Health & Research Journal

Vol 12, No 2 (2026)

Volume 12 Issue 2 April - June 2026

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doi: 10.12681/healthresj.41624

To cite this article:

Narliotis , G. P. (2026). Correlation between the duration of cardiopulmonary bypass (on-pump), mechanical support, and length of stay in the intensive care unit: A cross sectional study. *Health & Research Journal*, *12*(2), 73–81. https://doi.org/10.12681/healthresj.41624

HEALTH AND RESEARCH JOURNAL
E-ISSN:2459-3192

(2026), Volume 12, Issue 2

RESEARCH ARTICLE

CORRELATION BETWEEN THE DURATION OF CARDIOPULMONARY BYPASS (ON-PUMP), MECHANICAL SUPPORT, AND LENGTH OF STAY IN THE INTENSIVE CARE UNIT: A CROSS SECTIONAL STUDY

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Abstract

Background: Length of stay in the Intensive Care Unit (ICU) is a significant indicator in the management of cardiac surgery patients. Cardiopulmonary bypass (CPB) is used in a large number of cardiac procedures, while the duration of mechanical ventilation may affect both the length of ICU stay and the prognosis of these patients.

Method and Material: This was a cross-sectional study with convenience sampling, where data were collected from June 2024 to September 2024. The study involved 100 patients who underwent cardiac surgery with cardiopulmonary bypass at the General Hospital of Athens "HIPPOKRATEIO." Information was obtained from patients' medical and nursing records, without any direct interventions. A specially designed form, developed by the researcher based on a thorough review of the literature and the most frequently reported perioperative variables associated with postoperative ICU outcomes. The form included sections on personal history, comorbid conditions, surgical details, intraoperative complications, ICU length of stay, and postoperative outcomes. Statistical tests included the Chi-square (x^2) test, t-test, and Pearson correlation, with a significance level set at 5%. Statistical analysis was conducted using SPSS version 25.0.

Results: A total of 100 patients who underwent on-pump cardiac surgery were included. The majority were aged between 66 and 79 years, and 51% were male. A significant positive correlation was observed between the duration of cardiopulmonary bypass and both ICU length of stay ($p=0.015$) and the duration of mechanical ventilation ($p=0.018$). Similarly, longer surgery and aortic cross-clamp times were also associated with prolonged ICU hospitalization and extended respiratory support ($p<0.001$). These findings suggest that intraoperative time parameters significantly influence postoperative ICU outcomes.

Conclusions: The present study suggests that prolonged ICU stay is mainly influenced by comorbidities as well as intraoperative and postoperative factors, highlighting the need for optimization of perioperative management in cardiac surgery patients.

Keywords: Extracorporeal circulation, cardiac surgery, intensive care unit, length of stay, mechanical ventilation.

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Cite as: Narliotis, G. P. (2026). Correlation between the duration of cardiopulmonary bypass (on-pump), mechanical support, and length of stay in the intensive care unit: A cross sectional study. Health and Research Journal,12(2),73-81. https://ejournals.epublishing.ekt.gr/index.php/HealthResJ

INTRODUCTION

Cardiovascular diseases (CVD) remain a leading cause of death in the developed world, prompting more than 1.5 million cardiac surgical interventions annually.[1] The most common form of CVD is coronary artery disease, with all forms of CVD accounting for nearly 17.9 million deaths worldwide each year.[2] In Greece, approximately 10,500 patients undergo cardiac surgery each year.[3] Among these procedures, coronary artery bypass grafting (CABG) and valve replacements are the most frequent. Cardiopulmonary bypass (CPB) plays a critical role in many such interventions, allowing for temporary cardiac and pulmonary support.[4] Globally, over 1.25 million patients undergo CABG each year, while aortic valve replacement (AVR) and mitral valve replacement (MVR) comprise about 19% of surgeries.[5]

Cardiopulmonary bypass (on-pump) is essential in many cardiac

procedures as it temporarily replaces the heart and lungs' function, safeguarding end-organ perfusion. These patients often present with multiple comorbidities and advanced age. Postoperative complications such as arrhythmias, respiratory disturbances, prolonged ICU stay, and 30-day mortality are prevalent.[6] Postoperative management in the ICU is closely linked with the course of recovery. Extracorporeal circulation triggers activation of the coagulation system, which together with the consumption of clotting factors and platelets, increases the risk of bleeding. This risk is further amplified by hemodilution and activation of the fibrinolytic system during cardiopulmonary bypass.[7] Complications like surgical bleeding, stroke, and coagulation disorders may extend the ICU stay. Pulmonary complications include hemithorax atelectasis and acute respiratory failure, while renal function may deteriorate, causing acute kidney injury and necessitating dialysis. Metabolic disturbances such as hypothermia and hyperglycemia also demand vigilant nursing care. Cardiac complications include acute myocardial infarction, cardiomyopathy, and arrhythmias like atrial fibrillation.[8] Patients undergoing cardiac surgery are at considerable risk of developing postoperative atrial fibrillation (POAF), with reported incidences ranging from 15% to 50%. The lowest rates are observed after isolated CABG, while higher rates occur following valve surgery, particularly when CABG and valve procedures are combined.[9]

The duration of ICU stay serves as a prognostic indicator of survival and quality of life, influenced by both preoperative and postoperative factors.[10,11] In a retrospective study of 8,309 cardiac surgery ICU admissions, 14% stayed >7 days, operative mortality rose from 11% (≥7 days) to 35% (≥28 days) with increasing duration of ICU stay.[12] Maintaining anesthesia, mechanical ventilation, and hemodynamic support are immediate ICU goals. Continuous monitoring of respiratory rate, heart rate, temperature, and neurological and renal function enables stabilization. A planned, early pharmacological and mechanical weaning protocol may mitigate long-term complications and lead to successful extubation.[13]

Understanding the intra- and postoperative factors influencing ICU weaning and length of stay following on-pump cardiac surgery (OPCS) is critical for nursing planning and resource allocation at both scientific and clinical levels. Identifying these predictors allows for early risk stratification, targeted interventions, and the implementation of evidence-based protocols aimed at reducing postoperative complications, optimizing patient recovery, and shortening ICU duration. Moreover, such insights support more efficient utilization of critical care resources, enhance patient safety, and improve overall postoperative outcomes, including reduced morbidity and mortality. By systematically analyzing preoperative, intraoperative, and postoperative variables, clinicians and nursing staff can better anticipate complications such as arrhythmias, respiratory failure, renal dysfunction, and bleeding, thereby improving the quality of care and resource management in the ICU setting.

MATERIAL AND METHODS

This was a cross-sectional study conducted at the Cardiac Surgery Intensive Care Unit of "Hippokration" General Hospital in Athens from June to September 2024. Data were collected retrospectively from medical records. A total of 100 adult patients (≥18 years old) who underwent cardiac surgery with CPB and were admitted postoperatively to the ICU were included. Patients were selected using convenience sampling. The sample size was determined by time constraints and the availability of complete clinical data during the designated study period. All eligible patients consecutively admitted during this timeframe were considered for inclusion. One patient died intraoperatively and was included in the overall dataset but excluded from statistical outcome comparisons.

A structured data collection form was developed by the researcher, based on a thorough review of the literature and the most frequently reported perioperative variables associated with postoperative ICU outcomes. The form recorded patient demographics, comorbidities, type and urgency of surgery, CPB duration, intraoperative and postoperative events (e.g., fluid therapy, vasopressor use, transfusions), mechanical ventilation time, and length of ICU stay (LOS). Although the data collection form included clinical variables commonly found in cardiac risk assessment tools such as EuroSCORE, it was designed independently by the researcher for observational analysis and was not intended for risk stratification.

Descriptive statistics were used to summarize patient characteristics. The Kolmogorov-Smirnov test was employed to assess the normality of continuous variables. Continuous variables were expressed as mean ± standard deviation. Associations between variables were evaluated using Student's t-test, Pearson's correlation, and chi-square test where appropriate. A p-value <0.05 was considered statistically significant. SPSS v25.0 was used for analysis.

RESULTS

Among the 100 patients included in the study, 51% were male. The largest age group was between 66–79 years, representing 65% of the sample, while the mean age was 71.2 years (±8.3). The demographic and clinical characteristics of the patients are presented in Table 1. Hypertension was the most prevalent comorbidity (78%), followed by diabetes mellitus (35%) and COPD (14%). Atrial fibrillation was present in 9% of patients. Regarding surgical procedures, the majority (58%) underwent combined CABG and aortic valve replacement (AVR), while 23% underwent isolated AVR and 19% underwent mitral valve replacement (MVR). Table 2 shows an overview of patients and their comorbid conditions.

Several significant associations were observed:

- Diabetes mellitus was significantly associated with prolonged use of diuretics ($p = 0.029$).
- History of atrial fibrillation was associated with extended antiarrhythmic therapy in the ICU ($p < 0.001$).
- COPD was associated with lower PaO_2/FiO_2 ratios within the first 24 hours postoperatively ($p = 0.006$).
- History of smoking was associated with shorter ICU stay ($p = 0.003$) and reduced duration of mechanical ventilation ($p = 0.004$).
- Moderate body surface area (BSA) was associated with shorter duration of antiarrhythmic therapy ($p = 0.024$).
- Normal creatinine levels were associated with lower PaO_2/FiO_2 ratios ($p = 0.009$).

In terms of correlation analysis:

- A moderate positive correlation was observed between the duration of mechanical ventilation and ICU length of stay ($r = 0.54$, $p < 0.01$).
- A similar correlation was found between cardiopulmonary bypass (CPB) time and ICU length of stay ($r = 0.47$, $p < 0.01$).

Significant statistical associations of the patients are presented in Table 3. Correlation coefficients between variables of the patients are presented in Table 4.

DISCUSSION

The present study found that ICU stays ranged from 2 to 4 days, with 78.0% of patients remaining in the ICU for 2 days, while a smaller subgroup had prolonged stays of 3 to 4 days. Additionally, 20.0% of patients required mechanical ventilation for more than 2 days. Postoperative complications were observed in 21.0% of the sample, with atrial fibrillation (6.0%), hyperglycemia (6.0%), and bleeding (5.0%) being the most frequent.

The duration of ICU stay is a key indicator in hospital resource management. Reducing ICU stay in cardiac surgery patients may lead to lower healthcare costs, more efficient use of staffing and material resources, and improved bed availability. Conversely, prolonged ICU stays are associated with increased hospital expenditure and reduced ICU capacity. Understanding the preoperative and intraoperative factors that contribute to extended ICU stays can help reduce postoperative complications, enhance clinical outcomes, and improve overall quality of care in cardiac surgical patients.[14]

Previous research has shown that prolonged ICU stays following cardiac surgery affect 4% to 11% of patients, with variability attributed to inconsistent definitions of "prolonged" ICU stay — ranging from durations over or equal to 5 days.[15] Studies have identified multiple preoperative predictors for prolonged ICU stay, including advanced age, pre-existing cardiac arrhythmias (particularly atrial fibrillation), chronic obstructive pulmonary disease, and renal dysfunction.[16] In a retrospective study by Hein et al., 26% of patients who stayed more than 3 days in the ICU had independent risk factors including advanced age, renal and respiratory failure, heart failure, and readmission.[17] Similarly, Au et al. found that preoperative cognitive impairment in elderly cardiac surgery patients was associated with longer ICU stays (mean difference of 0.39 days).[18]

In our cohort, most patients had comorbidities, with hypertension (78.0%), diabetes mellitus (35.0%), and chronic kidney disease (17.0%) being the most prevalent. Diabetes, pre-existing cardiac arrhythmias — particularly atrial fibrillation, and COPD were associated with prolonged ICU stay and increased pharmacologic support (antiarrhythmics and diuretics).

Previous studies have highlighted the duration of CPB as a critical determinant of ICU LOS. According to Almashrafi et al., prolonged CPB is linked to extended mechanical ventilation and a higher incidence of complications such as arrhythmias and atelectasis—an association confirmed by the present study.[19] Likewise, intra- and postoperative complications, blood transfusions, and respiratory issues significantly impacted ICU stay. Osinaike et al. emphasized that prolonged ICU stays are strongly associated with respiratory complications, transfusions, and intra-aortic balloon pump (IABP) use. In a sample of 194 patients, the average ICU stay was 3.96 ± 1.60 days.[20]

Strategies for reducing ICU stay have focused on early extubation (EE) and hemodynamic stability through fluid balance optimization. Taylor et al. reported that EE is both safe and effective in appropriately selected patients, reducing ICU time without increasing complications.[21] The Society of Thoracic Surgeons (STS) considers extubation within 6 hours as a quality benchmark, though a universally accepted definition of EE remains lacking.[22] Zhang et al. examined 401 cardiac surgery patients using the Vasoactive-Ventilation-Renal (VVR) score to predict weaning failure from mechanical ventilation. This prognostic index combines parameters of hemodynamic, respiratory, and renal support. The study found a strong association between higher VVR scores at 72 hours post-op and extubation failure ($p<0.001$), correlating with longer ICU stay and higher mortality.[23] Similarly, in our study, prolonged CPB time, aortic cross-clamp duration, and use of vasopressors were significantly associated with the need for extended mechanical ventilation. We also found that impaired respiratory function ($PaO_2/FiO_2 < 200$), acute kidney injury, and the presence of COPD were significantly correlated with prolonged ICU stay. These findings align closely with the parameters assessed in the VVR model.

Thus, it becomes evident that the integrated evaluation of hemodynamic, pulmonary, renal status together with APACHE II scores and patient age, plays a crucial role in predicting ICU outcomes in cardiac surgery patients. Long-term survival analyses indicate that patients with prolonged ICU stays initially exhibit significantly lower survival rates. However, among those who survive the early critical period, 6-month to 3-year survival is comparable to patients without extended ICU hospitalization.[17] Our findings align with previous research indicating that a multifaceted approach is necessary to reduce ICU length of stay. Early identification and management of high-risk patients can therefore improve short-term outcomes, optimize resource use, and support recovery trajectories after OPCS. In addition, tailored weaning protocols and proactive management of comorbidities are decisive strategies.[24] Furthermore, ICU resource allocation, including personnel and monitoring tools, should account for these predictors to enhance care efficiency.

Limitations of this study include its retrospective design and the single-center setting, which may affect generalizability. Furthermore, the relatively small sample size may reduce the statistical power and the strength of the findings. Additionally, potential confounders such as intraoperative fluid balance, transfusion requirements, and anesthetic agents were not included in the dataset.

CONCLUSIONS

Future studies should incorporate these elements and validate predictive models across broader, multicenter populations. Emphasis should also be placed on examining the impact of enhanced recovery protocols and fast-track cardiac surgery pathways on ICU outcomes.

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ANNEX

TABLE 1. Demographic and Clinical Characteristics of the Sample

Variable	**Frequency (n)**	**Percentage (%)**
Male	51	51%
Age 66–79 years	65	65%
Hypertension	78	78%
Diabetes Mellitus	35	35%
COPD	14	14%
Atrial Fibrillation	9	9%
CABG + AVR	58	58%

TABLE 2. Comorbidities

Comorbidities	ICU Stay ≤2 Days			ICU Stay >3 Days		p-value
	n		%	n	%	
Presence of comorbidity	Yes	69	77.5	20	22.5	0.746
	No	9	81.8	2	18.2	
Smoking	Yes	19	95.0	1	5.0	*0.040*
	No	59	73.8	21	26.3	
Alcohol	Yes	9	81.8	2	18.2	0.746
	No	69	77.5	20	22.5	
Hypertension	Yes	59	75.6	19	24.4	0.284
	No	19	86.4	3	13.6	
Diabetes Mellitus (DM)	Yes	24	68.6	11	31.4	0.095
	No	54	83.1	11	16.9	
Chronic Kidney Disease (CKD)	Yes	14	82.4	3	17.6	0.634
	No	64	77.1	19	22.9	
Cardiac arrhythmia	Yes	10	66.7	5	33.3	0.250
	No	68	80.0	17	20.0	
Type of cardiac arrhythmia	- Atrial fibrillation	5	55.6	4	44.4	0.418
	- Atrial flutter	2	66.7	1	33.3	
	- First Degree AV block	1	100.0	0	0.0	
	- Second Degree AV block	2	100.0	0	0.0	
Stroke (CVA)	Yes	9	75.0	3	25.0	0.789
	No	69	78.4	19	21.6	
COPD	Yes	10	71.4	4	28.6	0.522
	No	68	79.1	18	20.9	
Pulmonary hypertension	Yes	13	81.3	3	18.8	0.732
	No	65	77.4	19	22.6	
Previous cardiac surgery	Yes	11	84.6	2	15.4	0.537
	No	67	77.0	20	23.0	

TABLE 3. Significant Statistical Associations

Variable	**Associated Outcome**	**p-value**
Diabetes Mellitus	Prolonged diuretic therapy	*0.029*
Atrial Fibrillation	Extended antiarrhythmic use	*<0.001*
COPD	Lower PaO2/FiO2 first 24h	*0.006*
Smoking	Shorter ICU stay & ventilation time	*0.003 / 0.004*
Moderate BSA	Shorter antiarrhythmic use	*0.024*
Normal creatinine	Lower PaO2/FiO2	*0.009*

TABLE 4. Correlation Coefficients Between Variables

VARIABLES	**Duration of CPB (min)**		**Duration of Surgery (h)**	**Aortic Cross-Clamp Time (min)**	**ICU Stay (days)**	**Mechanical Ventilation (days)**
Duration of CPB (min)	**r**	1	0.629	0.764	0.243	0.238
	p		*<0.001*	*<0.001*	*0.015*	*0.018*
	n	100	100	100	99	99
Duration of Surgery (h)	**r**	0.629	1	0.513	0.136	0.130
	p	*<0.001*		*<0.001*	0.178	0.199
	n	100	100	100	99	99
Aortic Cross-Clamp Time (min)	**r**	0.764	0.513	1	0.307	0.282
	p	*<0.001*	*<0.001*		*0.002*	*0.005*
	n	100	100	100	99	99
ICU Stay (days)	**r**	0.243	0.136	0.307	1	0.979
	p	*0.015*	0.178	*0.002*		*<0.001*
	n	99	99	99	99	99
Mechanical Ventilation Duration (days)	**r**	0.238	0.130	0.282	0.979	1
	p	*0.018*	0.199	*0.005*	*<0.001*	
	n	99	99	99	99	99