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Assessment of Intraoperative Fluctuations in Partial Pressure of Oxygen on Extubation Time in Adult Patients Undergoing Cardiac Surgery

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Abstract

Background: Cardiopulmonary bypass (CPB) has a significant impact on physiological oxygen regulation in cardiac surgery. Despite high values of arterial partial pressure of oxygen (PaO_2) being a long-standing protective factor, there are emerging indications that high or unstable oxygen levels could also lead to oxidative stress, inflammatory activation, and postoperative pulmonary dysfunction. The correlation between the variability of intraoperative (PaO_2) and postoperative extubation time is not studied properly. **Objective:** To determine the effect of intraoperative changes in arterial partial pressure of oxygen (PaO_2) on postoperative extubation period in adult patients undergoing elective cardiac surgery with cardiopulmonary bypass. **Methods:** The study was a prospective, observational one, conducted in the Cardiac Perfusion Unit of Omer Hospital and Cardiac Perfusion Unit of Gulab Devi Chest Hospital to assess intra and post operative parameters in adult patients who underwent elective cardiac surgery with cardiopulmonary bypass. Arterial blood gas analyses were performed at predefined intraoperative stages (CPB initiation, cooling, rewarming, and weaning). According to predefined criteria of fluctuation, patients were divided into Stable and Variable groups, according to the level of fluctuation of the patients in terms of the (PaO_2). The time of extubation was the period between ICU admission and the success of removal of endotracheal tube. To ascertain the relationship between the variability of the (PaO_2) and the duration during which the

extubation process was conducted, statistical analysis was conducted after accounting for the confounding factors. **Results:** Patients who had more intraoperative PaO_2 variation demonstrated longer extubation times. Increased variability in (PaO_2) was linked to higher chances of delayed extubation (>8 hours), indicating that the postoperative respiratory recovery is compromised. Intraoperative oxygen variability was concluded as being a clinically significant predictor of ventilatory recovery, not the absolute values of oxygen. **Conclusion:** On univariate analysis, intraoperative PaO_2 variability was associated with delayed extubation, but this association was not significant following adjustment for confounding variables. Aortic cross-clamp time continued to be an independent predictor of delayed extubation.. Physiologically stable oxygenation instead of liberal hyperoxia could be a possible solution to better postoperative respiratory outcomes. The results facilitate the creation of universal oxygenation management guidelines during CPB to improve recovery and maximize patient safety.

Keywords: Cardiopulmonary bypass, (PaO_2) variation, Hyperoxia, Oxidative stress, Extubation time, Cardiac surgery.

INTRODUCTION

Cardiac surgery is considered to be one of the most complicated spheres of contemporary surgical care, and the cooperation of surgical, anesthetic, and perfusion teams is to be taken care of precisely to guarantee the safety of patients and the best possible results[1].The implementation of cardiopulmonary bypass (CPB) has transformed cardiac surgery because it gave the surgeons the ability to carry out complex intracardiac surgery under the conditions of a controlled setting. Postoperative morbidity has emerged as one of the major concerns in adult cardiac surgery despite the major advancements in extracorporeal circulation technology, myocardial protection, anesthetic agents, and perioperative care[2].In the case of cardiopulmonary bypass, physiological processes of oxygen delivery and use are fundamentally changed. This excludes the lungs temporarily to the exchange of gases and the oxygenation can be fully performed with an extracorporeal oxygenator[3]. Consequently, arterial oxygen tension (PaO_2) is a variable that is controlled by the mechanical means instead of being regulated physiologically. High inspired oxygen fractions during CPB are usually applied

in common clinical practice to provide sufficient safety margin against hypoxia. As such, patients will often be subjected to supra-physiological levels of (PaO_2), which is usually in excess of 200-300 mmHg over a long duration[4].

Traditionally, the use of liberal oxygenation during CPB was believed to be good and protective. Nonetheless, in the last five years, there has been a growing clinical and experimental evidence that has brought into doubt this practice. Recent studies indicate that high oxygen levels might not be harmless, and can add to oxidative stress, endothelial dysfunction, inflammatory activation and microcirculatory dysfunction. Such pathophysiological alterations can have a negative outcome on the functionality of organs postoperatively, especially lungs, and, thus, the recovery parameters, including the duration of mechanical ventilation and time to extubation[5]. The extubation time is now an important quality indicator in cardiac anesthesia and intensive care practice. There is reduced length of stay in the ICU, less ventilator-associated complications, less cost on healthcare, and enhanced comfort of the patients with early extubation. On the other hand, a late extubation is usually a sign of dysfunction of the lungs, systemic inflammation, hemodynamic change, or metabolic imbalance, and it is all related to high morbidity. Although the clinical importance of the time taken to perform the extubation, it is determined by several interacting factors intraoperative and postoperative and the role of intraoperative fluctuations in the (PaO_2) during CPB is not clearly studied[6].

The synopsis of this study, which was approved, focuses on the intraoperative variability of (PaO_2) as a potentially changeable variable to affect the postoperative extubation time. Based on this background, the current study is conducted to critically assess intraoperative changes in (PaO_2) at specific phases of cardiopulmonary bypass and to determine the association between the changes and the extubation time in patients undergoing cardiac surgery.

Extracorporeal circulation is one of the methods used to temporarily replace the pumping mechanism of the heart and the lungs' exchange of gases. CPB circuit normally comprises of venous drainage cannulas, a venous reservoir, a mechanical pump, a membrane oxygenator, and a heat exchanger. Venous blood is drained from the patient, oxygenated in the oxygenator and sent back to the systemic circulation with regulated flow rates and temperature [7]. Cardiac output, alveolar-capillary diffusion, hemoglobin

concentration, pulmonary ventilation and oxygen extraction by tissues are some of the factors that determine oxygen delivery under normal physiological conditions. Ventilation-perfusion balance and hypoxic pulmonary vasoconstriction help the lungs to maintain their (PaO_2) in a small physiological range. However, the suspension of pulmonary regulation occurs during CPB and the process of oxygenation now relies entirely on the extracorporeal parameters under the control of the perfusionist[8].

Cardiopulmonary bypass presents a number of non-physiological states, which affect the oxygen delivery and consumption. Circuit priming causes hemodilution, which decreases the concentration of hemoglobin and oxygen-carrying capacity[9]. Microcirculatory perfusion is disturbed by non-pulsatile flow and oxygen-hemoglobin dissociation is influenced by hypothermia as well as diminished metabolic demand. Moreover, CPB causes a systemic inflammatory reaction (release of cytokines, complement), adhesion of leukocytes, all of which damage microvascular oxygen provision. These changes lead to the appearance of intricate correlation between the delivered oxygen and real use of oxygen by the tissues[10]. Excessive maintenance of elevated (PaO_2) during CPB does not lead to enhanced tissue oxygenation and can result in worse oxidative injury. Thus, the physiology of oxygen during CPB cannot be comprehended based on one program, but rather on a combination of two aspects: delivery of oxygen and cellular consumption[4][8].

Partial pressure of oxygen (PaO_2) constitutes the concentration of oxygen that is dissolved in blood in the arteries and is a major indicator of systemic oxygenation. Under normal conditions in an adult, (PaO_2) is kept at 75 to 100 mmHg. A value below this range would show a state of hypoxemia and values that are far beyond would show a state of hyperoxaemia[11]. In the cardiopulmonary bypass, the (PaO_2) depends on a number of factors, such as the oxygenator gas flow, oxygen fraction delivered, pump flow rate, hemoglobin concentration, acid-base condition, and temperature of the patient. Change in (PaO_2) levels could be wide ranging in the various stages of bypass especially initiation, cooling, rewarming, and offloading CPB[12]. Historically, elevated (PaO_2) at CPB has been applied as a proxy indicator of sufficient oxygen delivery. Nevertheless, recent studies note that (PaO_2) does not provide all the information about tissue oxygenation. Hyperoxaemia can cause vasoconstriction, decreased coronary and

cerebral blood flow and microcirculatory perfusion. These effects question the fact that increased (PaO_2) values are automatically protective and emphasize the necessity of balanced oxygen control measures[13].

Hyperoxia in cardiopulmonary bypass is a typical clinical event related to the free use of the supplemental oxygen. Although this is designed to inhibit hypoxia, it has been reported that hyperoxaemia conditions cause a number of negative physiological effects when administered over a long period of time. Hyperoxia intensifies the activity of reactive oxygen species (ROS) available to overwhelm the endogenous antioxidant defenses and lead to oxidative stress[14]. Cellular membranes, proteins and nucleic acids are damaged by oxidative stress which produces endothelial dysfunction, capillary permeability and inflammatory activation. Within the pulmonary system, these alterations can lead to impairment of the alveolar-capillary gas exchange, decrease of the lung compliance, and the promotion of postoperative respiratory complications including atelectasis and acute lung injury. These effects of the lungs are of direct importance to readiness to extubation and recovery after the operation[15].

Hypoxia during CPB, which is not a common occurrence, is a critical issue. Poor oxygen delivery can be caused by insufficient pump flow, anemia, malfunctioning of oxygenator or technical problems in the extracorporeal circuit. Hypoxic episodes are associated with anaerobic metabolism, lactic acidosis, and cellular damage, which may involve a variety of organ systems and slow down the stabilization postoperatively. Hyperoxia and hypoxia are the opposite ends of oxygenation that can have a negative impact on the postoperative outcomes. To reduce physiological stress and aid in recovery, it is therefore important to maintain (PaO_2) at an optimum level when the patient is under CPB[8][16].

In addition to absolute (PaO_2) values, the changes in oxygenation during cardiopulmonary bypass might be an independent cause of oxidative damage. The quick change in hypoxic and hyperoxic conditions, especially in the period of ischemia-reperfusion, increases the production of ROS. This effect is particularly applicable in cases of cross-clamping and reperfusion of the aorta as in these cases, previously ischemic tissues are rapidly exposed to elevated oxygen levels[17]. Mitochondrial dysfunction, inflammatory activation, endothelial damage and apoptosis have been

attributed to oxidative stress that occurs in response to changes in (PaO_2). They lead to dysfunction of postoperative organs such as pulmonary, renal, and nerve complications. Recent evidence indicates that keeping (PaO_2) in the near-physiological levels during the CPB can mitigate oxidative damage, as well as decrease overall postoperative inflammatory effects[18].

Extubation time is a clinical outcome of postoperative mean value that shows the ability of the patient to sustain sufficient ventilation, oxygenation, and airway protection. Early extubation is one of the core principles of fast-track cardiac anesthesia procedures and is linked to better outcomes. However, delayed extubation, in its turn, is usually a symptom of underlying respiratory dysfunction, systemic inflammation, or metabolic imbalance. The control of intraoperative (PaO_2) can affect the time of extubation in a variety of ways. The oxidative lung injury caused by hyperoxia potentially can damage the pulmonary mechanics and gas exchange, causing ventilatory demands[19]. Oxidative stress could further stimulate inflammatory reactions which could impair pulmonary dysfunction and slow down weaning off mechanical ventilation. On the other hand, hypoxic damage can impair various organ systems, which increases the recovery period. Direct causal relationships between intraoperative changes in (PaO_2) and extubation time have not yet been defined conclusively, but there is an increasing amount of evidence to indicate an indirect relationship, mediated by pulmonary and systemic inflammatory mechanisms. This relationship thus needs to be researched in order to maximize the oxygen management strategies used in CPB[20].

Close interaction between the perfusionist and the anesthesiologist is necessary to provide the best oxygen management during the cardiopulmonary bypass. The perfusionist controls the extracorporeal circuit and has to regulate pump flow, oxygenator, and arterial blood gas goals. Anesthetic depth, hemodynamic stability, pre- and post-bypass ventilation and postoperative respiratory control in anesthesia is supervised by anesthesiologist. In spite of the responsibility, there is a high level of variability in the (PaO_2) targets used at the time of CPB, amid the training, institutional practices, and clinical choices. This inconsistency highlights the fact that there are no uniform guidelines to apply when managing oxygen in CPB[21]. Improved communication and the ability to work as a team across different disciplines are

necessary in order to reduce the adverse effects of excessive changes in the (PaO_2) and maximize patient outcomes.

Despite advances in cardiac surgery, keeping stable oxygen levels during surgery is still tough. This difficulty stems from depending on clinicians' judgment instead of following evidence-based protocols. This study looks into whether changes in intraoperative (PaO_2) can predict delayed extubation. The goal is to offer scientific advice for better oxygen management and to improve patient outcomes.

LITERATURE REVIEW

The objective of this literature review is to give background information on the management of oxygen during the perioperative period in cardiac surgery and focus on the importance of PaO_2 in the CPB period. Cardiopulmonary bypass (CPB) assisted cardiac surgery is one of the most physiologically demanding clinical environments in terms of oxygen delivery and oxygen usage[22]. CPB involves the replacement of the healthy heart and lung functions by an extracorporeal circuit, leaving the entire burden of systemic oxygenation to the perfusionist and anesthesia team. In such conditions, it becomes necessary to regulate oxygenation accurately to ensure the preservation of the homeostasis of the cells, the continued functioning of the organs and the postoperative recovery[23].

Where normal pulmonary gas exchange does not occur, (PaO_2) has become the main measurable parameter on which oxygen management plans are based. Nevertheless, modern data is also growing to indicate that the absolute level of (PaO_2) as well as its intraoperative fluctuations has an impact on postoperative outcome[24]. Liberal oxygen therapy has been regarded as a protective intervention in heart surgery. Inspired oxygen fractions were regularly used in order to remove any perceived risk of hypoxia. This paradigm has been questioned in the last five years, though, by the accumulating evidence that excessive oxygen therapy and rapid changes in (PaO_2) can produce deleterious effects on pulmonary, cardiovascular, and neurological systems, ultimately slowing the recovery and extubation of the patient after surgery[25].

Oxygen transport physiology changed dramatically the instant the cardiopulmonary bypass was initiated. Circuit priming leads to hemodilution and, therefore, to a decrease in the concentration of hemoglobin and, therefore, in the

content of arterial oxygen even when the values of (PaO_2) are seemingly high. Also, non-pulsatile blood flow distorts microcirculatory perfusion, which lowers the effective supply of oxygen to the tissue. Oxygen usage is further complicated by the effect of hypothermia which is often used as part of CPB so that metabolic demand is minimized. Even though the consumption of oxygen is reduced by cooling, the leftward movement of the oxyhemoglobin dissociation curve affects the extraction of oxygen to tissues negatively. The need of oxygen during rewarming is tremendous and this puts tissues at risk of relative hypoxia in case oxygen supply is not properly compensated [26]. Murata T et al. (2021) showed that changes in (PaO_2), and not solitary values, are vital in the healing of patients after surgery. Their effort implied that repeated phases of relative hyperoxia and hypoxia interfere with cellular metabolism and increase the recovery time, such as delayed extubation and extended ICU stay. This observation is relevant in highlighting the need to comprehend the dynamics of (PaO_2) at the various phases of CPB as opposed to using fixed target values[27].

Hyperoxia in the course of cardiac surgery is an ordinary occurrence especially during CPB where oxygenator gas flows are often configured to provide supraphysiological oxygenation. Although this is supposed to ensure a margin of safety, it has been found that when exposed to excessive levels of oxygen, it will result in the formation of reactive oxygen species (ROS), oxidative stress, and cellular damage[28]. Lopez MG et al. (2024) examined oxygenation plans in valve surgery patients and found that a superior intraoperative (PaO2) level was closely linked to the poor quality of postoperative pulmonary functions. These findings were explained by the authors by the oxidative stress caused by hyperoxia that damages alveolar epithelium, impairs the activity of surfactants, and elevates pulmonary capillary permeability[29]. This type of pulmonary damage directly affects the quality of gas exchange and is a cause of increased mechanical ventilation and slow extubation. Likewise, it was also found that hyperoxia did not reduce the cardiovascular outcome, but it was related to elevated oxidative stress biomarkers [30]. Their regulated clinical trial proved that the overexposure to oxygen during CPB does not provide any extra protective value and even suppressed recovery processes by aggravating the inflammatory and oxidative processes[31].

MATERIAL AND METHODS

Study Design:

The study was a prospective, observational one, conducted in the Cardiac Perfusion Unit of Omer Hospital and Cardiac Perfusion Unit of Gulab Devi Chest Hospital to assess intra and post operative parameters in adult patients who underwent electively cardiac surgery with cardiopulmonary bypass.

Study Duration:

- Projected duration of study: 4 months (data collection, data analysis and data documentation).

Study Population:

- Adult patients (more than 18 years) undergoing elective cardiac surgery (CABG, valve replacement, MICS CABG or a combination) and are under general anesthesia and have a cardiopulmonary bypass.

Sample Size:

- The overall sample size of this study was 100 adult patients who are undergoing elective cardiac surgery under cardiopulmonary bypass (CPB).
- They separated into two groups according to the intraoperative status of oxygenation and postoperative clinical outcomes:

Sample Size Calculation:

The sample size was calculated using the z-formula for proportions:

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

This study was done with a convenience sample of **100 adult patients** undergoing elective cardiac surgery with cardiopulmonary bypass, due to the short amount of time and available resources.

Group A (Affected Group):

Patients with major changes in PaO_2 during surgery (during surgery, the change in PaO_2 was $\geqslant$150 mmHg or $\geqslant$30% from baseline).

Group B (Normal Group):

Patients with no major changes in PaO_2 during surgery (change < 150 mmHg and < 30% from baseline).

Sampling Technique:

The Non probability sampling method was used.

Inclusion Criteria

- Adults (18 years or older) who underwent elective cardiac surgery with CPB.
- (PaO_2) records with full intraoperative data.
- Extubated patients in the same ICU admission.

Exclusion Criteria

- Emergency or redo cardiac surgeries
- Most severe pulmonary disease (e.g. COPD, ARDS) Pre-existing.
- Missing data records or intraoperative complications that led to deviation of the protocols.

Equipment Used

- Arterial blood gas (ABG) analyzer
- Inline blood gas monitoring (if available)
- Patient monitors (perfusion flow, temperature, invasive arterial pressure, and SpO_2)

Screening Technique & Machine Used

- Intraoperative PaO_2 was measured using Arterial Blood Gas (ABG) analysis.
- Arterial blood samples were taken from the arterial line during CPB.
- PaO_2 readings was recorded at four stages: before CPB, during cooling, during rewarming, and during weaning.
- An automatic ABG Analyzer was used for PaO_2 measurement.
- Continuous oxygen monitoring was done using a multi-parameter patient monitor (SpO_2, BP, ECG, temperature).
- Oxygen delivery during CPB was controlled through the CPB machine oxygenator and gas blender system.
- All oxygen adjustments were performed by the perfusionists under anesthesiologist supervision.

DATA COLLECTION PROCEDURE

All the data were taken regarding anesthesia charts, perfusion records and ICU logs. The values of the (PaO_2) were measured at fixed times (ex: starting state, taking CPB, rewarming, after CPB, and after surgery).

Data were collected in a structured manner from multiple perioperative sources to ensure accuracy and consistency. Preoperative records were used to retrieve baseline demographic characteristics (age, sex, and body mass index (BMI)) used in the study. The measurements of intraoperative arterial oxygen tension (PaO_2) were determined using arterial blood gas (ABG) analyses and measured in mmHg. The variability of the PaO_2 was determined by calculating the difference between the maximum and minimum intraoperative levels of PaO_2. Parameters related to the perfusion, such as the flow rate, temperature, and hematocrit, were obtained in the perfusion records. Extubation time was the primary postoperative outcome and was measured in hours as the period between ICU admission and successful extubation and was documented in the ICU documentation. Moreover, the main possible confounders were cardiopulmonary bypass (CPB) time, aortic cross-clamp time, and anesthetic type that were retrieved from operative reports.

DATA ANALYSIS PROCEDURE

This prospective observational study included adult cardiac surgery patients who underwent CPB. Data on demographics, surgical details, intraoperative (PaO_2), and extubation time were collected using a validated proforma. ABG values at key CPB stages were analyzed to assess (PaO_2) variability ($\geqslant$150 mmHg or $\geqslant$30% from baseline as significant). Extubation beyond 8 hours was considered delayed.

Data were entered in Excel and analyzed with SPSS v26 using correlation and regression tests to explore relationships between (PaO_2) variability, extubation time, and confounders such as CPB duration and hematocrit. Confidentiality was strictly maintained.

Expected Outcomes:

- Correlation between intraoperative (PaO_2) variation and postoperative extubation period.

RESULTS

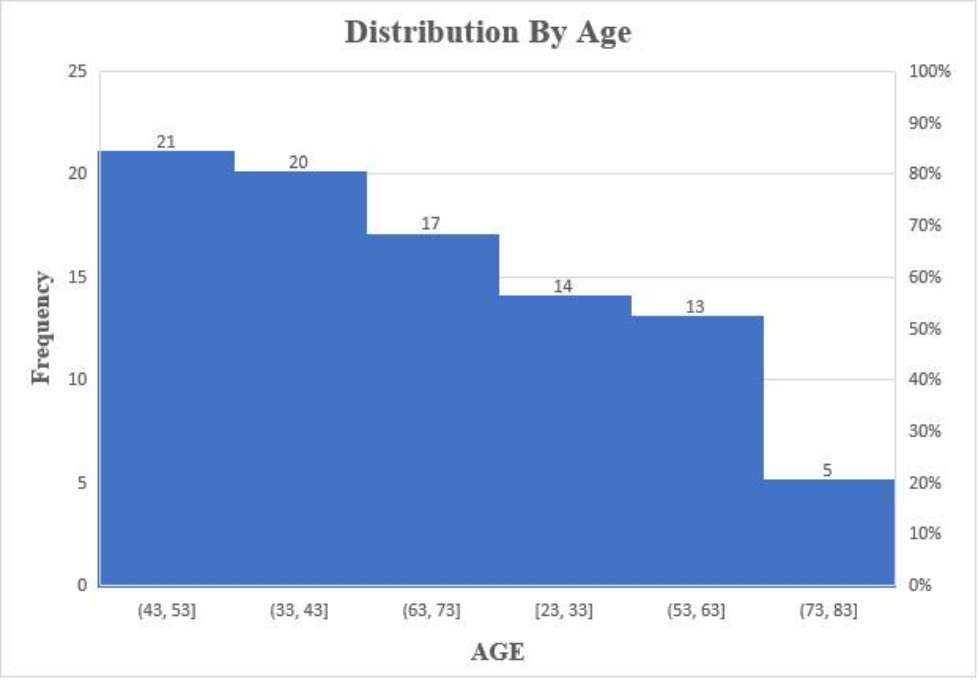
This table shows the mean age of participants (49.80 ± 15.34 years) and the gender distribution, with males comprising 80% and females 20% of the sample. Hypertension (52%) and diabetes (44%) were the most common comorbidities observed among the study population.

Table 1: *Baseline Demographic and Clinical Characteristics of Study Participants*

Variable		Mean ± SD
Age (years)		49.80 ± 15.34
		Frequency (%)
Gender	Male	80 (80.0%)
	Female	20 (20.0%)
Comorbid		
Hypertension		52(52.0%)
Diabetes		44(44.0%)

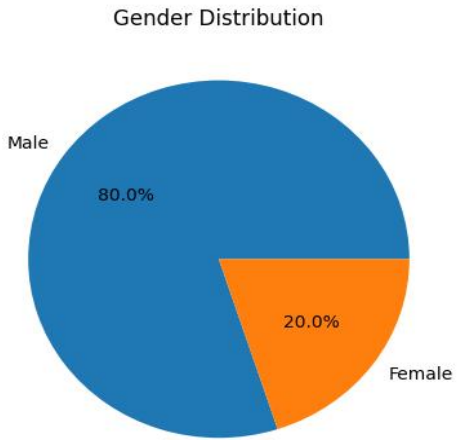
Baseline demographic and clinical characteristics of the study are presented graphically in Figures 1-3.

Figure 1: Histogram of Age Distribution of the Study participants



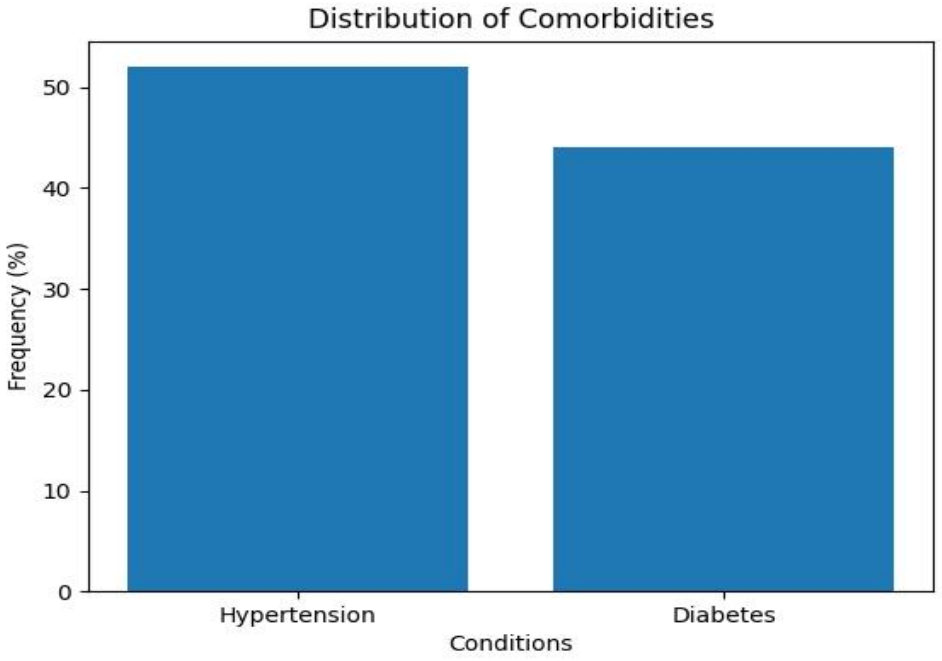
Histogram shows the age distribution of the study participants. The data represent a normal distribution with most of the patients around the mean age of 49.80 ± 15.34 years. This means that the majority of participants are of middle age category and the number of patients at age extremes is lower.

Figure 2: Pie Chart of Gender Distribution of Participants in the study.



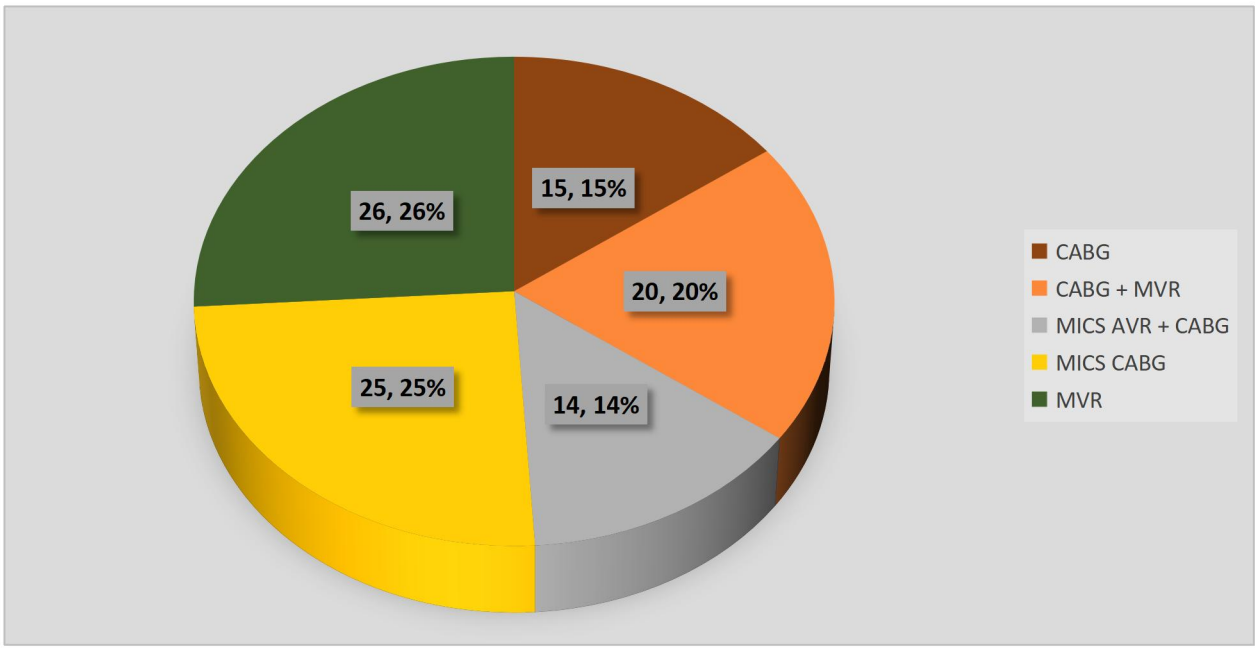
The pie chart shows the distribution of the gender of the study population. Males were the greatest percentage of participants (80%), with women having 20 percent. This shows that the sample size of patients undergoing cardiac surgery was higher among males.

Figure 3: Bar Chart of Distributions of Comorbid Conditions (Hypertension and Diabetes).



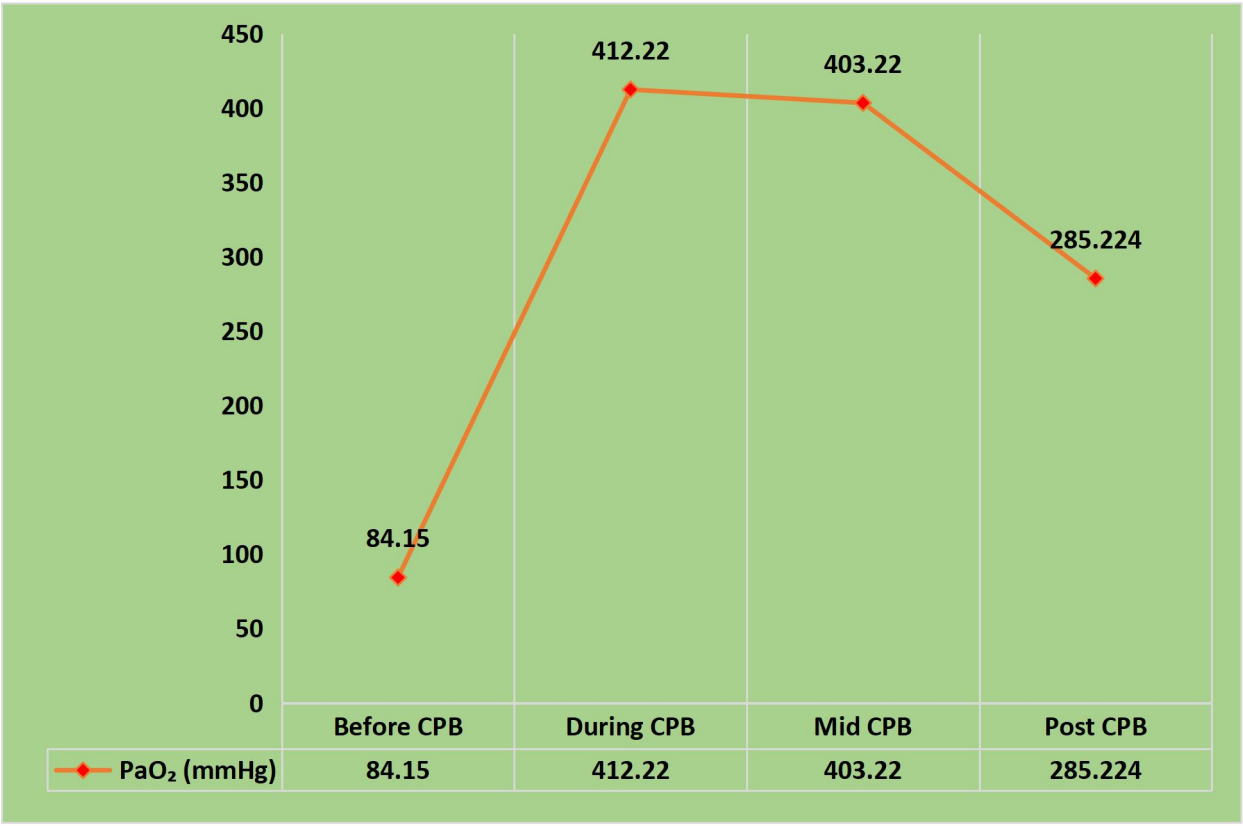
The bar chart shows the prevalence of common comorbid conditions among the people who participated in the study. Hypertension was found in 52% of the patients and diabetes in 44% of the patients. These results indicate that the most common comorbidities in the population under study are hypertension and diabetes.

Figure 4: Distribution of Surgical Procedures Among Study Participants



MVR (26%) and MICS CABG (25%) were the most frequently performed procedures, followed by CABG + MVR (20%). Isolated CABG (15%) and MICS AVR + CABG (14%) constituted smaller proportions of the surgical cases (Figure-4)

Figure 5: Intraoperative Changes in Partial Pressure of Oxygen (PaO_2) During Cardiac Surgery



The line graph shows that PaO_2 levels went up a lot during CPB (412.22 mmHg) compared to before CPB (84.15 mmHg). They then went down a little at mid-CPB (403.22 mmHg) and then went down a lot more after CPB (285.22 mmHg). This pattern shows that oxygen levels change a lot during surgery, especially during the CPB phase as shown in figure -5

Table 2: *Comparison of Mean PaO_2 Levels at Different Intraoperative Time Points*

Time Point	Mean ± SD (mmHg)	F	p-value
Before CPB	84.15 ± 8.08	42.17	<0.001
Initial CPB	412.22 ± 108.04		
Mid CPB	403.62 ± 97.58		
Post CPB	285.24 ± 132.18		

The mean PaO_2 levels showed significant variation across different intraoperative phases, increasing markedly during initial CPB (412.22 ± 108.04 mmHg) compared to pre-CPB levels (84.15 ± 8.08 mmHg), followed by a gradual decline at mid-CPB (403.62 ± 97.58 mmHg) and post-CPB (285.24 ± 132.18 mmHg). The difference was statistically significant ($F = 42.17$, $p < 0.001$), indicating substantial intraoperative fluctuations in oxygen levels during cardiac surgery.

Table 3. *Comparison of Perioperative Oxygenation and Extubation Time Between Stable and Variable groups*

Variable	Stable-Group (n=31)	Variable-Group(n=69)	p-value
	Mean ± SD		
Age (years)	49.23 ± 17.27	50.06 ± 14.51	0.803
CPB duration (min)	126.26 ± 35.01	125.87 ± 33.98	0.958
Clamp duration (min)	58.61 ± 53.36	71.96 ± 48.54	0.221
PaO_2 before (mmHg)	84.23 ± 6.99	84.12 ± 8.57	0.950
PaO_2 during (mmHg)	385.48 ± 88.62	424.24 ± 114.26	0.069
PaO_2 mid (mmHg)	392.70 ± 94.20	408.53 ± 99.35	0.456
PaO_2 post (mmHg)	371.69 ± 91.52	246.40 ± 129.63	0.001
Extubation time (hrs)	8.29 ± 4.97	10.41 ± 4.41	0.03

The Stable and Variable groups exhibited comparability in age, CPB duration, clamp time, and preoperative or intraoperative PaO_2 ($p > 0.05$). After CPB, the Variable-Group had much lower oxygen levels ($p = 0.001$) and longer extubation times ($p = 0.03$), which means that this group took longer time to recover and had lower oxygen levels Table-3.

Table 4: *Baseline Characteristics and Extubation Time in Stable and Variable Groups*

Variable	Category	Stable (n=31)	Variable (n=69)	p-value
		Frequency (%)		
Gender	Male	26 (83.9%)	54 (78.3%)	0.536
	Female	5 (16.1%)	15 (21.7%)	
HTN Type	No	14 (45.2%)	34 (49.3%)	0.679
	Yes	17 (54.8%)	35 (50.7%)	
DM Type	No	19 (61.3%)	37 (53.6%)	0.442
	Yes	12 (38.7%)	32 (46.4%)	
Procedure	CABG	3 (9.7%)	12 (17.4%)	0.324
	CABG+MVR	5 (16.1%)	15 (21.7%)	
	MICS AVR+CABG	4 (12.9%)	10 (14.5%)	
	MICS CABG	12 (38.7%)	13 (18.8%)	
	MVR	7 (22.6%)	19 (27.5%)	
Extubation	⩾8 hrs	13 (41.9%)	43 (62.3%)	0.048
	<8 hrs	18 (58.1%)	26 (37.7%)	

Baseline characteristics, comorbidities, and procedure types were comparable between the Stable and Variable groups ($p > 0.05$). Nonetheless, a markedly greater percentage of patients in the Variable Group experienced extubation ⩾8 hours (62.3% vs. 41.9%; $p = 0.048$), signifying a protracted postoperative recovery.

Statistical Analysis

The appropriate statistical tests comparing the baseline characteristics of the Stable and Variable PaO 2 groups were done according to the type of variables.

- **The Chi-square test** was used to test the connection between groups using categorical variables (gender, hypertension, diabetes, and type of procedure).
- **Continuous variables** (when it was used) were represented as mean and standard deviation and were compared with the help of the independent sample t-test (or ANOVA when it was necessary).
- **A p-value** of ⩽ 0.05 was considered statistically significant.

Interpretation of Results

The analysis showed that there was no statistically significant difference between the Stable and Variable groups in terms of baseline characteristics, including gender distribution, presence of hypertension, diabetes, and type of surgical procedure ($p > 0.05$).

Nevertheless, a greater difference was found in the time of extubation with a greater proportion of patients in the Variable PaO 2 group having delayed extubation (⩾8 hours) than in Stable group (62.3% vs 41.9%, $p = 0.048$).

It means that there was an equal amount of baseline characteristics, but intraoperative variability of PaO2 could be another source of delayed postoperative recovery.

Table 5: *Association of Perioperative Factors and PaO_2 with Extubation Time*

Variable	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Age	0.986 (0.961–1.012)	0.304	0.985 (0.958–1.013)	0.296
CPB (min)	0.996 (0.984–1.008)	0.505	1.004 (0.990–1.018)	0.583
Aortic Cross Clamp time (min)	0.986 (0.977–0.994)	0.002	0.985 (0.976–0.994)	0.002
PaO_2 >150 mmHg	0.996 (0.991–1.001)	0.03	0.996 (0.991–1.002)	0.188

Age, CPB duration, and PaO_2 >150 mmHg did not exhibit any independent effect, but aortic cross-clamp time was significantly correlated with extubation time (adjusted OR 0.985, $p = 0.002$). This suggested that perioperative PaO_2 changes did not directly affect recovery, longer clamp times delayed extubation.

CONCLUSION(S)

The present study indicated that the intraoperative fluctuations in arterial partial pressure of oxygen (PaO_2) during cardiopulmonary bypass was strongly linked with the postoperative outcomes of extubation in cardiac surgery patients. There was also a very high difference in the level of PaO_2 across the various intraoperative stages ($F = 42.17$, $p < 0.001$) which showed that oxygenation was very unstable during the surgical period. A statistically significant delay in extubation was observed in patients with a larger change

in intraoperative PaO_2 ($p = 0.03$), and a higher proportion of patients with a long duration of ventilation (⩾8 hours) than patients with stable oxygen levels (62.3% vs 41.9% $p = 0.048$) with an indication of impaired postoperative respiratory recovery. Though PaO_2 variability was significantly correlated with delayed extubation on a univariate analysis, the association was no longer significant after the confounding variables were taken into account ($p = 0.188$). Conversely, aortic cross-clamp time was found to be an independent and statistically significant predictor of delayed extubation (adjusted $p = 0.002$), highlighting the predominant role played by operative factors on postoperative recovery. To sum up, although the variability of intraoperative PaO_2 is a contributing factor to a delayed ventilatory response, it is not a predictive factor and depends on the factors of the surgery; thus, physiological oxygen stability and optimization of the operating parameters are crucial to enhance the postoperative results and enable a rapid extubation.

Variability in PaO2 was correlated with delayed extubation but did not appear to be an independent predictor, as other operative variables e.g. aortic cross-clamp time had a stronger influence.

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