

## Assessment of Post-Operative Risk Factors for Prolonged ICU Stay 48hrs -72hrs, after Valvular Surgeries

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### Abstract

**Background:** Valvular heart disease is a major contributor to cardiovascular morbidity, particularly in low- and middle-income countries where late presentation and rheumatic etiology are common. Patients undergoing valve surgery often experience complex postoperative courses due to preexisting pulmonary hypertension, ventricular dysfunction, and arrhythmias, leading to prolonged intensive care unit (ICU) stay. Extended ICU duration increases the risk of complications, healthcare costs, and resource burden, especially in resource-limited settings like Pakistan.

**Objective(s):** To assess postoperative hemodynamic, respiratory, and clinical risk factors associated with prolonged ICU stay ( $\geq 48$  hours) in patients undergoing valvular heart surgeries.

**Methodology:** A cross-sectional study was conducted on 70 patients undergoing isolated valvular surgery at a tertiary care hospital. Consecutive non-probability sampling was used. Data were collected prospectively at

ICU admission and during the first 48–72 postoperative hours, including variables such as mean pulmonary artery pressure (MPAP), PaO<sub>2</sub>/FiO<sub>2</sub> ratio, temperature, ventilation duration, and postoperative complications. Statistical analysis was performed using SPSS version 27. Group comparisons were conducted using Chi-square, independent t-test, and Mann–Whitney U test. Logistic regression analysis was applied to identify significant predictors of prolonged ICU stay.

**Results:** Out of 70 patients, a significant proportion experienced prolonged ICU stay ( $\geq 48$  hours). Elevated MPAP ( $\geq 21$  mmHg), impaired oxygenation (PaO<sub>2</sub>/FiO<sub>2</sub>  $\leq 300$ ), prolonged mechanical ventilation, hypothermia, low cardiac output syndrome, and acute kidney injury were significantly associated with extended ICU stay. Prolonged ventilation showed the strongest association (OR = 8.2), followed by low cardiac

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output syndrome and impaired oxygenation. Double-valve surgery and postoperative atrial fibrillation were also significant predictors.

**Conclusion:** Prolonged ICU stay after valvular surgery is primarily influenced by early postoperative complications and hemodynamic instability. Key predictors include impaired oxygenation, elevated pulmonary artery pressure, hypothermia, prolonged ventilation, and organ dysfunction. Early identification and management of these factors can improve patient outcomes and optimize ICU resource utilization.

## **Introduction**

### **CHAPTER 1**

Valvular heart disease is a major cause of cardiovascular morbidity worldwide, especially in low- and middle-income countries where rheumatic heart disease, limited diagnostic resources, and late presentation contribute to advanced disease requiring surgical intervention. Surgical management through valve repair or replacement remains the definitive treatment for severe mitral, aortic, or tricuspid valve pathology; however, these patients often present with long-standing pressure and volume overload, pulmonary hypertension, atrial fibrillation, and ventricular dysfunction, making their postoperative recovery more complex than that of patients undergoing coronary artery bypass grafting (CABG). Consequently, postoperative ICU stay after valvular surgeries is frequently prolonged due to challenges in hemodynamic stabilization, respiratory management, and organ support requirements [1-3].

In resource-limited environments such as Pakistan, ICU capacity is often constrained, and prolonged ICU stay places additional burden on healthcare systems by increasing morbidity, delaying patient turnover, and reducing availability of critical-care beds for incoming surgical cases. Extended ICU stay is well recognized to increase risks of ventilator-associated pneumonia, acute kidney injury, arrhythmias, and sepsis complications that further lengthen hospitalization and worsen outcomes. Identifying the early postoperative factors that contribute to prolonged ICU admission is therefore essential for improving clinical decision-making, optimizing resource allocation, and reducing postoperative morbidity [4, 5].

Most existing international literature on prolonged ICU stay focuses on CABG patients, with relatively limited data addressing isolated valvular surgeries. This is a significant gap because valvular surgery patients differ markedly in their perioperative physiology. Patients with mitral valve disease often have severe pulmonary hypertension and reduced lung compliance, predisposing them to prolonged ventilation and right ventricular dysfunction [6, 7].

Aortic valve replacement, due to its proximity to the conduction system, carries a higher risk of postoperative conduction abnormalities requiring temporary pacing. Tricuspid valve procedures are frequently associated with postoperative right heart failure and volume overload, both of which contribute to extended ICU stay. Additional valve-specific concerns such as residual gradients, paravalvular leaks, and prosthetic valve dysfunction further complicate early recovery [8,9].

Early postoperative indicators including elevated mean pulmonary artery pressure, impaired oxygenation (low PaO<sub>2</sub>/FiO<sub>2</sub> ratio), high lactate levels, postoperative hypothermia, prolonged vasopressor requirement, and conduction disturbances have been reported as important predictors of delayed recovery following cardiac surgery. Complications such as atrial fibrillation, pulmonary edema, low cardiac output syndrome (LCOS), acute kidney injury, re-intubation, and sepsis have been consistently associated with extended ICU stay in valvular surgery populations [10,11].

Despite these findings, there is limited evidence from South Asian settings, where patient characteristics, disease etiology (such as rheumatic heart disease),

perioperative practices, and ICU resources differ significantly from those in high-income countries. Furthermore, most regional studies combine CABG and valvular surgeries, failing to identify predictors that are unique to valve procedures. As Bowdish et al. noted, predictive models developed in Western healthcare systems may not be directly applicable to low-resource environments without localized validation. This highlights a clear need for focused research examining postoperative determinants of ICU stay specifically in patients undergoing valvular surgeries [12,13].

The postoperative management of patients undergoing cardiac surgery has been inseparable from intensive care since the earliest days of open-heart procedures. The physiological insults imposed by cardiopulmonary bypass systemic inflammatory response, hemodilution, coagulopathy, temperature dysregulation, and ischaemia-reperfusion injury require a level of monitoring and intervention that can only be reliably delivered in an ICU setting. In the immediate postoperative period, nursing and medical staff must simultaneously manage mechanical ventilation, vasoactive drug infusions, fluid balance optimization, cardiac rhythm disturbances, pain control, neurological assessment, and the surveillance of surgical bleeding, all within a timeframe that leaves little margin for delay or diagnostic error [14,15].

For the majority of patients undergoing uncomplicated valve surgery, the ICU stay is intended to be brief typically ranging from 12 to 24 hours of mechanical ventilation followed by extubation, and then a total ICU stay of no longer than 24 to 48 hours before step-down to a high-dependency or general cardiothoracic ward [10]. Fast-track cardiac anesthesia and enhanced recovery protocols have been developed with precisely this goal in mind, and in specialized centers, extubation within six hours of surgery is now routinely achievable for low-risk patients. However, a clinically important subset of patients does not follow this favorable trajectory. Instead, they accumulate complications, exhibit physiological instability, or develop end-organ dysfunction that necessitates an ICU stay extending to 48 to 72 hours or beyond, placing them in the category widely defined in the cardiac surgical literature as experiencing a prolonged ICU stay [16].

The consequences of prolonged ICU admission extend far beyond the individual patient. From a health-systems perspective, extended ICU occupancy translates directly into increased costs, reduced bed availability for other critically ill patients, and greater burden on nursing resources. From the patient perspective, each additional day in the ICU carries its own risks: ventilator-associated pneumonia, catheter-related bloodstream infection, delirium, physical deconditioning, venous thromboembolism, and psychological sequelae that may persist long after hospital discharge [13,14]. Identifying the factors that predispose a patient to prolonged ICU admission after valve surgery is therefore not merely an academic exercise it carries direct implications for preoperative risk counselling, surgical decision-making, resource allocation, and the optimization of perioperative care protocols [17].

Given the considerations outlined above, the rationale for the present study is clear and compelling. Valvular heart disease carries a substantial burden in Pakistan, and cardiac surgical services concentrated primarily in a small number of tertiary centers in major urban areas face persistent challenges of resource constraint, high patient volumes, and limited ICU bed availability. Understanding which preoperative, intraoperative, and early postoperative factors are most strongly and independently associated with ICU stays extending to 48–72 hours or beyond in this patient population would serve multiple important purposes [18].

First, such knowledge would enable the preoperative risk stratification of patients scheduled for valvular surgery, allowing clinicians to counsel patients and families more accurately about expected postoperative trajectories and resource requirements. Second, identification of modifiable risk factors such as preoperative nutritional status, glycemic control, anemia, or pulmonary function would provide actionable targets for rehabilitation or optimization protocols that could meaningfully shorten ICU stays.

Third, the data generated would lay the groundwork for the development and future validation of a locally appropriate prediction model that outperforms generic international scores in the Pakistani valvular surgical population [19].

The findings of this research also carry implications for hospital administration and ICU management. By characterizing the patient subgroups most likely to require prolonged ICU care, surgical programmers can plan ICU capacity allocation more intelligently, potentially reducing the frequency of emergency bed shortages and the associated adverse outcomes for both cardiac surgical and non-surgical critically ill patients. In a broader sense, the study contributes to the growing but still thin evidence base on cardiac surgical outcomes in South Asia and provides a foundation on which future prospective interventional studies aimed at reducing ICU stay duration can be built [20].

Therefore, this study aims to assess postoperative hemodynamic, respiratory, and clinical predictors associated with prolonged ICU stay (48–72 hours) following mitral, aortic, and tricuspid valve surgeries. Understanding these determinants was support early risk stratification, guide timely interventions, and improve ICU resource utilization in Pakistani cardiac surgery units.

Rationale of study is Valvular surgery patients often present with pulmonary hypertension, ventricular dysfunction, and rhythm disturbances, making their postoperative recovery more complex than other cardiac procedures. These factors increase the risk of hemodynamic instability, prolonged ventilation, and organ dysfunction, leading to extended ICU stay. Despite this higher risk, limited local evidence exists on postoperative predictors specific to valvular surgeries in Pakistan. Identifying these early risk factors is essential to improve patient outcomes and optimize ICU resource utilization.

## **CHAPTER 2**

### **LITERATURE REVIEW**

Azarfarin, et al., (2014) This case-control investigation examined perioperative factors contributing to extended intensive care unit stays beyond hours in adult patients undergoing cardiac surgery at a major cardiovascular referral center in Tehran, Iran. Participants were categorized into two cohorts based on ICU duration individuals with stays of hours or less, with prolonged stays exceeding this threshold. Prolonged ICU occupancy occurred in of isolated coronary artery bypass graft cases, of valve procedures, and combined CABG-valve operations. Patients experiencing ICU stays over 96 hours demonstrated greater requirements for blood transfusions and intravenous inotropes, alongside extended durations of anesthesia, cardiopulmonary bypass, and postoperative intubation. This group also exhibited significantly elevated rates of postoperative complications, including cardiac tamponade, surgical re-exploration, re-intubation, hemodialysis, and hemodynamic instability across all measures. Overall, roughly one-third of the cohort faced delayed ICU discharge due to a mix of medical complications and procedural variables, underscoring the need for additional prospective studies to refine risk stratification and mitigation strategies following cardiac surgery [21].

Zhang, et al., (2021) This retrospective observational study analyzed factors linked to extended intensive care unit (ICU) stays patients undergoing cardiac surgery with cardiopulmonary bypass at a tertiary hospital in China. Data extracted from hospital records showed that patients experienced prolonged ICU length of stay exceeding 72 hours, with a median LOS of hours across the cohort. Binary logistic regression identified several key risk factors for delayed ICU discharge, including longer CPB duration, extended mechanical ventilation, use of non-invasive ventilation support, lower postoperative PaO<sub>2</sub>/FiO<sub>2</sub> ratios within 6 hours, specific surgery types, intraoperative red blood cell transfusions, and postoperative arrhythmias both atrial and ventricular. These results offer practical insights for clinicians to pinpoint high-

risk patients early, allowing timely interventions to shorten recovery times and mitigate complications after CPB-assisted cardiac procedures [22].

Tunc M, et al., (2018) This retrospective analysis reviewed medical records from patients undergoing coronary artery bypass grafting or valvular heart surgery to identify risk factors for prolonged intensive care unit stays, defined as hours or more. The cohort had a mean age, with males, and experienced extended ICU occupancy. Preoperative factors like diabetes mellitus and reduced ejection fraction, intraoperative elements such as prolonged aortic cross-clamp and cardiopulmonary bypass times plus intra-aortic balloon pump use, and postoperative issues including arrhythmias, myocardial infarction, renal dysfunction requiring hemodialysis, need for two or more inotropic agents, infections, sepsis, and respiratory complications were all linked to longer stays. Multivariate logistic regression pinpointed intra-aortic balloon pump requirement, multi-agent inotropic support, postoperative myocardial infarction, and hemodialysis as independent predictors for each, while early mortality affected the patients. Protective strategies targeting myocardial and renal function during surgery could help shorten ICU durations and optimize resource use in open heart surgery patients [23].

Rotar, et al., (2022) Intensive care unit expenses represent a substantial share of overall costs for cardiac surgery patients, yet no validated tool reliably forecasts extended ICU length of stay, complicating staffing and resource planning. Researchers developed and tested a predictive model using data from patients in an institutional Society of Thoracic Surgeons database, with model training on cases and validation on records prolonged ICU LOS was defined as at least three postoperative days. Among these had isolated coronary artery bypass grafting, and overall experienced delayed discharge, with heightened risks among those with severe chronic obstructive pulmonary disease, recent pneumonia, dialysis-dependent renal failure, or reoperation stat. Lasso regression models incorporating preoperative and intraoperative STS variables achieved accuracy in predicting prolonged stays, while a preoperative-only version retained accuracy, enabling better patient counseling, resource allocation, and operational efficiency [24].

Curran, et al., (2022) Prolonged intensive care unit stays after cardiac surgery often signal adverse outcomes, yet limited data exist on how mortality risks evolve over time or vary by ICU duration. This study analyzed ICU admissions from cardiac surgery patients at the University of Michigan Medical Center, focusing on stays exceeding postoperative days; logistic regression assessed hospital mortality at days, while Cox regression evaluated long-term mortality among survivors. Operative mortality rose progressively with mechanical ventilation on assessment day consistently linked to higher odds across all models. Among hospital survivors of the prolonged-stay group, died during extended follow-up, with median survival of years longer ICU stays, postoperative pneumonia, and elevated discharge blood urea nitrogen increased long-term mortality hazard, while higher discharge platelet counts and cardiac transplantation offered protection. These patterns confirm that both short-term operative and late mortality escalate with ICU duration post-cardiac surgery, highlighting the value of vigilant monitoring and targeted interventions for at-risk patients [25].

Almashrafi, et al., (2016) Intensive care unit (ICU) care consumes substantial resources and often creates bottlenecks for downstream services like operating theaters worldwide. This systematic review synthesized evidence from studies identified via searches to pinpoint factors influencing ICU length of stay after cardiac surgery and assess their application in patient and resource management. Studies fell into two categories: those describing general predictors of prolonged LOS and those developing statistical models for forecasting it, though only two reported actual model implementations in practice. Consistently reported factors linked to extended stays included advanced age, atrial fibrillation or other arrhythmias, chronic obstructive

pulmonary disease, reduced ejection fraction, renal failure or dysfunction, and non-elective surgery. Cardiac ICUs frequently constrain hospital operations, underscoring the need to incorporate patient and surgical profiles into resource optimization strategies, with further research required to translate these insights into effective planning [26].

Evora, et al., (2016) Cardiopulmonary bypass procedures are thought to activate systemic inflammatory reaction syndrome. Strategies to curb systemic inflammation have been previously described. However, none of them is adequate, since "curbing" the extent of the inflammatory response requires a multimodal approach. The aim of the present mini-review is to discuss the main key points about the main principles in cardiopulmonary bypass curbing inflammation. No systematic literature search and extracted data from the accumulated experience of the authors. The preconceived idea of an association between severe inflammation and coagulation disorders is reviewed. Also, some fundamental concepts, CPB inflammatory biomarkers, the vasoplegic syndrome and the need for individual CPB protocols for children, diabetes and old patients, are discussed. The ways in which surgical technique (atraumatic vein harvest, biocompatibility and shear resistance of the circuit, monitoring, minimizing organ ischemia, minimal cross-clamping trauma, and blood management) are thought to curb SIRS induced by CPB and affect positively the patient outcome. Improved patient outcomes are strongly associated with these modalities of care, more than single or combinatorial drug strategies (aprotinin, tranexamic acid, pentoxifylline) or CPB modalities (minicircuits, heparin-coated circuits, retrograde autologous prime) [27].

Almashrafi A, et al., (2016) This retrospective observational study at a tertiary hospital in Oman from sought to pinpoint factors linked to extended postoperative length of stay after cardiac surgery and develop a reoperate predictive model for prolonged cardiac intensive care unit (CICU) LOS, benchmarking it against established cardiac risk scores. Among adult patients analyzed, 30.5% faced overall postoperative LOS of 11 days or more, while had CICU LOS extending to 5 days or beyond. Key drivers of prolonged CICU LOS included non-elective procedures, active congestive heart failure, renal impairment, combined coronary artery bypass grafting with valve surgery, and other complex operations beyond isolated CABG or valve repairs. The novel scoring system stratified patients into three risk tiers with prolonged CICU LOS probabilities and achieving strong discrimination factors tied to overall postoperative LOS encompassed body mass index, surgery type, cardiopulmonary bypass use, red blood cell transfusions, emergency status, and complication count the latter emerging as paramount. Tailoring care to individual profiles based on these attributes can streamline resource use, while routine data enable straightforward risk scores to flag high-risk cases for proactive management [28].

Gunnarsdottir, et al., (2020) To maximize the use of intensive care unit resources, it is important to estimate the prevalence and risk factors for prolonged ICU unit stay after coronary artery bypass grafting surgery. This retrospective cohort study included all patients who underwent primary isolated CABG at Landsite. Patient information was collected from hospital charts and death registries. Patients who stayed in the ICU for the conventional one night postoperatively were compared with those who needed longer stays in the ICU. Survival rate was estimated with the Kaplan-Meier method. Predictors for prolonged ICU stay were calculated with logistic regression and the outcome used to create a calculator that estimates the probability of prolonged ICU stay. Out of patients, required prolonged ICU stay. Patients with prolonged stay were more frequently female had a higher rate of cardiovascular risk factors and higher euro-score II. They also had a higher rate of impaired renal function before surgery and emergent surgery. Furthermore, these patients had higher rates of both short-term and long-term complications, and lower long-term survival five-year survival rate.

Independent risk factors for prolonged ICU stay were advanced age, female gender, euro-score II, history of heart diseases, impaired renal function and emergent surgery. Every fifth patient had a prolonged ICU stay after CABG. Several risk factors predicted prolonged ICU stay after CABG, in particular patients' medical condition before surgery, euro-score II and emergent surgery. A better understanding of the risk factors for prolonged ICU stay was hopefully aid in scheduling CABG surgeries [29].

Chin-Yee, et al., (2016) Very elderly patients aged 80 years and older are frequently admitted to intensive care units (ICUs), despite limited survival benefits and common preferences against aggressive life prolongation. This prospective observational cohort study across such patients (average age 85 years; median ICU stay 4 days), including a 610-patient longitudinal subset tracked for 12 months; costs were derived from ICU length of stay multiplied by unit rates from a Canadian academic center, with a generalized linear model identifying predictors. Hospital mortality reached patients, rising at one year among the longitudinal group. Average ICU admission cost per patient totaled escalating to per hospital survivor and per one-year survivor. A documented preference for comfort-focused care over life-sustaining measures independently lowered costs for both decedents and survivors. Given suboptimal outcomes and high financial burden, early goals-of-care discussions prove essential to avert unwanted interventions, curb expenditures, and align treatment with patient values [30].

Yu PJ, et al., (2016) This retrospective cohort study of 4,963 cardiac surgery patients from a single-center ICU assessed in-hospital and post-discharge survival by stratifying prolonged intensive care unit (ICU) stays into 1-2 weeks (3.3% of patients), 2-4 weeks (1.6%), and >4 weeks (2.9%). In-hospital mortality escalated with duration 11.1% for 1-2 weeks, 26.6% for 2-4 weeks, and 31.0% for >4 weeks yet plateaued beyond four weeks. Post-discharge survival among hospital survivors remained comparable for shorter stays (84.4%, 80.0%, and 75.3% at 6 months, 1 year, and 2 years for 1-2 weeks; similar for 2-4 weeks), but dropped sharply for >4-week stays (63.3%, 56.4%, and 41.1%, respectively), with postoperative stroke posing the highest one-year mortality risk. These findings indicate that while in-hospital death tracks ICU length initially, extended stays beyond four weeks signal markedly poorer long-term prognosis, particularly with neurologic complications [31].

Verburg, et al., (2017) This systematic review evaluated 31 prediction models for adult intensive care unit (ICU) length of stay (LOS) from 11 development studies and three external validations, sourced. Models aimed to support ICU capacity planning, flag unexpectedly long stays, and benchmark performance, requiring published variables free of organizational factors, high explained variance ( $R^2$ ), and minimal calibration bias. Cohorts spanned 253 to 178,503 admissions with median LOS of 2-6.9 days; however, two studies omitted variable details, three incorporated site-specific traits, and none achieved unbiased predictions  $R^2$  ranged 0.05-0.28 across patients and 0.01-0.64 across ICUs. Reporting quality scored 49-60/78, methodology 12-16/22 per critical appraisal checklists. Clinicians should approach these tools cautiously for forecasting LOS, as none fully meet criteria for reliable application in resource management or outlier detection [32].

Baxter, et al., (2020) Enhanced Recovery After Surgery protocols, widely adopted across surgical fields, coordinate multimodal perioperative strategies to optimize patient outcomes and healthcare efficiency. Their application in cardiac surgery (ERAS-C) remains underdeveloped despite promising early data, prompting this literature review of Medline-sourced studies on implementation, historical context, barriers, and initial results. Extracted elements spanned preoperative optimization, intraoperative techniques, and postoperative care, revealing consistent benefits akin to non-cardiac ERAS: hospital stays shortened by 1-4 days, intensive care unit durations reduced by 4-20 hours, opioid needs cut by 25%-60%, and faster resumption of mobility and oral intake. Cardiac-specific gains included 8%-14% lower postoperative

atrial fibrillation rates. These findings advocate broader ERAS-C adoption, urging rigorous trials to overcome cardiac surgery's unique challenges like mechanical support and anticoagulation demand [33].

Somlo, et al., (2018) Contemporary reimbursement models enable hospitals to profit from high procedural volumes, but surging caseloads often expose structural bottlenecks that delay care, worsen outcomes, and inflate expenses. A multidisciplinary team at Yale New Haven Hospital's Heart and Vascular Center conducted a retrospective analysis of operations and patient data, identifying delays in operating room-to-intensive care unit (ICU) transfers as a key inefficiency; pre-intervention, these delays correlated with 13% longer ICU stays, 16% greater blood loss, 10% higher 30-day readmissions, and 34% increased 30-day mortality, adding \$3,509,621 in costs, with a volume threshold triggering excess delays. Over 90 days, dynamic work design principles emphasizing human-centered process improvements were applied, yielding 16% fewer delayed transfers, 19% shorter ICU lengths of stay, and 19% overall cost reductions without altering surgical volume, mortality, readmissions, or reoperations. This approach demonstrates how targeted operational refinements can sustain quality amid rising demand while cutting system-wide expenditures [34].

Heimrath, et al. (2007) This retrospective review of 3,139 patients undergoing coronary artery bypass grafting (CABG) examined short- and long-term outcomes in those with prolonged intensive care unit (ICU) stays exceeding 48 hours, affecting individuals (19%). In-hospital mortality reached 10.0% in this group versus in others, with median hospitalization extending to 11 days compared to 6 days. Among hospital survivors, median follow-up spanned 31 months with complete data capture; Cox proportional hazards analysis revealed significantly reduced survival and freedom from cardiac readmissions for those with extended ICU use. Prolonged stay independently predicted the composite endpoint of death or readmission. These results underscore prolonged ICU occupancy after CABG as a marker of both early mortality and diminished late cardiac event-free survival [35].

Ross SW, et al., (2020) The novel coronavirus was first diagnosed in Wuhan, China in December 2019 and has now spread throughout the world, being verified by the World Health Organization as a pandemic on March 11. This had led to the calling of a national emergency on March 13 in the US. Many hospitals, healthcare networks, and specifically, departments of surgery, are asking the same questions about how to cope and plan for surge capacity, personnel attrition, novel infrastructure utilization, and resource exhaustion. Herein, we present a tiered plan for surgical department planning based on incident command levels. This includes acute care surgeon deployment (given their critical care training and vertically integrated position in the hospital), recommended infrastructure and transfer utilization, triage principles, and faculty, resident, and advanced care practitioner deployment [36].

Ibrahim et al. (2024) evaluated 314 patients and reported that 27% experienced prolonged ICU stay. Their multivariate analysis identified prolonged mechanical ventilation, acute kidney injury (AKI), sepsis, and extended inotrope use as independent predictors, with odds ratios ranging from 2.6 to 4.2. The authors emphasized that postoperative multiorgan dysfunction significantly contributes to increased ICU duration and hospital mortality [37].

Kapadohos et al. (2021) conducted large prospective observational studies including over 600 patients and reported prolonged ICU stay in approximately 20–25% of cases. Their findings revealed that low cardiac output syndrome (LCOS), AKI, and prolonged ventilation were significantly more common in patients with extended ICU stay. Multivariate models consistently demonstrated these variables as independent predictors, each with odds ratios exceeding 3.0. The authors concluded that early postoperative physiological failure is the primary determinant of ICU stay duration [38].

Nakasuji et al. (2022) investigated 137 patients undergoing coronary artery bypass grafting (CABG) and found that 21% required ICU stay beyond 72 hours. Elevated mean pulmonary artery pressure (MPAP  $\geq 21$  mmHg) and reduced PaO<sub>2</sub>/FiO<sub>2</sub> ratio ( $\leq 300$ ) were significantly associated with prolonged ICU stay. Logistic regression analysis confirmed both elevated MPAP and impaired oxygenation as independent predictors, highlighting the importance of early cardiopulmonary parameters [39].

Osinaike et al. (2021) evaluated 120 CABG patients and reported prolonged ICU stay in 28.3% of cases. Prolonged inotropic support, AKI, and extended mechanical ventilation were significantly more frequent among patients with longer ICU stays. Multivariate analysis identified inotropic support and AKI as independent predictors, underscoring the importance of hemodynamic stability and renal function in postoperative recovery [40].

## **OBJECTIVE(S)**

To identify and evaluate postoperative risk factors associated with prolonged ICU stay ( $\geq 48$ –72 hours) in patients undergoing valvular heart surgeries

## **PROBLEM STATEMENT**

Valvular surgery patients often experience postoperative instability due to pulmonary hypertension, ventricular dysfunction, and rhythm disturbances, increasing their risk of prolonged ICU stay. Existing research rarely focuses specifically on valvular procedures, limiting understanding of their unique postoperative predictors. In Pakistan, evidence on early postoperative factors leading to extended ICU admission remains scarce. Therefore, identifying these risk factors is essential to improve outcomes and optimize ICU resource utilization.

## **OPERATIONAL DEFINITION(S)**

### **Prolonged ICU Stay**

Prolonged ICU stay is defined as a postoperative ICU stay of  $\geq 48$  hours, measured from the time of ICU admission to ICU discharge. This threshold is widely used in cardiac surgery research to identify patients with delayed recovery and increased postoperative complications [3].

### **Elevated Mean Pulmonary Artery Pressure (MPAP)**

MPAP refers to the mean pressure measured through the pulmonary artery catheter within the first hour of ICU admission. MPAP  $\geq 21$  mmHg was considered elevated, as higher postoperative MPAP has been shown to predict prolonged ICU stay after cardiac surgery [5].

### **Impaired Oxygenation (PaO<sub>2</sub>/FiO<sub>2</sub> Ratio $\leq 300$ )**

The PaO<sub>2</sub>/FiO<sub>2</sub> (PF) ratio is calculated using the arterial blood gas taken within the first ICU hour. A PF ratio  $\leq 300$  indicates impaired oxygenation and early postoperative respiratory compromise [7].

### **Low Cardiac Output Syndrome (LCOS)**

LCOS refers to inadequate cardiac output resulting in poor tissue perfusion during the first **24 hours** postoperatively. It is identified by signs of hypoperfusion such as cold extremities, low urine output, elevated lactate ( $>2$  mmol/L), and **requirement of continuous inotropic or vasopressor support**. LCOS is a major predictor of delayed recovery and prolonged ICU monitoring after valve procedures [9].

### **Postoperative Conduction Disturbances**

Conduction disturbances include new-onset atrioventricular block, junctional rhythm, or severe bradyarrhythmia occurring after valvular surgery, especially aortic and mitral procedures. Patients who develop this rhythm issues may require temporary

spacing and prolonged ICU observation due to the risk of hemodynamic instability [11].

### CHAPTER 3

#### MATERIAL AND METHODS

**Study Design:** Cross Sectional Study.

**Settings:** CMA Hospital

**Study Duration:** 4 months after approval of the Synopsis.

**Sample Size:** The sample size was calculated using the single-proportion formula at 95% confidence and 5% precision. Based on published prevalence of prolonged ICU stay after cardiac surgery (13% for ICU stay >3 days) from Nakasuji et al. the initial sample size estimate was 174. Because the expected population of eligible surgeries during the study period is limited ( $N = 80-100$ ), the finite population correction was applied, yielding an adjusted sample size requirement of 61–70 patients. After adding 10% for incomplete data, the final recommended sample size is 70 participants.

**Formula:**

$$n_0 = \frac{Z^2 p(1-p)}{d^2}$$

Where:

- $Z = 1.96$  for 95% confidence
- $p = 0.13$  (13% prevalence of prolonged ICU stay >3 days. (Nakasuji et al.)
- $d = 0.05$  (5% precision)

**Calculate Initial Sample Size ( $n_0$ )**

$$\begin{aligned}n_0 &= \frac{1.96^2 \times 0.13 \times 0.87}{0.05^2} \\n_0 &= \frac{3.8416 \times 0.1131}{0.0025} \\n_0 &= \frac{0.4349}{0.0025} \\n_0 &= 173.96 \approx 174\end{aligned}$$

**Apply Finite Population Correction (FPC)**

Because our total eligible population is  $N = 80-100$  surgeries, FPC is required.

$$\begin{aligned}n &= \frac{n_0}{1 + \frac{n_0 - 1}{N}} \\n &= \frac{174}{1 + \frac{2.1625}{174}} \\n &= \frac{3.1625}{3.1625} \\n &= 55.0 \approx 55\end{aligned}$$

Final Sample Size = 70 participants [3]

**Sampling Technique:** Consecutive Non-Probability Sampling.

**Sample Selection:**

**Inclusion Criteria:**

Age  $\geq 18$  years, undergo isolated valvular surgery, including, Mitral valve replacement or repair, Aortic valve replacement, Tricuspid valve repair, Double-valve procedures (mitral + aortic, mitral + tricuspid), Postoperative admission to the Cardiac Surgery Intensive Care Unit, Patient or next-of-kin was to provide informed consent

**Exclusion Criteria:**

*CABG, CABG + valve, or other mixed cardiac procedures, Emergency surgery, Redo / re-operative cardiac procedures, Congenital, aortic, transplant, or LVAD cases, Pre-op intubation due to sepsis, Pre-op fever >38°C, Incomplete postoperative data, Age <18 years*

**ETHICAL CONSIDERATIONS**

*This research study was be conducted in accordance with the ethical rules and regulations set by the Ethical Review Committee of Superior University, Lahore. Full respect for the rights, dignity, safety, and well-being of all research participants was be ensured throughout the study. Written informed consent was be obtained from every participant prior to enrollment. All personal information and collected data were be kept strictly confidential and used only for research purposes. The anonymity of all participants was be maintained at every stage of the study, and no identifiable details was be disclosed in any report, publication, or presentation.*

**DATA COLLECTION PROCEDURE**

Data was be collected prospectively using a structured questionnaire at three defined time points. Immediately upon ICU admission (0–1 hour), core postoperative variables including MPAP, PaO<sub>2</sub>/FiO<sub>2</sub> ratio, core temperature, vasoactive support, ventilation status, and arterial lactate was be recorded directly from ICU monitors and the anesthesia handover, as early hemodynamic and respiratory parameters are established predictors of prolonged ICU stay. During the first 48–72 postoperative hours, continuous surveillance was be performed to document major complications such as re-intubation, arrhythmia, myocardial infarction, acute kidney injury, dialysis, pneumonia, sepsis, surgical site infection, IABP use, and re-exploration for bleeding, following criteria used in previous studies.

**DATA ANALYSIS PROCEDURE**

Data was be analyzed using SPSS Version 27. Continuous variables were be summarized as mean ± SD or median (IQR), while categorical variables were be presented as frequencies and percentages. Group comparisons between prolonged and non-prolonged ICU stay was be conducted using Chi-Square, independent t-tests or Mann–Whitney U tests for continuous data and Chi-square or Fisher’s Exact tests for categorical data. Variables showing significant association (p < 0.05) was then be entered into a binary logistic regression model to identify independent postoperative predictors of prolonged ICU stay.

**CHAPTER 5****RESULTS****Section 1: Demographics****Age:**

The study population consisted of 70 patients with a wide age distribution. The largest proportion of patients (31.4%) belonged to the 41–50 years age group, followed by 31–40 years (25.7%). Patients aged 51–60 years accounted for 20%, while younger individuals (18–30 years) represented 14.3%. Only a small percentage (8.6%) were older than 60 years. This indicates that middle-aged adults formed the majority of the study population.

*Table 1: Demographics*

<b>Age group (years)</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
18–30	10	14.3
31–40	18	25.7

41–50	22	31.4
51–60	14	20
>60	6	8.6
<b>Total</b>	<b>70</b>	<b>100</b>

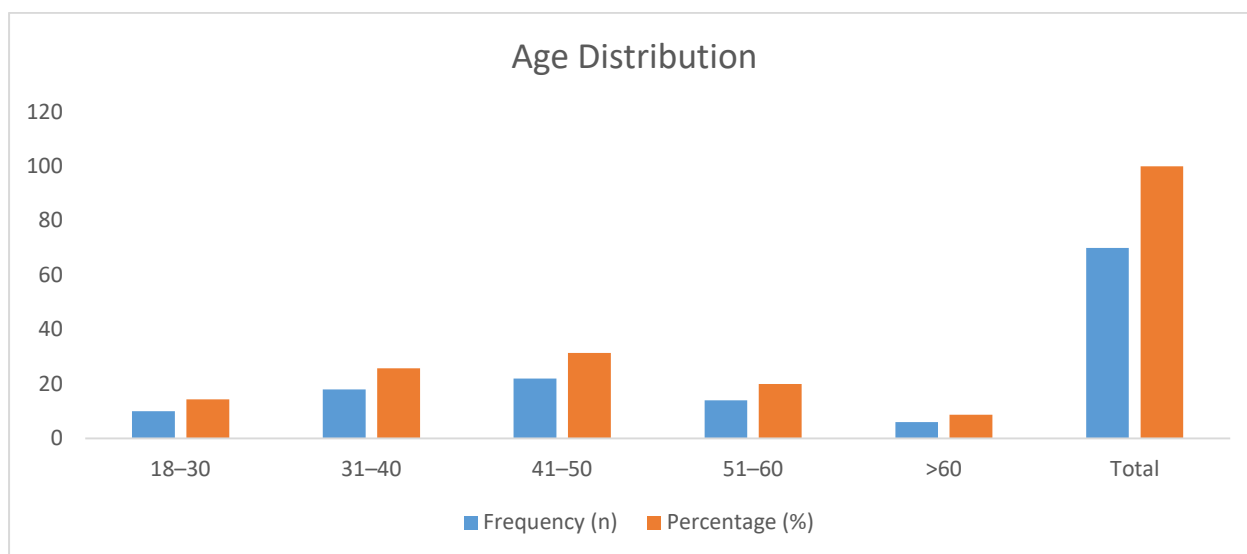


Figure 1: Age Distribution

**Gender:**

Among the participants, males constituted a slightly higher proportion (54.3%) compared to females (45.7%). This shows a mild male predominance in patients undergoing valve surgery in this cohort.

Table 2: Gender

Gender	Frequency (n)	Percentage (%)
Male	38	54.3
Female	32	45.7
<b>Total</b>	<b>70</b>	<b>100</b>

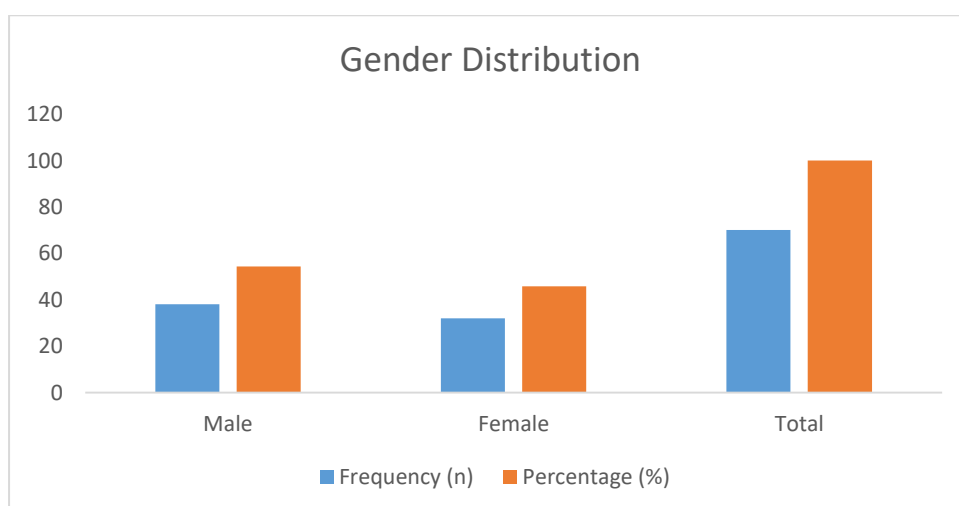


Figure 2: Gender Distribution

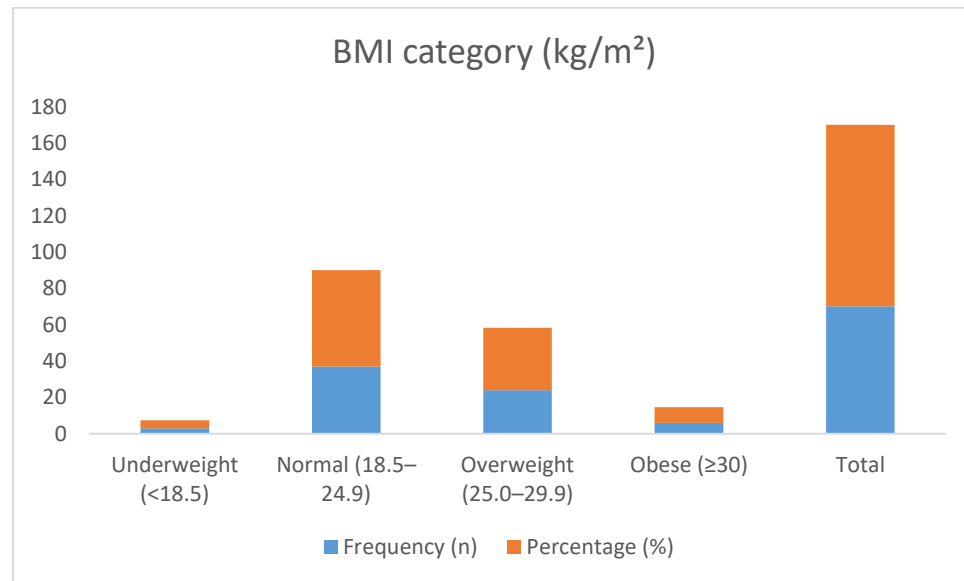
**BMI Category:**

More than half of the patients (52.9%) had a normal body mass index. Overweight individuals represented 34.3%, while obesity was observed in 8.6% of patients. Only

4.3% were underweight. These findings suggest that most patients had acceptable nutritional status, although a considerable proportion were overweight.

*Table 3: BMI category (kg/m<sup>2</sup>)*

<b>BMI category (kg/m<sup>2</sup>)</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
Underweight (<18.5)	3	4.3
Normal (18.5–24.9)	37	52.9
Overweight (25.0–29.9)	24	34.3
Obese (≥30)	6	8.6
<b>Total</b>	<b>70</b>	<b>100</b>



*Figure 3: BMI category (kg/m<sup>2</sup>)*

#### **Types of Valve Surgery:**

Mitral valve replacement (MVR) was the most commonly performed procedure (37.1%). Aortic valve replacement (AVR) accounted for 22.9%, while double-valve procedures were performed in 20% of patients. Mitral valve repair and tricuspid valve procedures were less frequent. This reflects the predominance of mitral valve pathology in the study population.

*Table 4: Types of Valve Surgery*

<b>Type of valve surgery</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
MVR	26	37.1
MV Repair	8	11.4
AVR	16	22.9
TV repair/replacement	6	8.6
Double-valve procedure	14	20
<b>Total</b>	<b>70</b>	<b>100</b>

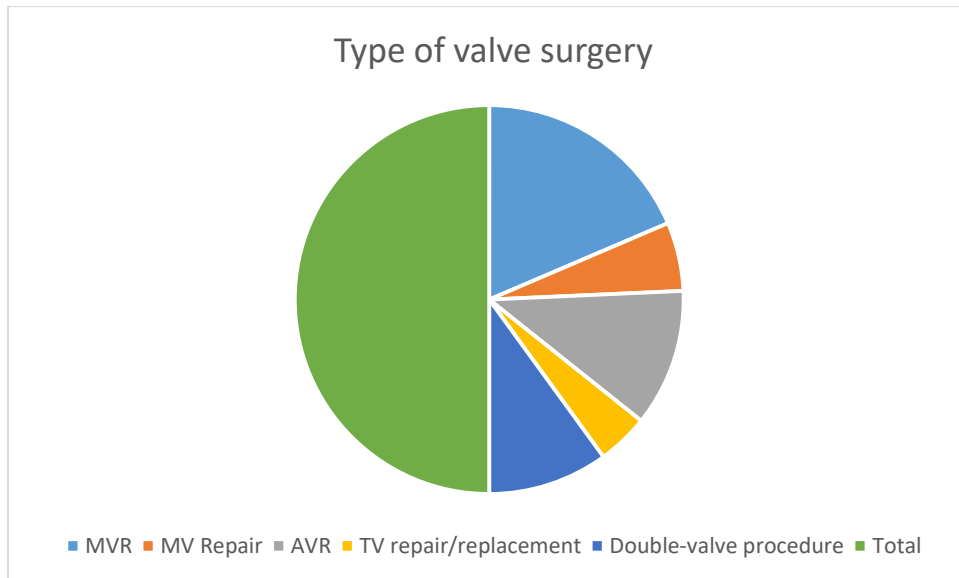


Figure 4: Type of valve surgery

### Preoperative Pulmonary Hypertension:

A significant proportion of patients had some degree of pulmonary hypertension. Mild pulmonary hypertension was most common (40%), followed by moderate (21.4%) and severe (11.4%) forms. Only 27.1% had no pulmonary hypertension. This highlights the high burden of pulmonary vascular involvement in these patients.

Table 5: Preoperative Pulmonary Hypertension

Preoperative pulmonary hypertension	Frequency (n)	Percentage (%)
None	19	27.1
Mild	28	40
Moderate	15	21.4
Severe	8	11.4
<b>Total</b>	<b>70</b>	<b>100</b>

### Preoperative Rhythm:

The majority of patients (67.1%) had normal sinus rhythm preoperatively. Atrial fibrillation was present in 25.7% of cases, while heart block and other arrhythmias were less common. This indicates that rhythm disturbances, particularly atrial fibrillation, were relatively frequent.

Table 6: Preoperative Rhythm

Preoperative rhythm	Frequency (n)	Percentage (%)
Sinus rhythm	47	67.1
Atrial fibrillation	18	25.7
Heart block	3	4.3
Other	2	2.9
<b>Total</b>	<b>70</b>	<b>100</b>

### Left Ventricular Ejection Fraction Categories:

Most patients had either normal (34.3%) or mildly reduced (40%) left ventricular function. Moderate dysfunction was observed in 21.4%, while severe dysfunction was rare (4.3%). This suggests that the majority of patients had relatively preserved cardiac function before surgery.

*Table 7: Left Ventricular Ejection Fraction Categories*

<b>LVEF category</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
Normal ( $\geq 55\%$ )	24	34.3
Mild dysfunction (45–54%)	28	40
Moderate dysfunction (30–44%)	15	21.4
Severe dysfunction ( $< 30\%$ )	3	4.3
<b>Total</b>	<b>70</b>	<b>100</b>

**ICU Stay:**

The majority of patients (65.7%) had a shorter ICU stay ( $< 48$  hours), whereas 34.3% required prolonged ICU care ( $\geq 48$  hours). This division was used for further comparative analysis.

*Table 8: ICU stay group*

<b>ICU stay group</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
ICU stay $< 48$ hours	46	65.7
ICU stay $\geq 48$ hours	24	34.3
<b>Total</b>	<b>70</b>	<b>100</b>

**MPAP category:**

More than half of the patients (57.1%) had MPAP values below 21 mmHg, while 42.9% had elevated MPAP. This indicates a substantial proportion with increased pulmonary pressures.

*Table 9: MPAP category*

<b>MPAP category</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
$< 21$ mmHg	40	57.1
$\geq 21$ mmHg	30	42.9
<b>Total</b>	<b>70</b>	<b>100</b>

**Hypothermia:**

Postoperative hypothermia was observed in 30% of patients, while 70% maintained normal body temperature. This suggests that hypothermia remains a relatively common perioperative issue.

*Table 10: Hypothermia*

<b>Hypothermia</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
No	49	70
Yes	21	30
<b>Total</b>	<b>70</b>	<b>100</b>

**Acute Kidney Injury:**

Most patients (82.9%) did not develop acute kidney injury, whereas 17.1% experienced AKI. Although less frequent, AKI represents a significant postoperative complication.

<b>Acute kidney injury</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
No	58	82.9
Yes	12	17.1
<b>Total</b>	<b>70</b>	<b>100</b>

**Postoperative Dialysis:**

Only 2.9% of patients required dialysis, indicating that severe renal impairment was uncommon.

*Table 11: Postoperative Dialysis*

Postoperative Dialysis	Frequency (n)	Percentage (%)
No	68	97.1
Yes	2	2.9
<b>Total</b>	<b>70</b>	<b>100</b>

**Postoperative Pneumonia:**

Postoperative pneumonia occurred in 10% of patients, while 90% remained free from this complication. This reflects a relatively low incidence of respiratory infections.

*Table 12: Postoperative Pneumonia*

Pneumonia	Frequency (n)	Percentage (%)
No	63	90
Yes	7	10
<b>Total</b>	<b>70</b>	<b>100</b>

**Inferential Statistics:****Table 1. Independent sample t-test for continuous variables**

This table compares continuous variables between patients with shorter and prolonged ICU stay. There was no statistically significant difference in age and BMI between the two groups ( $p > 0.05$ ), indicating these factors did not influence ICU duration. The  $\text{PaO}_2/\text{FiO}_2$  ratio was significantly lower in patients with prolonged ICU stay ( $p < 0.001$ ), suggesting poorer oxygenation. Core temperature was significantly lower in the prolonged ICU group ( $p = 0.001$ ), indicating an association between hypothermia and longer ICU stay. LVEF showed a borderline association ( $p = 0.058$ ), suggesting a possible but not definitive relationship with ICU duration.

*Table 13: Independent sample t-test for continuous variables*

Variable	ICU stay <48 hrs (n=46) Mean $\pm$ SD	ICU stay $\geq$ 48 hrs (n=24) Mean $\pm$ SD	t-value	p-value
Age (years)	43.2 $\pm$ 10.9	47.8 $\pm$ 12.5	-1.54	0.128
BMI (kg/m <sup>2</sup> )	24.2 $\pm$ 3.2	25.3 $\pm$ 3.7	-1.26	0.214
$\text{PaO}_2/\text{FiO}_2$ ratio	322 $\pm$ 74	248 $\pm$ 61	4.28	<0.001
Core temperature (°C)	36.2 $\pm$ 0.4	35.8 $\pm$ 0.5	3.61	0.001
LVEF (%)	52.4 $\pm$ 8.1	48.1 $\pm$ 9.2	1.94	0.058

**Table 2. Mann–Whitney U test for skewed continuous variables:**

This table presents comparisons for non-normally distributed variables. MPAP was significantly higher in patients with prolonged ICU stay ( $p = 0.002$ ), indicating that elevated pulmonary pressure is associated with worse outcomes. ICU stay duration and hospital stay were significantly longer in the prolonged ICU group ( $p < 0.001$ ), confirming the expected relationship.

Table 14: Mann–Whitney U test for skewed continuous variables

Variable	ICU stay <48 hrs (n=46) Median (IQR)	ICU stay ≥48 hrs (n=24) Median (IQR)	p-value
MPAP (mmHg)	19 (16–23)	25 (22–30)	0.002
ICU stay (hours)	28 (22–37)	61 (52–84)	<0.001
Hospital Stay (days)	7 (6–9)	10 (8–13)	<0.001

**Table 3. Chi-square test for early postoperative risk categories:**

The analysis shows significant associations between several clinical factors and prolonged ICU stay: Higher MPAP ( $\geq 21$  mmHg) was significantly associated with longer ICU stay ( $p = 0.018$ ). Poor oxygenation ( $\text{PaO}_2/\text{FiO}_2 \leq 300$ ) strongly correlated with prolonged ICU stay ( $p = 0.001$ ). Prolonged ventilation ( $>12$  hours) had a very strong association ( $p < 0.001$ ). Low cardiac output syndrome was significantly more frequent in prolonged ICU cases ( $p = 0.004$ ). Postoperative atrial fibrillation also showed a significant relationship ( $p = 0.02$ ). These findings highlight important early postoperative predictors of ICU prolongation.

Table 15: Chi-square test for early postoperative risk categories

Variable	Category	ICU stay <48 hrs (n=46)	ICU stay ≥48 hrs (n=24)	p-value
MPAP category	<21 mmHg	31 (67.4%)	9 (37.5%)	<b>0.018</b>
	≥21 mmHg	15 (32.6%)	15 (62.5%)	
PaO <sub>2</sub> /FiO <sub>2</sub> category	>300	32 (69.6%)	7 (29.2%)	<b>0.001</b>
	≤300	14 (30.4%)	17 (70.8%)	
Prolonged ventilation >12 hrs	No	39 (84.8%)	11 (45.8%)	<b>&lt;0.001</b>
	Yes	7 (15.2%)	13 (54.2%)	
Low cardiac output syndrome	No	41 (89.1%)	14 (58.3%)	<b>0.004</b>
	Yes	5 (10.9%)	10 (41.7%)	
Postoperative AF	No	40 (87.0%)	15 (62.5%)	<b>0.02</b>
	Yes	6 (13.0%)	9 (37.5%)	

**Table 4. Chi-Square Test for Early Postoperative Risk Categories:**

This analysis identified several significant predictors of prolonged ICU stay: Double-valve surgery increased the risk more than fourfold (OR = 4.26). Moderate to severe pulmonary hypertension and elevated MPAP were significant predictors. Poor oxygenation ( $\text{PaO}_2/\text{FiO}_2 \leq 300$ ) increased risk more than five times. Hypothermia was associated with a fourfold increased risk. Low cardiac output syndrome and acute kidney injury were strong predictors. Prolonged ventilation showed the highest risk (OR = 8.2). Postoperative atrial fibrillation and pneumonia were also significant contributors. Overall, these results demonstrate that both preoperative and postoperative clinical factors significantly influence ICU stay duration.

Table 16: Chi-Square Test for Early Postoperative Risk Categories

Variable	Category	ICU stay <48 hrs (n=46)	ICU stay ≥48 hrs (n=24)	p-value
MPAP category	<21 mmHg	31 (67.4%)	9 (37.5%)	0.018
	≥21 mmHg	15 (32.6%)	15 (62.5%)	

PaO <sub>2</sub> /FiO <sub>2</sub> category	>300	32 (69.6%)	7 (29.2%)	0.001
	≤300	14 (30.4%)	17 (70.8%)	
Prolonged ventilation >12 hrs	No	39 (84.8%)	11 (45.8%)	<0.001
	Yes	7 (15.2%)	13 (54.2%)	
Low cardiac output syndrome	No	41 (89.1%)	14 (58.3%)	0.004
	Yes	5 (10.9%)	10 (41.7%)	
Postoperative AF	No	40 (87.0%)	15 (62.5%)	0.02
	Yes	6 (13.0%)	9 (37.5%)	

### Univariate Logistic Regression for Prolonged ICU Stay:

Table 17: Univariate Logistic Regression for Prolonged ICU Stay

Variable	Crude OR	95% CI	p-value
Double-valve surgery	4.26	1.26–14.36	0.02
Moderate/severe pulmonary hypertension	3.18	1.14–8.87	0.027
MPAP ≥21 mmHg	3.45	1.23–9.66	0.018
PaO <sub>2</sub> /FiO <sub>2</sub> ≤300	5.56	1.91–16.19	0.002
Hypothermia (<36°C)	4.09	1.38–12.13	0.011
Low cardiac output syndrome	5.88	1.67–20.68	0.006
Acute kidney injury	5.25	1.36–20.19	0.016
Prolonged ventilation (>24 hrs)	8.2	2.40–28.06	0.001
Postoperative AF	4	1.26–12.72	0.019
Pneumonia	5.81	1.02–32.97	0.047

## CHAPTER 5 DISCUSSION

The present study evaluated the clinical, perioperative, and postoperative factors associated with prolonged ICU stay in patients undergoing valve surgery. The findings highlight that both preoperative hemodynamic status and early postoperative complications play a critical role in determining ICU outcomes. In this study, the majority of patients belonged to the middle-aged group, particularly between 41–50 years. This is consistent with regional patterns where valvular heart disease tends to present earlier compared to Western populations, largely due to rheumatic etiology. The slight male predominance observed in this study aligns with several previous reports; however, gender was not found to significantly influence ICU stay, suggesting that outcomes are more dependent on physiological rather than demographic factors [17,18].

Body mass index did not show a significant association with prolonged ICU stay. Although obesity is often considered a risk factor in cardiac surgery, our findings suggest that BMI alone may not be a strong independent predictor, which is in agreement with studies showing inconsistent relationships between BMI and postoperative outcomes. Mitral valve replacement was the most commonly performed procedure, reflecting the high prevalence of mitral valve disease in the studied population. Importantly, double-valve surgery emerged as a significant predictor of prolonged ICU stay. This finding is supported by existing literature, where more complex surgical procedures are associated with longer operative times, increased physiological stress, and higher complication rates [22,23].

A key finding of this study was the strong association between pulmonary hypertension and prolonged ICU stay. Patients with moderate to severe pulmonary hypertension and elevated mean pulmonary artery pressure (MPAP  $\geq 21$  mmHg) were significantly more likely to require extended ICU care. This is consistent with previous studies demonstrating that increased pulmonary pressures contribute to right ventricular dysfunction and impaired postoperative recovery. Preoperative cardiac rhythm abnormalities, particularly atrial fibrillation, were relatively common; however, postoperative atrial fibrillation showed a stronger association with prolonged ICU stay. This suggests that new-onset or persistent arrhythmias after surgery may have a greater impact on patient outcomes than preexisting conditions [16,28].

Left ventricular ejection fraction (LVEF) showed a borderline association with ICU stay duration. Although patients with lower LVEF tended to have longer ICU stays, the relationship was not statistically significant. Similar findings have been reported in other studies, where mild to moderate ventricular dysfunction does not independently predict poor outcomes unless accompanied by other complications. Oxygenation status, as assessed by the PaO<sub>2</sub>/FiO<sub>2</sub> ratio, was one of the most significant predictors of ICU duration. Patients with impaired oxygenation ( $\leq 300$ ) had significantly prolonged ICU stays. This finding is consistent with the established role of respiratory dysfunction in delaying recovery following cardiac surgery [34,37].

Hypothermia was also identified as an important factor associated with prolonged ICU stay. Patients with lower core temperatures were more likely to experience delayed recovery, which may be due to its effects on coagulation, metabolism, and organ function. This aligns with existing evidence emphasizing the importance of maintaining normothermia during and after surgery. Postoperative complications, particularly prolonged ventilation, low cardiac output syndrome, and acute kidney injury, showed strong associations with extended ICU stay. Among these, prolonged ventilation emerged as the most significant predictor, increasing the likelihood of prolonged ICU stay more than eightfold. This reflects the critical role of respiratory function and ventilatory support in postoperative recovery [29,33].

Similarly, low cardiac output syndrome was strongly associated with prolonged ICU stay, highlighting the importance of adequate myocardial performance in the early postoperative period. Acute kidney injury, although less frequent, significantly increased the risk of prolonged ICU stay, supporting previous findings that renal dysfunction is a major determinant of morbidity after cardiac surgery. Postoperative pneumonia, although observed in a smaller proportion of patients, was also associated with increased ICU duration. This underscores the impact of infectious complications on recovery and resource utilization [39,40].

Overall, the findings of this study are consistent with previously published literature, demonstrating that prolonged ICU stay after valve surgery is multifactorial. Key contributors include elevated pulmonary pressures, impaired oxygenation, hypothermia, complex surgical procedures, and early postoperative complications such as prolonged ventilation and cardiac dysfunction.

## **CONCLUSION(S)**

This study showed that prolonged ICU stay after valvular surgery is influenced by both preoperative and postoperative factors. Important predictors included elevated pulmonary artery pressure, poor oxygenation, hypothermia, prolonged ventilation, low cardiac output syndrome, and acute kidney injury. Early identification of these risk factors can improve recovery, reduce complications, and optimize ICU resource use.

## **RECOMMENDATION(S)**

Patients with pulmonary hypertension or complex valve procedures should be identified as high risk before surgery.

Postoperative care should focus on maintaining oxygenation, normothermia, early extubation, and close monitoring of cardiac and renal function.

These measures may help reduce ICU stay and improve overall surgical outcomes.

## **LIMITATION(S)**

The study included only 70 patients, which may limit the generalizability of the findings. A larger sample size could provide more robust and statistically reliable results.

Data were collected from a single institution, which may not reflect practices, patient characteristics, or outcomes in other hospitals or regions.

The study focused only on immediate postoperative outcomes and ICU stay duration. Long-term outcomes such as survival, quality of life, and late complications were not evaluated.

Although several factors were analyzed, some potential confounders (e.g., intraoperative variables, surgeon experience, and preoperative comorbidities) were not fully controlled or adjusted.

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