vs. 19.6%, P = 0.045), in-hospital mortality (4.7% vs. 6.5%, P = 0.028), ischemic stroke (1.5% vs. 2.3%, P = 0.040), and prolonged mechanical ventilation (7.9% vs. 10.2%, P = 0.014). Thirty-day readmission rates and length of stay were also lower among IABP recipients. Conclusions: Preoperative IABP use was associated with modestly improved in-hospital outcomes and lower short-term readmissions, with the most pronounced benefits among high-acuity patients. These hypothesis-generating findings support a selective, severity-guided role for preoperative IABP, warranting prospective validation.

**Keywords:** Mitral Regurgitation, intra-aortic balloon pump, in-hospital outcomes, mechanical circulatory support

## Introduction

Mitral regurgitation (MR) represents one of the most prevalent forms of valvular heart disease, affecting approximately 1.7% of the general United States population, with prevalence rising substantially with advancing age and approaching 10% among individuals older than 75 years [1]. Acute MR is characterized by the abrupt loss of mitral valve competence, resulting in pathological retrograde flow from the left ventricle (LV) into the left atrium (LA) during systole [2]. When left untreated, severe MR portends a poor clinical prognosis, significantly impaired quality of life, and substantially elevated risks of morbidity and mortality, irrespective of the underlying etiology or lesion type [3]. Given the potentially life-threatening nature of severe MR, the American College of Cardiology/American Heart Association (ACC/AHA) guidelines emphasize prompt diagnosis and timely intervention to mitigate adverse clinical outcomes [4]. Despite considerable advances in diagnostic modalities and hemodynamic support strategies, the optimal management of acute MR remains a subject of ongoing clinical debate, with current guidelines emphasizing prompt surgical intervention alongside phar-

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macological afterload reduction as the cornerstones of therapy [5]; however, the role and timing of mechanical circulatory support, particularly IABP use, are not well defined. The IABP, a mechanical circulatory support device, is often employed in critically ill cardiac patients as a bridge to definitive surgical treatment. Although randomized trials such as IABP-SHOCK II demonstrated no mortality benefit for routine IABP use in cardiogenic shock complicating acute myocardial infarction, the device continues to serve as a temporary stabilization strategy in valvular shock and as perioperative support for high-risk cardiac surgery [6]. While the evidence base for IABP use in valvular heart disease remains limited, prior surgical data in high-risk patients undergoing aortic valve replacement have demonstrated improved perioperative outcomes with prophylactic IABP support, an observation that raises the possibility of a broader hemodynamic stabilization role for this device in the context of structurally mediated valvular disease [7]. Evidence specific to MR is also emerging; a recent series of critically ill patients presenting with acute severe MR and hemodynamic collapse demonstrated that the use of temporary percutaneous mechanical circulatory support as a bridge to definitive intervention was not only feasible but was associated with favorable short-term survival outcomes [8]. Evidence specifically supporting preoperative IABP use in the surgical MR population, however, remains limited. The present study sought to evaluate the association between preoperative IABP utilization and clinical outcomes in patients undergoing surgical correction for MR, with the ultimate goal of informing future clinical practice and contributing to evidence-based guideline development in this understudied population.

## Methods

### *Study design and population*

We conducted a retrospective observational cohort study utilizing the Nationwide Readmissions Database (NRD) from 2016 through 2020, a large nationally representative administrative database maintained by the Healthcare Cost and Utilization Project (HCUP) under the Agency for Healthcare Research and Quality (AHRQ). The NRD captures de-identified inpatient discharge records from participating U.S. hospitals and enables longitudinal linkage of hospitalizations within a given state during a calendar year through the use of unique patient identifiers (Supplementary Table 1). As this study relied exclusively on de-identified, publicly available administrative data, institutional review board approval was not required [9].

Inclusion criteria were as follows: adult patients (≥18 years) admitted with a diagnosis of mitral regurgitation, identified using validated International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) diagnosis codes (Supplementary Table 2), who underwent surgical mitral valve repair or replacement during the index hospitalization, identified using ICD-10 Procedure Coding System (ICD-10-PCS) codes. The requirement for surgical correction during the same admission was used as a proxy for clinically significant, hemodynamically relevant disease, ensuring that MR represented the primary indication for surgery rather than an incidental finding. Only the first hospitalization per patient per calendar year was included in the analysis.

Exclusion criteria included patients younger than 18 years and hospitalizations with missing data on age, sex, in-hospital mortality, or length of stay. For readmission analyses, patients who died during the index hospitalization were excluded to minimize survival bias, and December discharges were excluded to allow adequate follow-up. To ensure sufficient follow-up for readmission analyses, we included discharges within the first 11 months of the year for 30-day readmissions, the first 9 months for 90-day readmissions, and the first 6 months for 180-day readmissions. Patient demographics, hospital characteristics, comorbidities (defined using the Elixhauser Comorbidity Software), and procedural variables were extracted. Hospitals were categorized by bed size and teaching status using NRD definitions.

### *Outcomes*

The primary endpoint was major adverse cardiac and cerebrovascular events (MACCE), defined as a composite of in-hospital mortality, ischemic stroke, and acute myocardial infarction (MI). Secondary endpoints included in-hospital mortality and perioperative complications, including sudden cardiac arrest (SCA), ischemic stroke, pericardial complications, major bleeding, venous thromboembolism (VTE), pulmonary embolism (PE), acute MI, acute kidney injury (AKI), and prolonged mechanical ventilation (>96 hours). All-cause readmissions were evaluated at 30, 90, and 180 days after discharge using NRD patient linkage numbers; analyses were restricted to patients discharged alive, with only the first readmission event considered for each interval. All primary and secondary outcomes were identified using validated ICD-10-CM diagnosis and ICD-10-PCS procedure codes from the NRD database (Supplementary Tables 3, 4).

*Statistical analysis*

Baseline characteristics were summarized using descriptive statistics. Categorical variables were reported as frequencies and percentages and compared using Pearson's chi-square test. Continuous variables were expressed as means ± standard deviation for normally distributed data or medians with interquartile range [Q1, Q3] for non-normally distributed data, and compared using Student's t-test or the Wilcoxon rank-sum test, as appropriate. Distributions of continuous variables were examined visually using histograms, and patterns of missing data were assessed using Little's missing completely at random (MCAR) test [10]. A $p$-value >0.05 indicated data missing completely at random, whereas a $p$-value <0.05 suggested data missing not at random (MNAR). Given the small proportion of missing values and their random nature, observations with missing data were excluded from analyses through listwise deletion.

To identify independent predictors of in-hospital outcomes, survey-weighted multivariable mixed-effects logistic regression models were constructed, accounting for the complex sampling design of the NRD including discharge weights, strata, and clustering. Covariates were selected based on clinical relevance, prior literature, and univariable associations (Supplementary Table 5). Baseline disease severity, as captured by the All Patient Refined Diagnosis-Related Group (APR-DRG) severity of illness subclass, and the presence of cardiogenic shock were incorporated as covariates to account for differences in baseline acuity and to mitigate confounding by indication. Multicollinearity among model covariates was assessed using variance inflation factors (VIF) and tolerance statistics; no evidence of problematic collinearity was identified, with all VIF values remaining below 5. Results are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs), with statistical significance defined as a two-sided $p$-value of less than 0.05. To further examine whether the association between preoperative IABP use and outcomes varied according to baseline illness severity, stratified multivariable logistic regression analyses were performed across APR-DRG severity categories; mild, moderate, major, and extreme.

To further validate our findings, propensity score matching (PSM) was performed using Mahalanobis distance matching with a caliper of 0.2 of the standard deviation of the logit of the propensity score. Matching variables included baseline demographics, comorbidities, baseline disease severity as measured by APR-DRG, and cardiogenic shock (Supplementary Table 6). Cardiogenic shock was identified using ICD-10-CM code R57.0. Covariate balance after matching was assessed using standardized mean differences, with values <0.1 indicating adequate balance [11] (Supplementary Figure 1). Propensity score matching was similarly applied to evaluate 30-, 90-, and 180-day readmission outcomes, restricting analyses to patients who survived the index hospitalization to minimize survival bias. All statistical analyses were performed using Stata version 18.0 (StataCorp LLC, College Station, TX), incorporating survey design elements, including discharge weights, stratification, and clustering, in accordance with HCUP guidelines. Matching quality was assessed using graphical methods, including box plots (Supplementary Figure 1). The central illustration was created using BioRender.

## Results

A total of 33,644 hospitalizations for surgical repair of MR were identified, of which 1,691 (5.0%) involved preoperative IABP use and 31,953 (95.0%) did not. After 1:1 propensity score matching, 964 pairs were analyzed (**Table 1A**, **1B**). In the matched cohort, the median age was similar between groups (68 years [IQR 15] in the no-IABP group vs. 68 years [IQR 16] in the IABP group), and the proportion of male patients was nearly identical

**Table 1A.** Baseline characteristics in the propensity score-matched cohort by preoperative IABP use

| Baseline Characteristics | No IABP N = 964 N (%) | IABP N = 964 N (%) | SMD |
|---|---|---|---|
| Age (Median + IQR) | 68 (15) | 68 (16) | 0.010 |
| Indicator of Sex | | | |
| Male | 616 (63.9) | 609 (63.2) | 0.022 |
| Female | 348 (36.1) | 355 (36.8) | |
| Insurance Type | | | |
| Medicare | 597 (61.9) | 583 (60.5) | 0.005 |
| Medicaid | 67 (7.0) | 94 (9.8) | |
| Private insurance | 260 (27.0) | 242 (25.1) | |
| Self-pay | 23 (2.4) | 26 (2.7) | |
| No charge | 0 (0.0) | 1 (0.1) | |
| Other | 17 (1.8) | 18 (1.9) | |
| Type of Admission | | | |
| Non-elective | 237 (24.7) | 511 (53.1) | 0.601 |
| Elective | 724 (75.3) | 451 (46.9) | |
| Hospital Characteristics: Hospital Bed Size | | | |
| Small | 45 (4.7) | 48 (5.0) | 0.065 |
| Medium | 191 (19.8) | 219 (22.7) | |
| Large | 728 (75.5) | 697 (72.3) | |
| Hospital Characteristics: Control/Ownership of Hospital | | | |
| Government, nonfederal | 68 (7.1) | 74 (7.7) | 0.002 |
| Private, non-profit | 797 (82.7) | 787 (81.6) | |
| Private, invest-own | 99 (10.3) | 103 (10.7) | |
| Hospital Characteristics: Teaching Status of Urban Hospitals | | | |
| Metropolitan non-teaching | 137 (14.2) | 102 (10.6) | 0.064 |
| Metropolitan teaching | 810 (84.0) | 854 (88.6) | |
| Non-metropolitan hospital | 17 (1.8) | 8 (0.8) | |
| Hospital Characteristics: Hospital Urban-Rural Designation | | | |
| Large metropolitan areas with at least 1 million residents | 609 (63.2) | 594 (61.6) | 0.031 |
| Small metropolitan areas with fewer than 1 million residents | 338 (35.1) | 362 (37.6) | |
| Micropolitan areas | 17 (1.8) | 8 (0.8) | |
| Admission Day | | | |
| Mon - Fri | 909 (94.3) | 838 (86.9) | 0.246 |
| Sat - Sun | 55 (5.7) | 126 (13.1) | |

| | | | |
|---|---|---|---|
| Transfer Flag | | | |
| Not a transfer or other same-day stay | 887 (92.0) | 781 (81.0) | 0.267 |
| Transfer involving two discharges from different hospitals | 30 (3.1) | 93 (9.7) | |
| Same-day stay involving two discharges from different hospitals | 20 (2.1) | 45 (4.7) | |
| Same-day stay involving two discharges at the same hospital | 22 (2.3) | 30 (3.1) | |
| Same-day stay involving three or more discharges at the same or different hospitals | 5 (0.5) | 15 (1.6) | |
| Median Household Income National Quartile for Patient ZIP Code | | | |
| 0-25th percentile | 237 (25.0) | 253 (26.8) | 0.019 |
| 26th to 50th percentile | 246 (26.0) | 215 (22.8) | |
| 51st to 75th percentile | 221 (23.3) | 254 (26.9) | |
| 76th to 100th percentile | 243 (25.7) | 223 (23.6) | |
| Rehab Transfer | | | |
| Not a combined record or a combined record not involving rehabilitation, evaluation, or other aftercare | 933 (96.8) | 916 (95.0) | 0.089 |
| Combined record involving transfer to rehabilitation, evaluation, or other aftercare | 31 (3.2) | 48 (5.0) | |
| Patient State is the Same as Hospital State | | | |
| Nonresident | 87 (9.0) | 84 (8.7) | 0.008 |
| Resident | 877 (91.0) | 880 (91.3) | |
| All Patient Refined DRG: Risk of Mortality Subclass | | | |
| Minor likelihood of dying | 25 (2.6) | 0 (0.0) | 1.430 |
| Moderate likelihood of dying | 314 (32.6) | 4 (0.4) | |
| Major likelihood of dying | 418 (43.4) | 236 (24.5) | |
| Extreme likelihood of dying | 207 (21.5) | 724 (75.1) | |
| All Patient Refined DRG: Severity of Illness Subclass | | | |
| Minor loss of function (includes cases with no comorbidity or complications) | 58 (6.1) | 1 (0.1) | 1.111 |
| Moderate loss of function | 216 (22.4) | 19 (2.0) | |
| Major loss of function | 476 (49.4) | 310 (32.2) | |
| Extreme loss of function | 214 (22.2) | 634 (65.8) | |

Abbreviations: MR: Mitral Regurgitation; IABP: Intra-Aortic Balloon Pump; IQR: Interquartile Range; DRG: Diagnosis-Related Groups.

**Table 1B.** Baseline medical comorbidities in the propensity score-matched cohort by preoperative IABP use

| Comorbidities | No IABP N = 964 N (%) | IABP N = 964 N (%) | SMD |
|---|---|---|---|
| Diabetes | 218 (22.6) | 243 (25.2) | 0.052 |
| Hyperlipidemia | 490 (50.8) | 522 (54.2) | 0.077 |
| Hypertension | 616 (63.9) | 620 (64.3) | 0.005 |
| Smoker | 243 (25.2) | 258 (26.8) | 0.043 |
| Obesity | 174 (18.1) | 170 (17.6) | 0.023 |
| CKD Stage 3 or higher | 162 (16.8) | 160 (16.6) | 0.010 |
| ESRD | 36 (3.7) | 42 (4.4) | 0.030 |
| Cardiogenic shock | 92 (9.6) | 137 (14.2) | 0.046 |
| Prior CVA | 42 (4.4) | 54 (5.6) | 0.057 |
| Defibrillation | 33 (3.4) | 47 (4.9) | 0.081 |
| PPM | 46 (4.8) | 44 (4.6) | 0.008 |
| OSA | 97 (10.1) | 104 (10.8) | 0.004 |
| Pulmonary Disease | 163 (17.0) | 180 (18.7) | 0.053 |
| Pulmonary Hypertension | 380 (39.4) | 366 (38.0) | 0.014 |
| RVHF | 0 (0.0) | 15 (1.6) | 0.176 |
| Hypothyroidism | 109 (11.3) | 91 (9.4) | 0.057 |
| Anemia | 51 (5.3) | 48 (5.0) | 0.007 |
| Liver Disease | 27 (2.8) | 30 (3.1) | 0.002 |
| Malnutrition | 66 (6.9) | 130 (13.5) | 0.230 |

Abbreviations: MR: Mitral Regurgitation; IABP: Intra-Aortic Balloon Pump; CKD: Chronic Kidney Disease; ESRD: End Stage Renal Disease; CVA: Cerebrovascular Accident; PPM: Permanent Pacemaker; OSA: Obstructive Sleep Apnea; RVHF: Right Ventricular Heart Failure.

(63.9% vs. 63.2%) (Supplementary Figure 2). Insurance type, hospital bed size, ownership, teaching status, urban-rural designation, median household income quartile, and most comorbidities (including diabetes, hypertension, chronic kidney disease stage ≥3, end-stage renal disease, pulmonary hypertension, and liver disease) were also generally well balanced between groups. However, patients in the IABP group were more likely to be admitted non-electively (53.1% vs. 24.7%) and on weekends (13.1% vs. 5.7%) and were disproportionately classified as having extreme severity of illness (65.8% vs. 22.2%) and extreme risk of mortality (75.1% vs. 21.5%) by APR-DRG. Cardiogenic shock was more frequent in the IABP group (14.2% vs. 9.6%). In addition, malnutrition (13.5% vs. 6.9%) and right ventricular heart failure (1.6% vs. 0%) were more frequent among patients who received preoperative IABP.

*Propensity score-matched in-hospital outcomes*

After 1:1 propensity score matching accounting for baseline illness severity, patients who received preoperative IABP had lower rates of MACCE (16.8% vs. 19.6%, P = 0.045), in-hospital mortality (4.7% vs. 6.5%, P = 0.028), ischemic stroke (1.5% vs. 2.3%, P = 0.040), prolonged mechanical ventilation (7.9% vs. 10.2%, P = 0.014), and pericardial complications (2.2% vs. 3.5%, P = 0.041) compared with those who did not receive IABP. Rates of SCA (6.2% vs. 7.4%, P = 0.310), acute myocardial infarction (3.1% vs. 3.5%, P = 0.620), venous thromboembolism (0.1% vs. 0.3%, P = 0.770), and pulmonary embolism (1.1% vs. 0.8%, P = 0.390) were similar between groups. In contrast, rates of acute kidney injury were numerically higher in the IABP group, although this difference did not reach statistical significance (33.6% vs. 31.8%, P = 0.080). Preoperative IABP use was also associated with a shorter median length of stay (10 days [IQR 8] vs. 13 days [IQR 11], P<0.001) (**Table 2**) (**Figure 1**).

*Multivariable logistic regression analysis of in-hospital outcomes*

After accounting for baseline clinical characteristics, preoperative IABP use was indepen-

**Table 2.** Propensity score-matched in-hospital outcomes in MR patients with and without preoperative IABP

| In-hospital Outcomes | IABP (n = 964) | No IABP (n = 964) | *P* value |
|---|---|---|---|
| | N (%) | N (%) | |
| MACCE | 162 (16.8) | 189 (19.6) | 0.045 |
| In-hospital mortality | 45 (4.7) | 63 (6.5) | 0.028 |
| SCA | 60 (6.2) | 71 (7.4) | 0.310 |
| Stroke | 14 (1.5) | 22 (2.3) | 0.040 |
| VTE | 1 (0.1) | 3 (0.3) | 0.770 |
| Pulmonary Embolism | 11 (1.1) | 8 (0.8) | 0.390 |
| Myocardial Infarction | 30 (3.1) | 34 (3.5) | 0.620 |
| Pericardial Complications | 21 (2.2) | 34 (3.5) | 0.041 |
| AKI | 324 (33.6) | 307 (31.8) | 0.080 |
| Prolonged mechanical ventilation | 76 (7.9) | 98 (10.2) | 0.014 |
| Length of Stay, days (IQR) | 10 (8) | 13 (11) | <0.001 |

Abbreviations: MR: Mitral Regurgitation; IABP: Intra-Aortic Balloon Pump; SCA: Sudden Cardiac Arrest; MACCE: Major Adverse Cardiac and Cerebrovascular Events; VTE: Venous Thromboembolism; MI: Myocardial Infarction; AKI: Acute Kidney Injury.

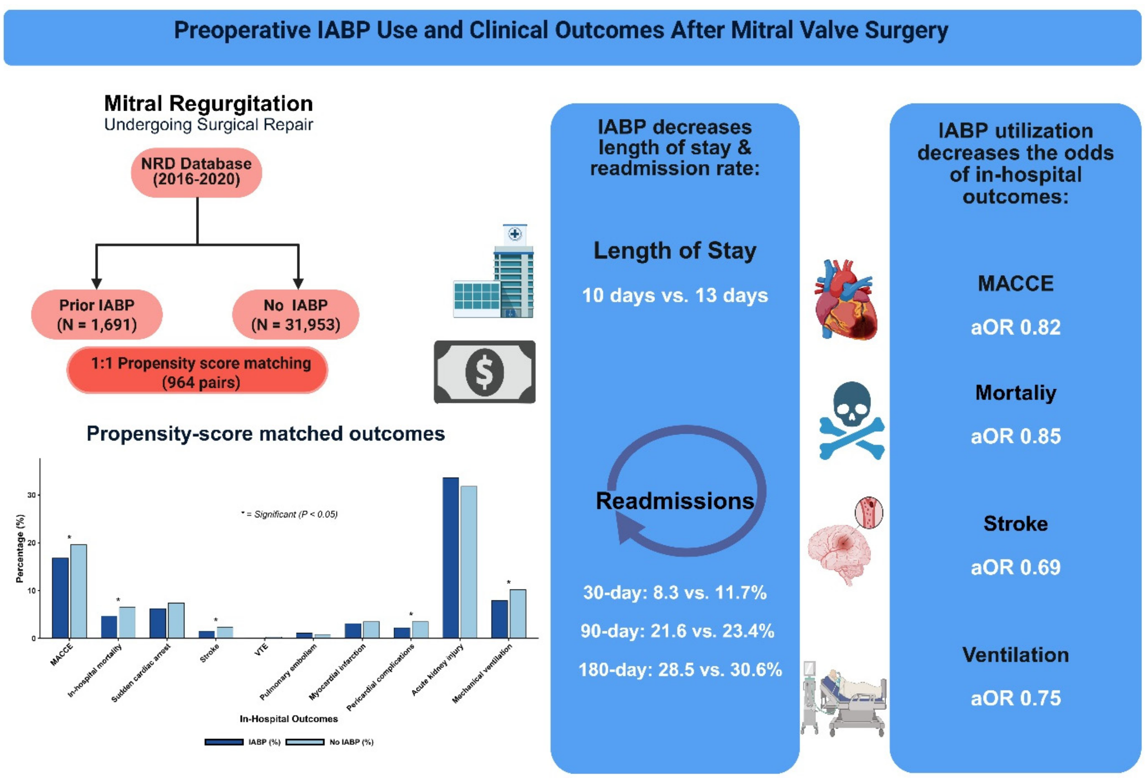


**Figure 1.** Central illustration.

dently associated with lower odds of MACCE (aOR: 0.82; 95% CI: 0.68-0.98; P = 0.041) and in-hospital mortality (aOR: 0.85; 95% CI: 0.71-0.95; P = 0.022). IABP use was also associated with reduced odds of ischemic stroke (aOR: 0.69; 95% CI: 0.43-0.86; P = 0.030), pericardial complications (aOR: 0.68; 95% CI: 0.46-0.99; P = 0.045), and prolonged mechanical ventilation (aOR: 0.75; 95% CI: 0.60-0.94; P = 0.010). In contrast, no significant associations were observed between IABP use and SCA (aOR: 0.90; 95% CI: 0.75-1.08; P = 0.270), MI

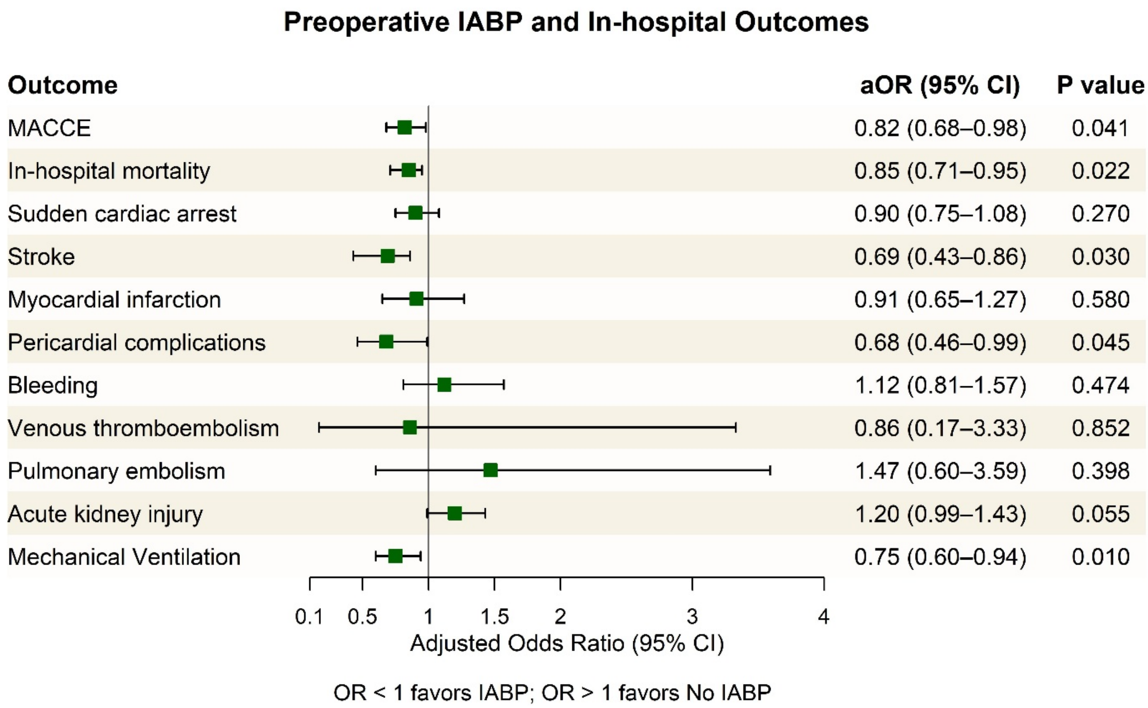


**Figure 2.** Preoperative IABP and in-hospital outcomes after mitral valve surgery. Abbreviations: IABP, Intra-aortic balloon pump.

(aOR: 0.91; 95% CI: 0.65-1.27; P = 0.580), VTE (aOR: 0.86; 95% CI: 0.17-3.33; P = 0.852), PE (aOR: 1.47; 95% CI: 0.60-3.59; P = 0.398), or bleeding events (aOR: 1.12; 95% CI: 0.81-1.57; P = 0.474). The association with AKI did not reach statistical significance (aOR: 1.20; 95% CI: 0.99-1.43; P = 0.055) (**Figure 2**).

*Stratified analysis based on APR-DRG severity*

The association between preoperative IABP use and outcomes varied by APR-DRG severity of illness. No significant associations were observed among patients with mild or moderate illness severity. In contrast, among patients with major illness severity, IABP use was associated with lower odds of MACCE (aOR 0.86, 95% CI 0.74-0.97; P = 0.030). Similarly, in the extreme illness severity subgroup, IABP use was associated with lower odds of MACCE (aOR 0.78, 95% CI 0.56-0.92; P = 0.005) and lower odds of in-hospital mortality (aOR 0.81, 95% CI 0.65-0.94; P = 0.040) (**Table 3**).

*Readmission outcomes*

In the propensity-matched cohort, patients who received IABP prior to surgery had significantly lower 30-day readmission rates compared with those who did not (8.3% vs. 11.7%, P = 0.020). However, no significant differences were observed in 90-day (21.6% vs. 23.4%, P = 0.420) or 180-day (28.5% vs. 30.6%, P = 0.500) readmission rates between the two groups (**Figure 3** and Supplementary Table 7).

## Discussion

Data on the use of preoperative IABP in patients undergoing surgical correction for MR remain limited. This study evaluates the association between preoperative IABP use and clinical outcomes in this population. While prior studies have largely focused on IABP use in cardiogenic shock or MI, our analysis examines its potential role in a contemporary surgical MR population. Our findings revealed that preoperative IABP use was associated with lower odds of MACCE, in-hospital mortality, ischemic stroke, and prolonged mechanical ventilation. These associations were not consistent across all surgical candidates; rather, they were most evident among patients with higher baseline illness severity, particularly those in the major and extreme APR-DRG strata. This pattern suggests that any potential

**Table 3.** In-hospital outcomes stratified by APR-DRG severity of illness

| APR-DRG Severity | Adjusted OR | 95% Confidence Interval | *P* value |
|---|---|---|---|
| MACCE | | | |
| Mild | 1.01 | 0.68-1.51 | 0.960 |
| Moderate | 0.91 | 0.72-1.14 | 0.410 |
| Major | 0.86 | 0.74-0.97 | 0.030 |
| Extreme | 0.78 | 0.56-0.92 | 0.005 |
| All-cause Mortality | | | |
| Mild | 0.97 | 0.61-1.54 | 0.900 |
| Moderate | 0.93 | 0.71-1.22 | 0.600 |
| Major | 0.86 | 0.68-1.09 | 0.210 |
| Extreme | 0.81 | 0.65-0.94 | 0.040 |

Adjusted odds ratios for in-hospital mortality and MACCE across APR-DRG severity strata derived from multivariable logistic regression. The association between IABP and outcomes became progressively stronger with increasing severity of illness, with lower odds of mortality and MACCE observed in the major and extreme strata, and no significant effect in the mild-risk group. Abbreviations: MACCE: Major Adverse Cardiac and Cerebrovascular Events.

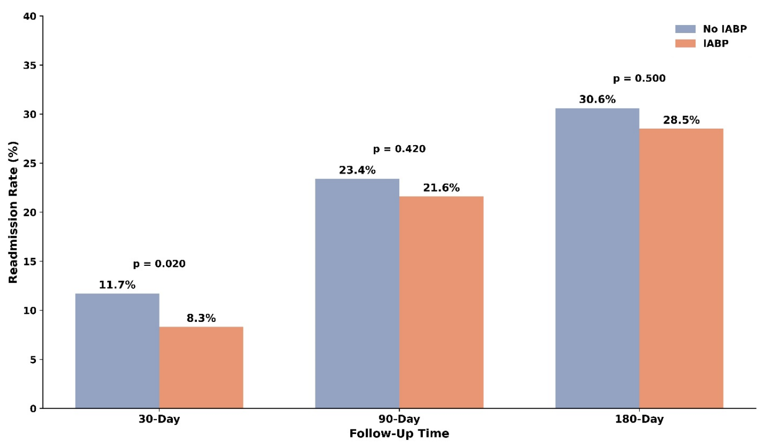


**Figure 3.** Readmissions after mitral valve surgery by preoperative IABP use. Bar chart illustrating readmission rates at 30, 90, and 180 days in a propensity score-matched cohort of patients with mitral regurgitation undergoing surgical repair. Readmissions are stratified by the use of intra-aortic balloon pump prior to surgery. Exact percentages are displayed above each bar.

benefit of IABP may be limited to carefully selected, high-acuity patients in whom preoperative hemodynamic stabilization is clinically relevant. The progressive strengthening of the association with increasing illness severity supports a selective, severity-guided approach to preoperative IABP utilization rather than routine use across all surgical MR patients. Taken together, these observations are hypothesis-generating and underscore the need for prospective studies with granular hemodynamic data to better define the optimal patient profile for preoperative IABP use in surgical mitral regurgitation.

Randomized evidence evaluating the clinical utility of IABP in the setting of cardiogenic shock has been largely neutral. Most notably, the landmark IABP-SHOCK II trial failed to demonstrate a reduction in 30-day mortality with routine IABP use in patients presenting with acute myocardial infarction complicated by cardiogenic shock, a finding that remained consistent at both 1-year and long-term follow-up assessments [6, 12, 13]. More recently, randomized data evaluating early IABP support in patients with cardiogenic shock attributable to acute decompensated heart failure have similarly failed to demonstrate a meaningful survival benefit [14]. In the cardiac surgical setting, randomized trials conducted in high-risk patient populations have similarly failed to establish a consistent reduction in mortality or major perioperative complications with routine preoperative IABP use [15]. In contrast, Wahab et al. reported that pre-procedural IABP use in patients undergoing primary percutaneous coronary intervention (PCI) was associated with substantially lower rates of MACCE (23% vs. 77%) and significantly reduced in-hospital mortality (19% vs. 59%), suggesting a potentially more favorable hemodynamic role for the device in select procedural contexts [16]. Although that study examined IABP use specifically in the context of PCI, it nonetheless reflects a broader pattern in which preemptive hemodynamic unloading prior to definitive intervention may favorably influence periprocedural outcomes. Consistent with our findings, limited observational data in elderly patients undergoing aortic valve replacement for severe aortic stenosis without significant concomitant coronary artery disease have suggested that prophylactic IABP use may reduce perioperative cardiac morbidity, an observation that lends further support to the physiological rationale of hemodynamic unloading and coronary perfusion augmentation as a preoperative stabilization strategy in structurally mediated valvular disease (7). While those data were derived from a small, single-center cohort undergoing aortic valve surgery, the present study evaluates a substantially larger, nationally representative population of patients undergoing mitral valve surgery, offering a broader and more generalizable perspective on the potential role of preoperative IABP in valvular heart disease. Complementing these observations, small case-series data in acute MR complicated by cardiogenic shock have demonstrated that early initiation of mechanical circulatory support can effectively stabilize forward cardiac output and serve as a viable bridge to definitive surgical intervention, with reported survival-to-discharge rates of approximately 80% despite exceptionally high predicted operative mortality [8]. Similarly, recent case-based evidence has further demonstrated that temporary mechanical circulatory support can serve as an effective hemodynamic bridge to definitive mitral valve surgery in patients presenting with significant hemodynamic instability, facilitating clinical stabilization and optimizing the patient's physiological state prior to operative intervention [17]. IABP operates via counterpulsation, augmenting diastolic coronary perfusion pressure while reducing LV afterload and myocardial oxygen demand, and has been shown to reduce intracardiac shunting and the degree of MR while enhancing forward cardiac output, providing a compelling physiological rationale for its preoperative use in this population [18].

The observed lack of a statistically significant association between preoperative IABP use and acute kidney injury (AKI), despite a numerically higher AKI rate in the IABP group, warrants careful interpretation. This finding stands in contrast to prior reports in acute myocardial infarction populations and likely reflects differences in baseline illness severity, hemodynamic profile, and clinical context between the two populations, rather than a direct nephrotoxic effect of IABP therapy per se [19]. With respect to thromboembolic complications, the existing literature offers limited insight into venous thromboembolism (VTE) rates specifically in the context of IABP use. However, one study comparing patients who received anticoagulation during IABP support with those who did not reported VTE rates of 1.2% and 3.1%, respectively, with no statistically significant difference observed between the two groups [20]. These observations underscore the need for more rigorously designed studies to better characterize the thromboembolic risk profile associated with IABP use across different clinical contexts. Preoperative IABP use was associated with a significantly shorter length of stay and lower 30-day readmission rates. The absence of a corresponding difference at 90 or 180 days, however, likely reflects the temporally limited nature of IABP's hemodynamic support, which may stabilize patients through the immediate perioperative period without fundamentally modifying the longer-term trajectory of their underlying valvular or comorbid disease. The significantly lower rate of prolonged mechanical ventilation observed in the IABP group warrants careful consideration, as the need for extended ventilatory support is inherently influenced by the degree of underlying hemodynamic compromise. Preoperative IABP may mitigate the risk of respiratory failure by improving systemic perfusion and reducing LV afterload. A retrospective study of patients older than 60 years with cardiogenic shock reported higher mortality among those requiring both IABP and mechanical ventilation, though this difference did not reach statistical significance, likely reflecting the confounding influence of underlying comorbidities [21].

### Limitations

This study carries several limitations inherent to its retrospective observational design and reliance on administrative data. Although propensity score matching was employed to account for baseline illness severity and cardiogenic shock, residual confounding from unmeasured clinical variables, including hemodynamic parameters, echocardiographic findings, medication use, and surgical urgency, cannot be fully excluded. As with all administrative databases, the NRD relies on diagnostic and procedural coding, which is susceptible to misclassification and lacks granular clinical detail regarding IABP timing, duration of support, device-related complications, and perioperative hemodynamic response. While the PRDAY variable confirms that IABP placement preceded surgical intervention, the precise timing of device removal and the attribution of postoperative events cannot be ascertained. Furthermore, longitudinal follow-up beyond the index calendar year is not available within the NRD framework, precluding assessment of longer-term clinical outcomes. These findings should therefore be interpreted as hypothesis-generating and associative in nature, and prospective studies incorporating detailed clinical, hemodynamic, and procedural data are warranted to validate these observations and establish optimal patient selection criteria for preoperative IABP use in surgical MR.

## Conclusion

In this large national cohort of patients undergoing surgical correction for MR, preoperative IABP use was associated with lower rates of MACCE, in-hospital mortality, ischemic stroke, and prolonged mechanical ventilation, with the most pronounced associations among patients with greater baseline illness severity. Given the exploratory nature of these analyses, findings should be interpreted with appropriate caution and warrant prospective validation.

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## Disclosure of conflict of interest

None.

## Abbreviations

MR, Mitral Regurgitation; IABP, Intra-Aortic Balloon Pump; MACCE, Major Adverse Cardiac and Cerebrovascular Events; AKI, Acute Kidney Injury; MI, Myocardial Infarction; SCA, Sudden Cardiac Arrest; VTE, Venous Thromboembolism; NRD, Nationwide Readmissions Database; PSM, Propensity Score Matching; aOR, Adjusted Odds Ratio.

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