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Section Article

Title:

Association of Cardiopulmonary Bypass and Aortic Cross-Clamp Durations with ICU Length of Stay in Cardiac Surgery Patients: A Retrospective Study at Nasiriya Heart Center.

Running Title: Impact of CPB and Cross-Clamp Times on ICU Stay

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ABSTRACT

Background: Cardiopulmonary bypass (CPB) and aortic cross-clamping are essential components of many cardiac surgical procedures. However, prolonged durations have been linked to adverse outcomes, including delayed recovery and increased intensive care unit (ICU) resource utilization. Understanding their impact is critical for improving perioperative management and optimizing patient outcomes.

Objective: To evaluate the influence of cardiopulmonary bypass time (CPBT) and aortic cross-clamp time (ACCT) on intensive care length of stay for patients with elective cardiac surgery.

Methods: A retrospective clinical study was conducted at Nasiriya Heart Center, Iraq, between September 2023 and September 2024. A total of 100 patients (aged 18–65 years) who underwent elective cardiac surgery were included. Demographic data, type of surgery, admission and discharge dates, and intraoperative variables (CPBT and ACCT) were collected. Associations between CPBT, ACCT, and ICU stay were analyzed using appropriate statistical methods.

Results: Of the 100 patients, 47% were male and 53% female, with a mean age of 44 years. The mean CPBT was 112.6 ± 44.2 minutes, and the mean ACCT was 69.0 ± 34.5 minutes. Gender showed no significant effect on ICU stay. In contrast, both prolonged CPBT and ACCT were significantly associated with longer ICU stays (P = 0.047 and P = 0.005, respectively).

Conclusion: Extended CPBT and ACCT are significant predictors of prolonged ICU stay after cardiac surgery. Strategies to minimize intraoperative times may help reduce postoperative ICU occupancy and improve overall resource allocation in cardiac surgical care.

1. Introduction

Cardiopulmonary bypass (CPB) represents one of the most significant advancements in modern cardiac surgery. It is a specialized form of extracorporeal circulation in which systemic venous blood is diverted from the heart and lungs and routed through an external circuit, ensuring continuous systemic perfusion and oxygenation during surgery [1]. In most procedures, the heart is isolated from the systemic circulation by aortic cross-clamping (ACC), and a cardioplegic solution is administered. This technique allows surgeons to operate in a motionless and bloodless operative field while preserving vital organ function [2–4].

Despite its advantages, prolonged application of CPB and ACC carries a progressive risk of myocardial ischemia due to interruption of coronary perfusion [5]. To counteract ischemic injury, myocardial protection strategies such as cardioplegia, systemic hypothermia, and cardiac perfusion techniques have been employed. Nevertheless, ACC duration remains a major determinant of postoperative myocardial dysfunction and is closely linked with low cardiac output syndrome (LCOS), often necessitating inotropic support, mechanical assistance, and prolonged intensive care unit (ICU) management [6]. Multiple perioperative factors—including patient demographics, surgical type and complexity, duration of CPB, ACC time, renal dysfunction, and postoperative organ impairment—have been studied for their impact on outcomes [7,8]. Among these, prolonged mechanical ventilation (PMV) exceeding seven days has emerged as a significant determinant of mortality, residual disability, and overall length of stay (LOS) [8, 9]. However, most evidence originates from international centers, with limited data from Middle Eastern populations.

In Iraq, and particularly at the Nasiriya Heart Center, there remains a paucity of published studies addressing the relationship between intraoperative variables and ICU outcomes. Considering the potential implications for resource utilization and patient prognosis, it is essential to investigate these associations in local populations. Therefore, the present study aims to evaluate the relationship between CPB duration, ACC time, and *postoperative ICU stay in patients undergoing cardiac surgery at the Nasiriya Heart Center.*

2. Methodology

2.1. Study Design and Setting

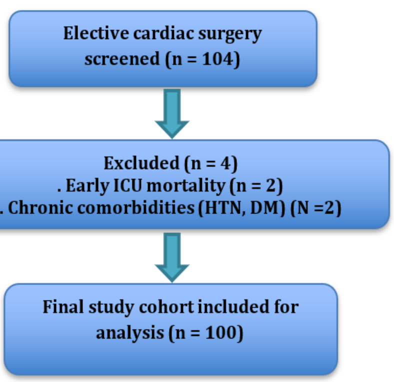
This retrospective, single-center study was conducted at the Nasiriya Heart Center for Cardiac Surgery, Dhi Qar, Iraq. The study included adult patients aged 18–65 years who underwent elective cardiac surgery requiring cardiopulmonary bypass (CPB) over a one-year period, between September 2023 and September 2024.

2.2. Study Population

Eligible patients were those admitted postoperatively to the intensive care unit (ICU) following elective cardiac surgery performed with CPB support. Exclusion criteria included; patients who underwent emergency cardiac surgery, patients who died within the early postoperative days in the ICU, and patients with incomplete or missing medical records.

A total of 104 patient records were initially screened. Four cases were excluded: two patients who died during the early ICU stay and two patients with chronic comorbidities (hypertension and diabetes mellitus). Ultimately, 100 patient records were included in the final analysis (Figure 1).

Figure 1. Flow diagram of patient selection for the retrospective cohort study.



2.3. Data Collection

Patient data were reviewed and extracted from medical records using a structured data collection form. The following parameters were assessed:

- *Demographic data: age and sex.*
- *Preoperative variables: diagnosis, clinical syndrome, left ventricular (LV) function, and risk category.*
- *Intraoperative variables: CPB duration (measured from initiation to termination) and aortic cross-clamp (ACC) time.*
- *Postoperative variables: duration of ICU stay, total length of hospital stay (LOS), and in-hospital mortality.*

Admission and discharge dates were documented to precisely determine ICU and hospital LOS.

2.4. Patient Grouping

Based on ICU length of stay, patients were stratified into three groups: Group I: ICU stay of 1–3 days, Group II: ICU stay of 4–6 days, and Group III: ICU stay exceeding 6 days. Preliminary analysis of the data indicated that the mean ICU stay was 4 days. Accordingly, a prolonged ICU stay was defined as an ICU admission exceeding 4 days following elective coronary artery bypass grafting (CABG) surgery.

2.5. Ethical Considerations

This study was approved by the Ethical Committee of the Dhi Qar Health Office. All procedures adhered to the ethical principles outlined in the Iraqi national research standards and international guidelines for studies involving human participants. Patient confidentiality was strictly maintained through anonymization of data prior to analysis.

2.6. Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 22 (SPSS Inc., Chicago, IL, USA). Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized using medians and interquartile ranges (IQRs).

The Kolmogorov–Smirnov test was applied to assess the normality of data distribution. As normality assumptions were not met for all variables, non-parametric statistical methods were used. Correlations between variables were assessed using Spearman's rank correlation coefficient, and group comparisons were performed with the Mann–Whitney U test. A two-tailed p-value < 0.05 was considered statistically significant.

3. Results

A total of 100 patients who underwent elective cardiac surgery with cardiopulmonary bypass (CPB) were included in the study. Patient characteristics are summarized in Table 1. The mean age was 44.1 ± 15.9 years (median 47 years), and 53% were female.

Table 1 Descriptive analysis of the patients' characteristics

Variable		N	Mean ± SD	Median	n (%)
Age (years)		100	44.1 ± 15.9	47	
Sex	Male	47	-	-	(47%)
	Female	53	-	-	(53%)

The mean CPB time was 112.6 ± 45.2 minutes (median 110, range 48–242 minutes), and the mean aortic cross-clamp (ACC) time was 69.0 ± 38.1 minutes (median 65, range 4–208 minutes) (Table 2).

Table 2 Descriptive analysis of the patients'

Intraoperative variables.

Variable	Mean ± SD	Median	Range
CPB time (min)	112.6 ± 45.2	110	48–242
ACC time (min)	69.0 ± 38.1	65	4–208

The association between gender and ICU length of stay was not significant (p = 0.089;2), indicating that male and female patients had similar ICU durations (Table 3).

Table 3. Gender and ICU stay

Gender	ICU Duration 1–3 Day	ICU Duration 4–6 Day	ICU Duration >6 Day	Total	Chi-square test (p value, df)
Male	30 (63.8%)	12 (25.5%)	5 (10.7%)	47	
Female	28 (52.8%)	17 (32.1%)	8 (15.1%)	53	p = 0.089, df = 2
Total	58 (58.0%)	29 (29.0%)	13 (13.0%)	100	

Increasing age was significantly associated with longer ICU stay (χ^2 test, p = 0.001). All patients aged <21 years stayed 1–3 days, whereas among patients >60 years, only 50% stayed 1–3 days; 25% stayed 4–6 days, and 25% stayed >6 days (Table 4).

Table 4. Age and ICU stay

Age Groups	1–3 Day	4–6 Day	> 6 Day	Total	Chi-square test (p value, df)
< 21 years	10 (100%)	0 (0%)	0 (0%)	10 (100%)	(0.001;6)
21–40 years	27 (96%)	1(4%)	0 (0%)	28 (100%)	
41–60 years	41(82%)	8 (16%)	1 (2%)	50 (100%)	
> 60 years	6 (50%)	3 (25%)	3 (25%)	12 (100%)	

Longer CPB time was significantly associated with prolonged ICU stay (p = 0.047). All patients with CPB <60 minutes stayed 1–3 days, while patients with CPB 180–240 minutes had only 50% staying 1–3 days, 33.3% staying 4–6 days, and 16.7% staying >6 days (Table 5).

Table 5 ICU Duration According to CPB Time

CPB time	1–3 Day	4–6 Day	> 6 Day	Total	Chi-square test (p value, df)
< 60 minutes	13 (100%)	0 (0%)	0 (0%)	13 (100%)	(0.047; 6)
60–119 minutes	49 (89.1%)	5 (9.1%)	1 (1.8%)	55 (100%)	
120–179 minutes	19 (73.1%)	5 (19.2%)	2 (7.7%)	26 (100%)	
180–240 minutes	3 (50%)	2 (33.3%)	1 (16.7%)	6 (100%)	

Longer ACC time was also significantly associated with prolonged ICU stay (p = 0.005). Patients with ACC <60 minutes predominantly stayed 1–3 days (88.1%), whereas those with ACC 180–240 minutes all stayed >4 days (Table 6)

Table 6. ACC time and ICU stay

ACC Time (minutes)	ICU Duration 1–3 Day	ICU Duration 4–6 Day	ICU Duration >6 Day	Total	Chi-square test (p value, df)
< 60 minutes	88.1% (n = 37)	5 (11.9%)	0 (0%)	100% (42)	p = 0.005, df = 6
60–119 minutes	85.7% (n = 42)	5 (10.2%)	2 (4.1%)	100% (49)	
120–179 minutes	71.4% (n = 5)	1 (14.3%)	1 (14.3%)	100% (7)	
180–240 minutes	0% (n = 0)	1 (50%)	1 (50%)	100% (2)	

4. Discussion

Cardiopulmonary bypass (CPB) is a medical technique used during certain surgical procedures, such as open-heart surgery. During CPB, the patient's blood is pumped through an artificial oxygenator and then returned to the body. While CPB is a life-saving procedure, it can also have several physiological effects on the body [10,11]. Cardiopulmonary bypass (CPB) induces a systemic inflammatory response, characterized by sequelae such as fever, coagulopathy, leukocytosis, edema, and multi-organ dysfunction [12, 13]. The severity of this response tends to increase with prolonged CPB duration. Furthermore, the extent of CPB-related complications has been shown to correlate not only with bypass duration but also with the patient's preoperative clinical condition (14,15).

In this context, the goal of medical professionals is to manage and minimize this response as much as possible to ensure the patient's safety and well-being. Various strategies and techniques, such as utilizing biocompatible materials in the CPB circuit, minimizing the duration of CPB, and administering anti-inflammatory medications, are employed to mitigate the inflammatory effects associated with CPB [1,2]

Undeniably, aortic cross-clamping is a common component of cardiac surgery, particularly during procedures like coronary artery bypass grafting (CABG). The aortic cross-clamp is used to temporarily stop blood flow through the aorta, allowing the surgeon to work on the heart without interference from blood flow. While aortic cross-clamping is necessary for the surgical procedure, it can also have implications in inflammation (e.g., Ischemia-Reperfusion Injury, Myocardial Inflammation, systemic effects on lungs and kidneys) [16-18]. To mitigate these effects, medical professionals take measures mainly by minimizing

Cross-Clamp Time to reduce the risk of ischemia-reperfusion injury and inflammation, by resorting to cardioplegia that protects the heart from ischemic injury during the period of cross-clamping, and closely monitor patients during and after surgery [19].

In the literature, numerous clinical investigations have consistently demonstrated that the lengths of ACC and CPB utilization during cardiac surgery independently influence the risks of both mortality and morbidity. To our knowledge, there is a paucity of such retrospective studies in IRAQ. To this purpose, we surveyed the association between cardiopulmonary bypass duration and aortic cross clamp time with post cardiac Surgery ICU hospitality in the Nasiriya Heart Center for Cardiac Surgery [20-22].

Our results showed that age, longer durations of CPB and ACC were associated with increased ICU length of stay (P=0.001*, 0.047* and 0.005* respectively). As contrary, the gender seems to be indifferent (P=0.089). Nonetheless, a discrepancy was noted in the literature. Bertrand et al. [23] and Ashraf et al [19] show no link between age and ICU bed occupancy after cardiac surgery while Rashid et al [24] noticed a slight prevalence in men over female. The difference in results may be due to different sets of patients with different perioperative variables and morbidity. Besides, cardiovascular diseases have long been seen as a condition affecting men. Although the age- specific rates of these conditions are higher in men than women in most age groups, the actual lifetime risk of them is similar for women and men [25,26].

In this study, the factor "age" is a good predictor of the ICU bed occupancy as shown in table 4 (P= 0.001). However, L. Santana-Cabrera et al concluded that no differences were found in ICU stay based on age, although a difference was found in mortality [27]. Similarly, Edison G. et al. reported that among survivors, age was not associated with ICU length of stay; however, in died individuals, increasing age correlated with prolonged ICU and overall hospital stay. [28]. Another study demonstrated that the increase in mortality with advancing age among ICU patients is not attributable to greater disease severity. Instead, it suggested that ICU mortality rises with age irrespective of treatment intensity. [29].

As expected, we found that CPB and ACC times predict strongly the length of stay in ICU with Pearson's rho= 0.325^{**}/P=0.047 and 0.302^{*}/P=0.005 respectively. These observations are in line with former studies. Nazish Alisher et al. prove this association [30]. Similarly, the findings of Szekely et al. were consistent with ours, as they reported a significant association between CPB duration and postoperative mechanical ventilation time [31]. Furthermore, several other studies have identified CPB duration as a risk factor for prolonged ICU stay in both pediatric and adult populations. [24, 32, 33]. Moreover, in Jan Bucerius et al. study, risk factors enhance by 1.59 times the length of stay in the ICU when the CPB was greater than 120 minutes, along with their result, in our study, the risk factors increase length of stay in ICU when the CPB was greater than 119 min [19]. Discordant results were also reported by other publications [34,35]. The discrepancy in findings is most likely attributable to variations in study methodologies and the inclusion of different sets of confounding perioperative variables compared with our study such as infection, UTI, vasculitis, pneumonia, diabetes and other inflammatory conditions that are very reliable risk factors determining the ICU and hospital durations as well as affecting mortality and other morbidity outcomes. Our current survey does not incorporate these factors which explains the clear and relevant association of CPB or ACC times to ICU bed occupancy. Moreover, the categorization of CPB and ACC times (as 30- minute categories) that we adopted in the same way as in Mehmood et al study yielded to a greater contribution in the ICU length of stay. This points up the importance of the continuous improvements brought in CBP and ACC technologies to alleviate their post-surgical consequences.

Of note, our study had several limitations. Mainly, it is a retrospective design and that it is a single-center study which provides a lesser quality of evidence in general and cannot exclude any causal relationships. Also, we were not able to assess postoperative outcomes (e.g. infection, pneumonia, noninfectious pulmonary complications, pneumothorax, chylothorax, cardiomyopathy, shock, mediastinitis, failure of sternal wound closure, necrotizing enterocolitis, bacteremia, extubation failure, length of MV…) for the reason of incomplete reports, neither mortality or survival, as the number of patients who died was small and not sufficient for any calculation. Thus, further studies involving a larger set of patients are required to confirm the presented findings. Lastly, as prolonged ICU stay is associated with poor post operatory outcomes and increased financial burden for patients, further Iraqi studies and more efforts are of utmost importance to investigate variables also prone to affect the duration of CBP, aortic clamping and the ICU discharge after cardiac surgeries.

5. Conclusion

Our study demonstrated that age, longer CBPT and ACCT duration lead to longer stay in the intensive care units. Prolonged ICU stay could worsen overall outcomes after cardiac surgeries and yield higher in-hospital morbidity. Therefore, intraoperative factors such as ACCT, CPBT should be taken into consideration to guide post-operative patient care.

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