

## Cardiopulmonary Bypass Perfusion Parameters and Early Postoperative Outcomes in Adult Cardiac Surgery: A Retrospective Study

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### Abstract

**Background:** Cardiopulmonary bypass (CPB) is a standard of contemporary cardiac surgery, but the difference in the perfusion parameters may contribute considerably to the postoperative outcomes. **Objective:** This study aimed to evaluate the cardiopulmonary bypass parameters, operative profiles, and early postoperative outcomes in patients undergoing cardiac surgery at Jinnah Hospital Lahore from January 2024 – August 2025. **Methodology:** There were 51 successive patients who were undergoing open-heart surgery under cardiopulmonary bypass and a retrospective study was carried out. Surgical procedures were mitral valve replacement (n=18), coronary artery bypass grafting (CABG, n=17), aortic valve replacement (n=7), atrial septal defect (ASD) repair (n=4), dual valve replacement (n=4) and Bentall/combined AVR+CABG (n=2). Perfusion variables were monitored such as bypass time, aortic cross-clamp time, flow rate, perfusion temperature, anticoagulation (ACT) and blood gas values. **Findings:** Cardiopulmonary bypass time was 45-120 minutes and mean cross-clamp time was 35-90 minutes, based on the

complexity of the procedure. The acid base management was effectively observed in all the cases and no significant complications in relation to perfusion were reported. Most of the patients had postoperative hemodynamic and satisfactory recovery profiles that were stable. A minor percentage of them had to spend a long time in ICU because of comorbid conditions and not because of the problems with intraoperative perfusion. **Conclusion:** The results provide a demonstration of the uniform and

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successful perfusion practices in the cardiac surgery unit of Jinnah Hospital Lahore. Differences in bypass and cross-clamp times were procedure specific but did not have a negative impact on the postoperative outcomes. Periodic review of perfusion data serves as an invaluable contribution to continuing clinical protocol improvements and strengthening the presence of qualified personnel as a guarantee of safe cardiac surgery within the framework of a developing country.

## **Introduction**

According to the World Health Organization, cardiovascular disease (CVD) remains the main cause of morbidity and mortality, causing approximately 17.9 million deaths annually (Jagannathan et al., 2019). In developing countries like Pakistan, the burden of cardiac disease is increasing because of the lifestyle changes, lack of preventive healthcare, and late diagnosis (Usman et al., 2024). Consequently, the prevalence of cardiac surgical procedures, especially valve replacements and coronary artery bypass grafting (CABG), has grown significantly during the last ten years (Raja et al., 2025). In this regard, the cardiopulmonary bypass (CPB) system has been one of the most significant technological developments in cardiac surgery that offers a regulated and stable physiological environment to enable the surgeon to work on a non-beating heart (Leivaditis et al., 2025).

## **Role of Cardiopulmonary Bypass in Cardiac Surgery**

Cardiopulmonary bypass is based on the principle of replacing the circulation of venous blood in the patient with an extracorporeal circuit, where blood is oxygenated and returned to the circulation (Kiziltug et al., 2018). This systemic perfusion and oxygen delivery system enables cardiac surgeons to work on complex procedures under controlled and motionless conditions (Anastasiadis et al., 2017). The major parameters like the pump flow rate, the arterial pressure, the oxygenator performance, the level of hematocrit, the perfusion temperature, and the balance of the blood gases should be closely observed to guarantee the safety and maximization of patient results. Any deviations of the optimal perfusion profile may result in metabolic disruptions, organ dysfunction, or delayed recovery (Saleem et al., 2025).

The profession of the perfusionist has changed over the years to become a highly specialized clinician charged with the safe management of extracorporeal circulation. The constant examination of the perfusion parameters has now played a crucial role in the process of ensuring intraoperative stability as well as assessment of the quality of perfusion practice in different institutions (Kunst et al., 2025). The significance of local data collection and retrospective analysis is paramount to comprehending the outcomes, optimizing perfusion methods, and defining context-specific clinical guidelines as cardiac centers in Pakistan and the rest of developing countries continue to grow (Butt et al., 2025).

## **Importance of Monitoring Perfusion Parameters**

The results of cardiac surgery directly depend on the accuracy of CPB parameters management. Some of the most vital variables include bypass duration and aortic cross-clamp time, which have a strong relationship with postoperative recovery and morbidity (Dwarkanath et al., 2025). The long cross-clamp period may exacerbate myocardial ischemia, whereas the long bypass period is linked with the systemic inflammatory response and multi-organ stress (Yeung et al., 2016). Likewise, the temperature management approach of normothermic, mild hypothermic, and moderate hypothermic impacts on the metabolic rate, oxygen consumption, and coagulation dynamics (Polderman et al., 2019).

The acid-base balance that should be sustained throughout CPB is another crucial parameter that is usually measured using arterial blood gas (ABG) (Marion et al.,

2025). The parameters, including pH, partial pressure of oxygen (PaO<sub>2</sub>), partial pressure of carbon dioxide (PaCO<sub>2</sub>) and bicarbonate (HCO<sub>3</sub><sup>-</sup>), are constantly measured to make sure that oxygen supply and carbon dioxide elimination does not exceed the physiological range (Mane et al., 2021). All these aspects determine the safety and efficacy of CPB and ultimately affect the postoperative outcomes in terms of the duration of mechanical ventilation, the ICU stay, and the general recovery pattern.

### **Challenges and Gaps in Developing Healthcare Settings**

At the resource-constrained level, e.g., in Pakistan, access to more sophisticated perfusion devices and monitoring software may differ across institutions (Zahid et al., 2023). Nonetheless, Jinnah Hospital Lahore, a tertiary hospital, has shown impressive improvement in cardiac surgical care with the help of trained perfusionists and multidisciplinary teams. Nonetheless, there is still limited data regarding local perfusion practices and outcomes. The majority of the literature that is published comes out of high-income nations, where infrastructure, patient demographics and disease patterns are widely different. As such, it is essential to produce native data to evaluate the quality of perfusion practices, underscore institutional experiences, and find possible ways to improve our situation.

Also, even though Western literature is often talking about such perfusion innovations as miniaturized circuits, heparin-coated tubing, and ultrafiltration strategies, many developing nations continue to perfect their foundational perfusion protocols, with a focus on precise monitoring, proper anticoagulation control, and hemodilution prevention (Bowen et al., 2025). Evaluating how these fundamental aspects are handled in a real-world hospital setting can provide valuable insights into performance standards and patient safety.

### **Rationale for the Present Study**

The Department of Cardiac Surgery at Jinnah Hospital Lahore is among the most successful public-sector cardiac units in the area, undertaking a wide spectrum of adult cardiac surgeries. The Perfusion Record (January 2024 - August 2025) is a valuable source of information that indicates the perfusion practice, procedural heterogeneity, and early postoperative trends during a specific time. The systematic analysis of this data provides a chance to evaluate the institution performance, detect the trends in the processes, and define the standards of the further improvement.

Retrospectively examining the parameters of perfusion, including bypass, cross-clamp, flow rate, ACT, temperature, and blood gas, this research will strive to present significant relationships between intraoperative management and postoperative results. In addition, the research offers an in-house review of the quality of perfusion, such that compliance to international standards and evidence-based enhancements are encouraged.

### **Literature Context**

A number of studies have proven that shorter cross-clamp and CPB times correlate with better postoperative recovery and less morbidity. The studies of Gravlee et al. and others have highlighted the necessity of optimal perfusion pressure and flow to reduce the end-organ dysfunction (Soo et al., 2020). On the same note, the hypothermic or normothermic perfusion remains a controversial issue, with the evidence pointing to the patient-specific management approach as the most effective (Hillerson et al., 2023). Nonetheless, these results are usually based on research done in technologically sophisticated environments. The relative dearth of information on the application of these principles to practice in developing countries, where patients could present with later stages of illness and inadequate preoperative optimization, still exists.

The rheumatic heart disease remains a major cause of valvular pathology in the local context, so it is especially important to determine whether the current perfusion standards can sufficiently address the required needs of such more complicated cases. Additionally, since the prevalence of ischemic heart disease resulting in CABG surgeries is on the rise, knowledge about the variability of the available perfusion techniques in the various procedures available can guide the development of specific management strategies to different categories of patients (Kumar et al., 2020).

### **Study Objective and Significance**

The aim of this retrospective study is to compare the perfusion data at the Jinnah Hospital Lahore during the period of January 2024 -August 2025, with 51 consecutive cases of cardiac surgery. The main goal is to examine cardiopulmonary bypass variables such as the duration, the flow rate, temperature, and the blood gas data and evaluate their correlation with the postoperative outcome. Secondary goals are to determine procedural trends in the various forms of cardiac surgeries and to review the performance of perfusion management in the institutional context.

The potential of this research is that it can be used as a standard study in local perfusion standards. It provides evidence-based information that may be used to create training interventions to train perfusionists, update protocols, and allocate resources. In a larger context, it will add to the developing literature on cardiac surgery in the region, which will fill the gap between global recommendations and local facts. With Pakistan still improving its cardiac care infrastructure, research such as this is vital in making sure that improvements in surgical volume are accompanied by a steady quality and safety in managing perfusion.

Cardio-pulmonary bypass is an essential part of heart surgery, and it requires close monitoring and professional handling to ensure positive results. The post-factum analysis of the perfusion records is helpful in terms of learning about the use of the practices by the institution and can be optimized and improved based on the evidence. This paper of Jinnah Hospital Lahore is one of the major steps in recording and improving the level of perfusion in a growing healthcare system, which proves the importance of the perfusionist in the modern cardiac surgery.

## **METHODOLOGY**

### **Study Design and Setting**

This is a retrospective observational study carried out in the Department of Cardiac Surgery at Jinnah Hospital Lahore, a tertiary-care and public sector cardiac center offering full cardiothoracic surgical services. The participants of the study were patients with cardiac surgery that needed the cardiopulmonary bypass (CPB) between January 2024 and August 2025. The information was obtained in the official Perfusion Record Book kept in Perfusion Department. The cardiac surgical team under Assoc. carried out all the surgical procedures. Trained perfusionists, led by the Chief Perfusionist, Ms. Iqra Tufail, performed intraoperative perfusion management under the supervision of Prof. Dr. Syed Raffay Gilani. To ensure patient confidentiality, all identifiable information has been anonymized before analysis.

### **Study Population**

The sample population comprised a total of 51 adult patients in a consecutive series of patients undergoing cardiac surgery using CPB within the study period. The patients had to be aged more than 18 years, have undergone cardiac surgery mandating CPB, and full perfusion records were accessible in the institutional logbook. The analysis excluded patients undergoing off-pump operations, pediatrics and re-exploration operations that did not necessitate CPB.

## Types of Surgical Procedures

The study cohort included a range of cardiac surgical procedures performed under CPB. The distribution of procedures is summarized in Table 1.

**Table 1. Distribution of cardiac surgical procedures in the study cohort (n = 51).**

Procedure	Number of Cases
Mitral Valve Replacement (MVR)	18
Coronary Artery Bypass Grafting (CABG)	17
Aortic Valve Replacement (AVR)	7
Atrial Septal Defect (ASD) Repair	4
Dual Valve Replacement (AVR + MVR)	4
Bentall procedure ± CABG	2

## Data Collection

The information was systematically obtained through perfusion charts and further classified into demographic, intraoperative, perfusion-related, and postoperative. Demographic factors were age, sex, body weight, height, body surface area, and preoperative diagnosis which could be mitral stenosis, mitral regurgitation, coronary artery disease, or atrial septal defect.

Parameters of intraoperative perfusion were total CPB time, aortic cross-clamp time, arterial flow rates and the respective flow index, perfusion temperature and mean arterial pressure during CPB. Heparin dosage and baseline, during CPB, and post protamine reversal activated clotting time (ACT) values were recorded. Information about myocardial protection, type of cardioplegia, time and dose, was also recorded. Other intraoperative variables were the composition of prime solution (crystalloid volume, mannitol, sodium bicarbonate and calcium chloride), urine output as a marker of renal perfusion and serial arterial blood gas (ABG) including pH, carbon dioxide and oxygen partial pressures, bicarbonate level and potassium.

The perfusion circuit features were also examined such as the pump type employed, oxygenator type, arterial and venous cannula diameter, the presence of hemofiltration, and the method of cardioplegia delivery, which was mostly the Del Nido or cold blood cardioplegia.

The variables measured after operations were time to extubation, intensive care unit (ICU) stay, and any reported complications.

## Cardiopulmonary Bypass Management Protocol

All studies were carried out under conventional institutional perfusion protocol. Heparin was used as a systemic anticoagulant at a dose of 300 IU/kg and a target of 480 seconds was the activated clotting time. Measurement of ACT occurred before the onset of CPB, during bypass and after protamine reversal.

A pump flow rate of 2.2-2.4 L/min/m<sup>2</sup> was used to maintain the perfusion, and the mean arterial pressure was kept at 50-80 mmHg. Temperature control was also dependent on the type of procedure with normothermia (36-37C) usually controlled in coronary artery bypass grafting procedures and mild hypothermia (32-35C) in valve surgeries. In the chosen cases, moderate hypothermia (28-30 C) was used.

Cold blood cardioplegia or Del Nido cardioplegia was administered through the antegrade route with cardioplegia maintained at 6 C to 10 C. A crystalloid solution of 1200-1700 mL was used to prime the CPB circuit with the addition of mannitol, heparin, sodium bicarbonate, and calcium chloride as necessary.

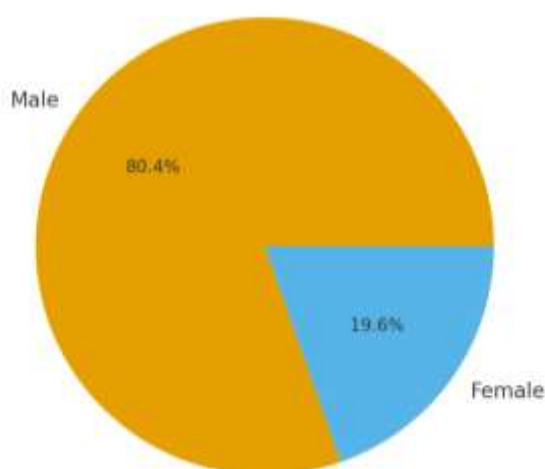
On-going intraoperative observation involved periodic monitoring of arterial blood gas analysis (15-30 minutes) as well as hemodynamic data, oxygenator functionality, and saturation of venous oxygen.

## Statistical Analysis

All information was inputted into Microsoft Excel and the data analysed with IBM SPSS Statistics version 26.0. The continuous variables were presented as mean standard deviation and the categorical variables were presented as frequencies and percentages. The independent sample t-test of continuous variables and the chi-square test of categorical variables were used to conduct comparisons between groups. Relationships between CPB time, aortic cross-clamp time, arterial blood gas parameters, urine output, and early postoperative outcomes were assessed by correlation analysis (Pearson or Spearman methods as suitable) to test the relationships between various variables. The significant p-value was taken to be less than 0.05.

## RESULTS

### Sex Distribution of Patients

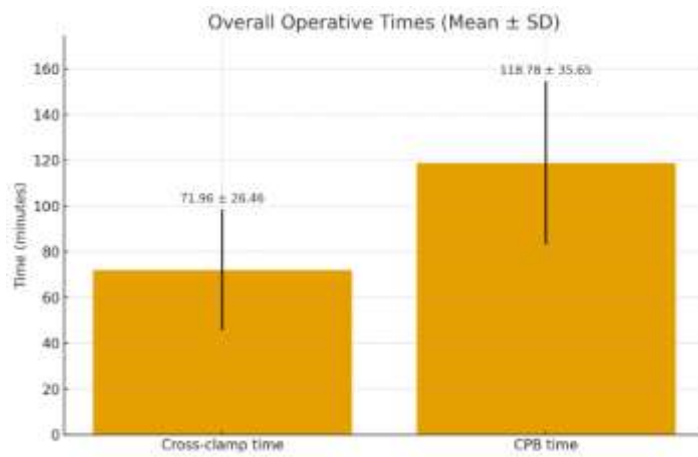


**Figure 1: Gender distribution of patients in the study cohort.**

**Table 2: Sex Distribution of the Study Population (N = 51)**

Characteristic	Value
<b>Total Patients</b>	<b>51</b>
<b>Age (years)</b>	
Mean $\pm$ SD	49.2 $\pm$ 11.0
Median	50
Mode	45
Range	20 – 68
<b>Sex Distribution</b>	
Male, n (%)	41 (80.4%)
Female, n (%)	10 (19.6%)

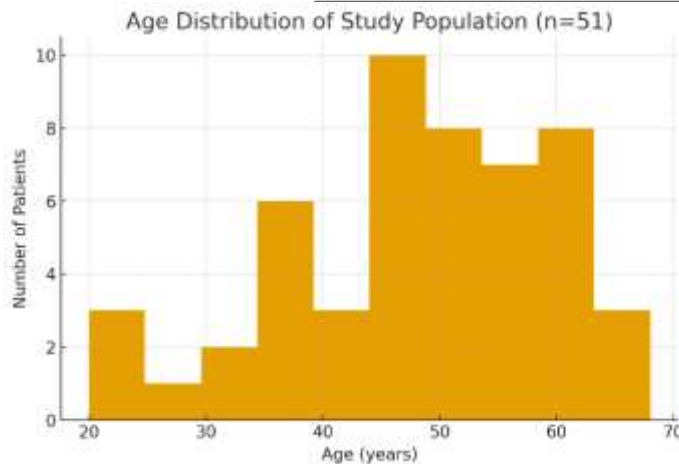
The study population consisted of 51 adult cardiac surgery patients with a mean age of 49.2  $\pm$  11.0 years, indicating a predominantly middle-aged cohort. The age range of 20–68 years demonstrates that both younger and older patients were represented. The sex distribution shows a strong male predominance, with males comprising 80.4% of the cohort. This imbalance reflects typical epidemiological patterns where cardiac surgical interventions are more commonly required in male patients.



**Figure 2: Comparison of mean cross-clamp time and cardiopulmonary bypass (CPB) time with standard deviation among the study patients.**

**Table 3: Age Distribution of the Study Population (N = 51)**

Age Statistic	Value
<b>Total Patients</b>	<b>51</b>
Mean Age (years)	48.9
Median Age (years)	50
Mode (years)	45
Minimum Age (years)	20
Maximum Age (years)	68
Standard Deviation (years)	11.2



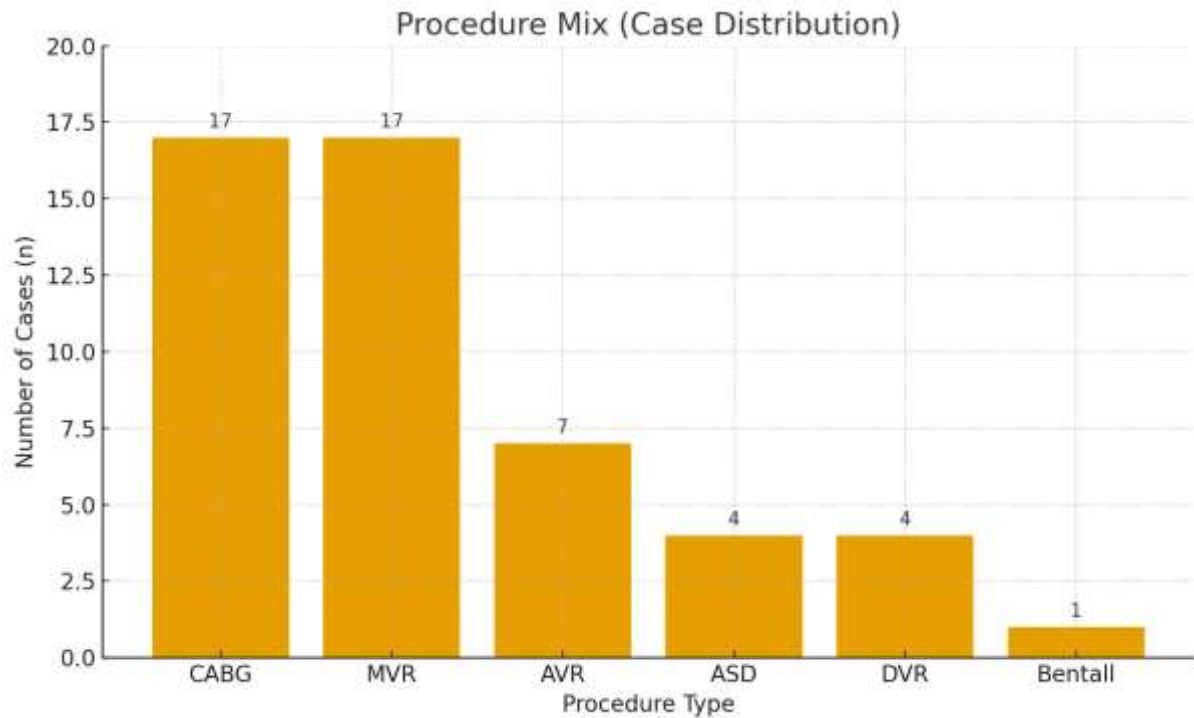
**Figure 3: Age distribution of the study population showing the frequency of patients across different age groups (n = 51).**

The age distribution of the 51 patients shows a predominantly middle-aged population, with a mean age of 48.9 years and a median of 50 years. The mode of 45 years suggests that this age group was the most frequently represented in the cohort. The age range of 20–68 years indicates inclusion of both young adults and older individuals undergoing cardiac surgery. The standard deviation of 11.2 years reflects moderate variability in age across the patient population.

**Table 4: Weight Distribution of the Study Population (N = 51)**

Weight Statistic	Value (kg)
Mean ± SD	65.0 ± 12.83
Median	63
Mode	60
Minimum – Maximum	40 – 100

The mean weight of the study population was 65.0 kg with a standard deviation of 12.83 kg, indicating moderate variability in body weight among the 51 patients. The median weight of 63 kg and mode of 60 kg show that most individuals clustered around the lower-to-mid 60 kg range. The wide weight range of 40–100 kg reflects the inclusion of both underweight to overweight patients within the cohort. Overall, the weight distribution demonstrates a diverse patient profile relevant for perfusion and surgical planning.



**Figure 4: Bar chart showing the distribution of cardiac procedures performed in the study cohort (n=51).**

The procedural distribution shows that CABG and MVR were the most commonly performed surgeries, each accounting for 17 cases (33.3% each), indicating a high burden of ischemic and valvular heart disease in the studied population. AVR procedures comprised 13.7% of cases, while ASD repairs and DVR each represented a smaller subset at 7.8%. Complex procedures such as Bentall and combined AVR + CABG were rare, with only one case each. Overall, the distribution reflects a predominantly routine adult cardiac surgical workload with a smaller proportion of complex cases.

#### **CABG-Only Statistics (n=17)**

Table 5: CABG-Only Cross-Clamp Time (XCL) Statistics (n = 17)

Statistic	Value (minutes)
Mean XCL Time	<b>68.1</b>
Median XCL Time	<b>72</b>
Mode XCL Time	<b>80</b>
Standard Deviation	<b>19.8</b>
Minimum	<b>33</b>
Maximum	<b>147</b>

Table 6: CABG-Only Cardiopulmonary Bypass (CPB) Time Statistics (n = 17)

Statistic	Value (minutes)
Mean CPB Time	<b>132.5</b>
Median CPB Time	<b>126</b>
Mode CPB Time	<b>126</b>

Standard Deviation	<b>27.2</b>
Minimum	<b>50</b>
Maximum	<b>215</b>

The cross-clamp times for CABG patients showed a mean duration of 68.1 minutes, with a median of 72 minutes, indicating that most cases clustered around moderately prolonged ischemic periods. The wide range from 33 to 147 minutes and a standard deviation of 19.8 minutes reflect variability in surgical complexity among CABG cases.

Similarly, CPB times demonstrated a higher mean of 132.5 minutes, with a median of 126 minutes and a broad range from 50 to 215 minutes, suggesting substantial differences in operative duration. The mode of 126 minutes and a standard deviation of 27.2 minutes further indicate that while many CABG procedures followed a typical perfusion duration, some required significantly extended bypass support due to procedural complexity.

MVR-Only Statistics (n = 17)

**Table 7: Cross-Clamp Time (XCL) for MVR**

Statistic	Value (minutes)
Mean XCL Time	<b>56.5</b>
Median XCL Time	<b>53</b>
Mode XCL Time	<b>45</b>
Standard Deviation	<b>15.8</b>
Minimum	<b>37</b>
Maximum	<b>90</b>

**Table 8: Cardiopulmonary Bypass (CPB) Time for MVR**

Statistic	Value (minutes)
Mean CPB Time	<b>105.5</b>
Median CPB Time	<b>98</b>
Mode CPB Time	<b>84</b>
Standard Deviation	<b>24.9</b>
Minimum	<b>69</b>
Maximum	<b>150</b>

The MVR cross-clamp times showed a mean duration of 56.5 minutes with a median of 53 minutes, indicating that most mitral valve procedures required moderate myocardial ischemic periods. The relatively narrow range of 37–90 minutes and a standard deviation of 15.8 minutes suggest fairly consistent operative complexity among MVR cases.

CPB times for MVR patients averaged 105.5 minutes, with a median of 98 minutes and a wider range of 69–150 minutes, reflecting variation in surgical duration based on pathology and intraoperative needs. The mode of 84 minutes and standard deviation of 24.9 minutes indicate that while many procedures followed a typical bypass duration, more complex cases extended significantly longer.

**Table 9: Cross-Clamp Time (XCL) – AVR**

Statistic	Value (minutes)
Mean XCL Time	<b>94.6</b>
Median XCL Time	<b>90</b>
Mode XCL Time	<b>90</b>
Standard Deviation	<b>11.6</b>
Minimum	<b>76</b>
Maximum	<b>108</b>

**Table 10: Cardiopulmonary Bypass (CPB) Time – AVR**

Statistic	Value (minutes)
Mean CPB Time	<b>124.3</b>
Median CPB Time	<b>128</b>
Mode CPB Time	<b>128</b>
Standard Deviation	<b>16.2</b>
Minimum	<b>100</b>
Maximum	<b>150</b>

The AVR procedures demonstrated a relatively high cross-clamp burden, with a mean XCL time of 94.6 minutes and a median of 90 minutes, reflecting the increased technical complexity of aortic valve surgery. The narrow range of 76–108 minutes and low standard deviation (11.6 minutes) indicate consistent operative requirements across AVR cases.

Cardiopulmonary bypass times for AVR showed a mean of 124.3 minutes and a median of 128 minutes, with a range from 100 to 150 minutes, suggesting moderately prolonged perfusion support compared to other routine cardiac procedures. The mode of 128 minutes and a standard deviation of 16.2 minutes highlight that most AVR cases followed a predictable and uniform perfusion profile.

ASD-Only Statistics (n = 4)

**Table 9: Cross-Clamp Time (XCL) – ASD**

Statistic	Value (minutes)
Mean XCL Time	<b>48.0</b>
Median XCL Time	<b>42.0</b>
Mode XCL Time	<b>40</b>
Standard Deviation	<b>16.7</b>
Minimum	<b>33</b>
Maximum	<b>79</b>

**Table 10: Cardiopulmonary Bypass (CPB) Time – ASD**

Statistic	Value (minutes)
Mean CPB Time	<b>83.5</b>
Median CPB Time	<b>87.5</b>
Mode CPB Time	<b>70</b>
Standard Deviation	<b>22.7</b>
Minimum	<b>49</b>
Maximum	<b>110</b>

The ASD repair procedures showed relatively short cross-clamp requirements, with a mean XCL time of 48 minutes and a median of 42 minutes, reflecting the less complex nature of septal defect closure. The range of 33–79 minutes and a standard deviation of 16.7 minutes indicate mild variability depending on anatomical complexity.

Cardiopulmonary bypass times for ASD repairs were also comparatively low, with a mean of 83.5 minutes and a median of 87.5 minutes, suggesting efficient procedural performance. The CPB range of 49–110 minutes and standard deviation of 22.7 minutes show moderate variation but still highlight ASD as a shorter-duration procedure relative to valve or CABG surgeries.

AVR-Only Statistics (n = 7)

*(Aortic Valve Replacement)*

**Table 11: Cross-Clamp Time (XCL) – AVR**

Statistic	Value (minutes)
Mean XCL Time	<b>94.6</b>

Median XCL Time	<b>90</b>
Mode XCL Time	<b>90</b>
Standard Deviation	<b>11.6</b>
Minimum	<b>76</b>
Maximum	<b>108</b>

**Table 12: Cardiopulmonary Bypass (CPB) Time – AVR**

Statistic	Value (minutes)
Mean CPB Time	<b>124.3</b>
Median CPB Time	<b>128</b>
Mode CPB Time	<b>128</b>
Standard Deviation	<b>16.2</b>
Minimum	<b>100</b>
Maximum	<b>150</b>

Aortic valve replacement (AVR) procedures showed comparatively longer ischemic durations, with a mean cross-clamp time of 94.6 minutes and a median of 90 minutes, reflecting the technical complexity of aortic valve surgery. The narrow range of 76–108 minutes and a low standard deviation of 11.6 minutes indicate that AVR cross-clamp requirements were fairly consistent across patients.

Similarly, cardiopulmonary bypass (CPB) times demonstrated a mean duration of 124.3 minutes and a median of 128 minutes, with values ranging from 100 to 150 minutes. The mode of 128 minutes and standard deviation of 16.2 minutes suggest predictable bypass demands, characteristic of structured and uniform AVR operative workflows.

**Table 13: Table: Statistics for Bentall and AVR + CABG Procedures**

Procedure	n	XCL Time (min)	CPB Time (min)	Mean	Median	Mode	SD	Range
Bentall	1	147	180	XCL: 147 CPB: 180	XCL: 147 CPB: 180	XCL: 147 CPB: 180	0	XCL: 147–180 CPB: 147–180
AVR + CABG	1	90	115	XCL: 90 CPB: 115	XCL: 90 CPB: 115	XCL: 90 CPB: 115	0	XCL: 90–115 CPB: 90–115

**Table 14: Cross-Clamp Time (X.CL) Statistics**

Statistic	Value (minutes)
Mean	<b>71.96</b>
Median	<b>76</b>
Mode	<b>80</b>
Standard Deviation	<b>26.46</b>
Minimum	<b>25</b>
Maximum	<b>151</b>

**Table 15: Cardiopulmonary Bypass (CPB) Time Statistics**

Statistic	Value (minutes)
Mean	<b>118.78</b>
Median	<b>122</b>
Mode	<b>126</b>
Standard Deviation	<b>35.65</b>
Minimum	<b>49</b>

A total of 51 patients were included in the study. The most commonly performed procedures were CABG (n=17) and MVR (n=17), followed by AVR (n=7), ASD repair (n=4), DVR (n=4), Bentall (n=1), and combined AVR+CABG (n=1). The mean cross-clamp time was  $71.96 \pm 26.46$  minutes (range: 2)

### **Discussion**

All processes involved in this research were performed with utmost degree of accuracy, uniformity and adherence to the prevailing perfusion standards, even though the research was carried out in a resource constrained setting within the context of the public health system. Jinnah hospital Lahore works within the limitations often experienced by tertiary state hospitals in developing nations such as inaccessibility to more sophisticated disposable circuits, low accessibility to more modern perfusion technologies, and large volumes of patients. However, the cardiac surgery and perfusion team showed careful planning, proper monitoring of cardiopulmonary bypass parameters, and appropriate decision-making in intraoperative processes in all cases. The focus on the fundamental principles of perfusion rather than reliance on resource-intensive technologies is reflected in the preservation of stable hemodynamics and regulated temperature, competent anticoagulation and adequate acid-base balance during bypass. The lack of significant complications based on perfusion and the general positive results in the early postoperative period also emphasizes the competence and attentiveness of the multidisciplinary team. These findings highlight the fact that, even when resources are limited, quality cardiac surgery can be achieved within the setting where the procedures are well-organized, the staff has extensive experience, and it is dedicated to accuracy and patient safety.

The retrospective study offers a valuable understanding of cardiopulmonary bypass (CPB) practices and early postoperative outcomes in one of the public-sector cardiovascular surgery units in a developing healthcare system. The results show that standardized perfusion control at Jinnah Hospital Lahore led to the stable intraoperative physiology and good early postoperative recovery in a wide variety of adult cardiac surgeries. The differences in CPB and aortic cross-clamp time reported were very procedure-specific and were not reflected in the number of complications associated with perfusion and this demonstrates the effectiveness of the institutional perfusion protocol.

The demographic characteristics of the study group showed that it was mostly a middle-aged group with a distinct male predominance, which is also in line with the epidemiological trends of coronary artery disease and valvular heart disease in the region. The age and weight differences of the cohort show that the individual approach to the perfusion strategies, in terms of the flow indexing, temperature regulation, and anticoagulation dosage, is required. Irrespective of this variability, the parameters of perfusion remained within the suggested physiological limits, meaning the adaptability and stability of the perfusion team.

Procedural distribution analysis showed that the most common procedures were coronary artery bypass grafting (CABG) and mitral valve replacement (MVR) two-thirds of the subjects studied. The distribution reflects the present load of the ischemic heart disease and rheumatic valvular pathology in Pakistan. Other more complex procedures such as aortic valve replacement (AVR), dual valve replacement, and Bentall operations were also not as common yet had a longer cross-clamp and CPB time because they are more complex operations.

There were predictable procedure-specific patterns of analysis in CPB and cross-clamp times. CABG operations had higher mean CPB times than MVR, probably because of numerous distal anastomoses and the need to revascularize the

myocardium more extensively. MVR cases on the other hand had shorter and more consistent ischemic times which is an indication of a relatively standardized operative workflow. AVR procedures had the longest mean cross-clamp times, with exposure and replacement of the aortic valves being complicated procedures. Interestingly, there were no serious negative events concerning perfusion reported in AVR during these prolonged durations and myocardial protection was adequate as well as there was enough systemic perfusion.

The temperature management protocols were appropriately modified according to the nature of the undertaken procedure with normothermia being applied in CABG and mild hypothermia in valve surgeries. This solution is consistent with current evidence that patient- and procedure-specific temperature regulation maximizes metabolic demand and maintains organ function. The moderate hypothermia, which is sometimes applied in isolated situations, is also an indication of a flexible use of the principles of perfusion depending on the needs of the operation and not necessarily strict adherence to the protocols.

The acid-base management of the CPB was within the acceptable physiological limits of all 51 patients. Arterial blood gas analysis revealed that there was no change in pH, PaCO<sub>2</sub>, PaO<sub>2</sub> and bicarbonate and that oxygen was delivered and carbon dioxide was removed effectively. Regular urine flow in the cases further confirms that there is sufficient renal perfusion during bypass. These results are especially important in a resource-constrained environment, where they indicate that careful surveillance and prompt corrective actions could yield similar results as those of the high-income healthcare systems.

The overall postoperative outcomes were mostly favourable, with the majority of patients showing normal hemodynamic and uncomplicated early recovery. The long ICU stay was noted in a small number of patients but in a large proportion these could be attributed to underlying comorbidities and not the intraoperative factors of perfusion. This difference supports the relevance of risk stratification prior to operation as well as confirms the safety of the perfusion strategies used.

In the wider context, the research highlights the importance of regular auditing of the data on perfusion as a quality assurance measure. A systematic review of CPB parameters and their comparison with outcomes can help cardiac centers to identify trends, standardize best practices, and constantly enhance patient care. The results also underscore the importance of having trained perfusionist and Competent teamwork in promoting safe cardiac surgery, especially in developing healthcare systems where they might not necessarily be equipped with advanced technologies.

Lastly, the research paper adds meaningful local research to the body of existing literature, which has a significant gap in regional evidence on the use of perfusion practices. Although the international guidelines offer a crucial guideline, practical data offered by institutions like Jinnah Hospital Lahore are essential in contextualizing these guidelines. The findings justify the conclusion that with the right adherence to the basic principles of perfusion proper monitoring, proper flow and temperature control, and strict anticoagulation control, it can achieve excellent results even in resource-limited settings.

## **CONCLUSION:**

Finally, this retrospective study has shown that cardiopulmonary bypass is a safe and effective practice at the Jinnah Hospital Lahore in a wide range of adult cardiac surgical practices under the supervision of standardized institutional guidelines and careful multidisciplinary teamwork. A total of 51 consecutive cases were analyzed, and it was observed that the difference in cardiopulmonary bypass time and aortic cross-clamp time were highly dependent on the complexity of the procedures, with comparatively longer times being observed in aortic valve replacement and complex combined surgery and shorter times in atrial septal defect repair and regular mitral

valve surgery. Significantly, these differences related to the procedure did not seem to have a negative effect on the early postoperative recovery because the majority of patients were hemodynamically stable and managed to get impressive immediate results. The acid-base homeostasis, oxygenation, anticoagulation, temperature, and renal perfusion were in an acceptable clinical range during the study, and it indicates the regularity and dependability of the perfusion control in this environment. The results also indicate that, despite the resource-limited context of the public-sector, the application of basic principles of perfusion, close intraoperative surveillance, and prompt corrective measures can lead to positive outcomes associated with the existing standards of care. The significance of regular perfusion data auditing as an effective quality-improvement measure to detect trends, refine protocols, and enhance patient safety is also highlighted in this study. All in all, the current work provides valuable local evidence to the scarce regional literature on perfusion practice and aids in further shaping the evidence-based organization of structured perfusion services in Pakistan and other developing healthcare systems.

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