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ASSESSMENT OF THE IMPACT OF AORTIC CROSS-CLAMP TIME ON POSTOPERATIVE EXTUBATION TIME IN ADULTS PATIENTS UNDERGOING CARDIOPULMONARY BYPASS CARDIAC SURGERY

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Abstract

Background: Aortic cross-clamping is a critical element of cardiac surgery under cardiopulmonary bypass (CPB). The duration of aortic cross clamp (ACC), however, may increase myocardial ischemia, inflammatory response and postoperative cardiopulmonary complications which may results in late postoperative extubation. Objective: To evaluate the effect of the length of aortic cross clamp on the time to extubation after cardiac surgery in adult patients who have undergone cardiopulmonary bypass surgery. Methodology: A cross-sectional observational study was carried out in 100 adult cardiac patients who underwent elective cardiac surgery under CPB in Omer hospital and cardiac care center and Gulab devi chest hospital. Data for demographics, intraoperative and postoperative information were extracted from the anesthesia records, perfusion chart and the ICU monitoring records.SPSS version 27 was used for data analysis for variables such as aortic cross-clamping time, CPB duration, and extubation time. Pearson correlation analysis were used to assess the relationship between ACC time and delayed extubation. Results: The mean age of patients was 49.80 ± 15.34 years, and 80% of the patients in the study were males. The mean CPB duration was 125.99 ± 34.13 minutes, while the

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mean ACC duration was 67.82 ± 50.19 minutes. Patients with delayed postoperative recovery had longer ACC duration than did patients with a stable recovery (71.96 ± 48.54 minutes versus 58.61 ± 53.36 minutes). Patients who had prolonged recovery had delayed extubation ⩾8 hours more often (62.3% vs 41.9% p = 0.048). Logistic regression analysis showed that aortic cross-clamp time was an independent factor associated with delayed extubation (p = 0.002). Conclusion: A longer aortic cross-clamp time is strongly related to post-operative extubation delay in adult cardiac surgery patients undergoing CPB. Efforts to minimize ischemic exposure during surgery can enhance postoperative recovery and speed up extubation.

Keywords: Aortic cross-clamp time, cardiopulmonary bypass, extubation time, cardiac surgery, myocardial ischemia, delayed extubation.

INTRODUCTION

Cardiopulmonary bypass (CPB) is a routine surgical procedure that is life-saving and is used for the treatment of a broad range of cardiovascular disease including coronary artery disease, valvular heart disease and congenital cardiac defects. Despite the many advances in surgery, myocardial protection, anesthetic management, and postoperative intensive care, postoperative morbidity is still a major clinical issue in the post-open-heart surgical patient. Aortic cross-clamp (ACC) time is one of the most important intra-operative factors that affects the post-operative outcomes [1].

Aortic cross-clamp is used in most cardiac surgical procedures under CPB. In this stage, the ascending aorta is clamped (stopped) to separate systemic circulation from the heart, so that the surgeons can operate without any movement or blood loss. This allows for precise surgical manipulation, but also causes global myocardial ischemia and interruption of coronary blood flow. Cardioplegia and hypothermia are most important to protect the myocardium during this period, but still may lead to large amounts of metabolic and cell damage if exposure to ischemia is prolonged [2].

Postoperative outcome of many patients is known to be influenced by the aortic cross-clamp time. The more time the cross-clamp is open, the more chances of myocardial ischemic damage, oxidative stress, inflammatory activation and ischemia-reperfusion injury. When the aortic clamp is removed and coronary blood flow returns to the previously ischemic myocardial tissue, the production of reactive oxygen species

(ROS), calcium overload, mitochondrial dysfunction and endothelial injury occurs. These pathophysiological mechanisms contribute to myocardial stunning, decreased cardiac contractility, arrhythmia and systemic inflammatory responses with possible detrimental effects in the recovery [3].

Myocardial injury is not the sole effect of the prolonged ACC, as there are also significant effects on pulmonary and systemic physiology. The CPB procedure itself is linked to inflammatory activation from contact of blood with nonendothelial surfaces, hemodilution and temperature changes. This inflammatory response is further exacerbated by prolonged periods of ischemia and reperfusion, with associated endothelial dysfunction, increased capillary permeability, impaired gas exchange and decreased lung compliance. The mechanical ventilatory support and postoperative extubation can be prolonged due to these physiological disturbances [4].

Extubation time after cardiac surgery is deemed to be a crucial parameter of early recovery after surgery. Early extubation has been associated with improved pulmonary function, reduced length of stay in the intensive care unit (ICU), reduced health care costs, reduced complications related to the use of a ventilation device and improved outcome. In Contrast increased morbidity, long intensive care unit stay, greater risk of pulmonary infections, fatigue of the respiratory muscles and utilization of the hospital resources have been associated with delayed extubation. Therefore, during clinical practice, it is crucial to understand what factors might be playing a role in delayed extubation during surgery and facilitate postoperative care and recovery [5].

Aortic cross-clamp duration has been shown in several studies to be a significant predictor of adverse postoperative events, such as low cardiac output syndrome, renal dysfunction, prolonged ICU stay, neurologic complications and mortality. It is also believed that prolonged ischemia time after cross clamping could have a profound effect on postoperative respiratory recovery mechanism based on recent evidence. Exposure to long duration of ACC is associated with prolonged mechanical ventilation because of myocardial dysfunction, pulmonary inflammation and delayed systemic recovery [6].

Aortic cross-clamp time and extubation time are issues that have been studied more and more in the context of cardiac anesthesia and perfusion in modern times. The

concept of fast-track cardiac anesthesia protocols is to move towards early extubation to facilitate recovery and maximize the use of resources in the ICU. However, longer operating time can compromise the quick recovery goals as it can lead to increased ischemic damage, and may be associated with a longer window for CP stabilization. Thus, knowledge of the role of ACC duration on extubation after surgery, may help the surgeon to optimize extubation timing, myocardial protection strategies and/or perioperative management [7].

While it is recognized that long ACC is important, most previous studies have focused on primary cardiovascular complications and mortality rather than recovery from the respiratory effects of the surgery and outcome of postoperative extubation. In addition, findings have been limited to the use in different populations, surgical procedures, anesthetic techniques, and institutional protocols. Existing literature on the correlation of the prolonged time spent in the ACC and extubation time for adult cardiac surgery patients is sparse, especially in the regional medical center [8].

The present study, therefore, sets out to evaluate whether the intraoperative aortic cross-clamp time affects postoperative extubation time in adult cardiac surgery patients undergoing CPB. This study aims to give clinically relevant data that can help to optimize perioperative management, which should lead to fewer postoperative complications and better postoperative recovery after cardiac surgery, by analyzing the relationship between ACC duration and postoperative ventilatory recovery.

LITERATURE REVIEW

Cardiac surgery using cardiopulmonary bypass (CPB) requires aortic cross clamping. It interrupts the coronary blood flow, so as to create a bloodless surgical field, but at the same time, it exposes the myocardium to the global ischemia condition. During this ischemic period, myocardial cells switch to anaerobic metabolism which causes ATP depletion, acidosis, calcium overload and myocardial cells begin to swell [9].

Prolonged Aortic cross clamp (ACC) duration may be associated with greater myocardial stress levels and can exceed cardioplegic protective levels. Reopening blood flow after the removal of the clamps causes ischemia-reperfusion injury, which leads to oxidative stress and inflammation and to endothelial dysfunction and impaired myocardial contractility. However, several studies have demonstrated that a long ACC

time is associated with worse postoperative complications such as arrhythmia, low cardiac output syndrome, prolonged ventilation and death [10].

During cardiac surgery, myocardial protection is essential since the aortic cross-clamping stops the delivery of blood to the heart. During ischemia, the heart's oxygen consumption and metabolism are typically decreased by cardioplegia and systemic hypothermia [11].

Even with these protective measures, ischemic duration may be long enough to result in myocardial injury and postoperative ventricular dysfunction. Once the cross clamp is removed, reperfusion will generate reactive oxygen species (ROS) and inflammatory mediators, resulting in an ischemia-reperfusion injury and late hemodynamic recovery [12].

CPB is a technique used during cardiac surgery to sustain systemic circulation, but can lead to activation of inflammatory processes, oxidative stress and organ dysfunction. Inflammatory pathways are activated with increased ischemic time and are exacerbated by blood contact with artificial extracorporeal surfaces [13]. Longer ACC duration is often accompanied by a longer CPB duration and more complex surgery. Research has shown that prolonged ischemic exposure during CPB is associated with various myocardial, pulmonary, renal and delayed postoperative complications [14].
Pulmonary dysfunction is a common complication after cardiac surgery with CPB. An extended period of ACC will lead to greater systemic inflammation, pulmonary endothelial damage, increased capillary permeability, pulmonary edema, impaired gas exchange, and decreased lung compliance [15].

Also, prolonged myocardial ischemia can further affect cardiac output and pulmonary perfusion; which can lead to further decompensation of the respiratory system. There have been several studies, reporting that there is a significant association between extended ACC time and prolonged mechanical ventilation, respiratory distress, and delayed extubation postoperatively [16].

The time after extubation is a significant period of recovery post cardiac surgery. Early extubation is shown to be associated with less intensive care unit (ICU) stay, less health care costs, and fewer complications related to the ventilator. But delayed

extubation still occurs and can be affected by a number of factors such as: length of CPB, myocardial dysfunction, pulmonary complications, and length of ACC time [17].

Patients who have been cross-clamped for a longer period of time tend to have systemic inflammation, decreased cardiopulmonary function, and a delayed hemodynamic stabilization, which requires a longer ventilatory support [18]. ICU length of stay is a significant predictor of post cardiac surgery morbidity. The longer patients stay in the ICU, the longer they take to recover, especially if they need to be ventilated for an extended period of time [19].

Longer duration of the ACC has been correlated with longer duration of the ICU stay, because of myocardial dysfunction, pulmonary dysfunction and systemic inflammatory response. Research indicates that the risk of earlier extubation, better cardiopulmonary recovery and decreased length of stay in the ICU are associated with a shorter ACC duration [20].

Thus, the analysis of the relationship between the duration of the ACC and post-extubation can guide perioperative management and improve patient outcomes.

MATERIAL AND METHODS

Study Design

This study was conducted as a cross-sectional non-interventional observational study in the Cardiac Perfusion Unit of Omer Hospital and Cardiac Care Center and Gulab Devi Chest Hospital. The study evaluated intraoperative and postoperative clinical data of adult patients undergoing elective cardiac surgery under cardiopulmonary bypass (CPB).

Study Duration

The total duration of the study was four months, including data collection, data analysis, interpretation, and documentation of findings.

Study Population

The study population consisted of adult patients aged 18 years and above undergoing elective cardiac surgery requiring cardiopulmonary bypass. Surgical procedures included coronary artery bypass grafting (CABG), mitral valve replacement (MVR), minimally invasive cardiac surgery (MICS CABG), aortic valve replacement (AVR), and combined cardiac procedures.

Sample Size

A total of 100 adult cardiac surgery patients undergoing CPB were included in the study using a non-probability convenient sampling technique.

The patients were categorized into two groups according to intraoperative aortic cross-clamp duration:

Sample Size Calculation

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

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

Using a 95% confidence level (Z = 1.96), p = 0.5, and d = 0.01, the required sample size is:

$$n = \frac{1.96^2 \times 0.5 \times 0.5}{0.01^2} \approx 98.$$

However, due to available resources, the study were include 100 patients

Group A (Prolonged Cross-Clamp Group)

Patients with prolonged aortic cross-clamp time greater than 90 minutes.

Group B (Normal Cross-Clamp Group)

Patients with aortic cross-clamp time less than or equal to 90 minutes.

Inclusion Criteria

- Adult patients aged 18 years or older.
- Patients undergoing elective cardiac surgery under cardiopulmonary bypass.
- Availability of complete intraoperative and postoperative records.
- Patients successfully extubated during the same ICU admission.

Exclusion Criteria

- Emergency cardiac surgeries.
- Redo cardiac surgeries.
- Patients with severe pre-existing pulmonary disease such as chronic obstructive pulmonary disease (COPD) or acute respiratory distress syndrome (ARDS).
- Patients with incomplete intraoperative or postoperative records.
- Intraoperative complications resulting in deviation from standard surgical or anesthetic protocols.

Data Collection Procedure

Clinical data were collected from anesthesia charts, perfusion records, operative reports, and ICU monitoring records. Demographic variables including age, gender, body mass index (BMI), and comorbidities were recorded.

Intraoperative variables included:

- Aortic cross-clamp time
- Cardiopulmonary bypass duration
- Hematocrit level
- Perfusion flow rate
- Type of cardiac surgery
- Temperature during CPB

Postoperative variables included:

- Extubation time
- Duration of ICU stay
- Need for prolonged mechanical ventilation

Extubation time was defined as the total duration in hours from ICU admission following surgery until successful removal of the endotracheal tube.

Delayed extubation was considered when extubation occurred more than 8 hours after ICU admission.

Equipment Used

The following equipment and monitoring systems were used during the surgical procedures:

- Cardiopulmonary bypass machine
- Arterial blood pressure monitoring system
- Multi-parameter patient monitor
- Arterial blood gas analyzer
- Temperature monitoring devices
- Perfusion flow monitoring system

Data Analysis

Data were entered and analyzed using Statistical Package for Social Sciences (SPSS) version 27.0.

Descriptive statistics were calculated for demographic and clinical variables. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages.

Pearson correlation analysis was performed to evaluate the relationship between aortic cross-clamp time and postoperative extubation duration. Independent sample t-tests were used to compare extubation times between patient groups. Multiple linear regression analysis was performed to assess the independent effect of aortic cross-clamp duration on extubation time while controlling for confounding variables including age, BMI, CPB duration, hematocrit, and type of surgery.

A p-value of less than 0.05 was considered statistically significant.

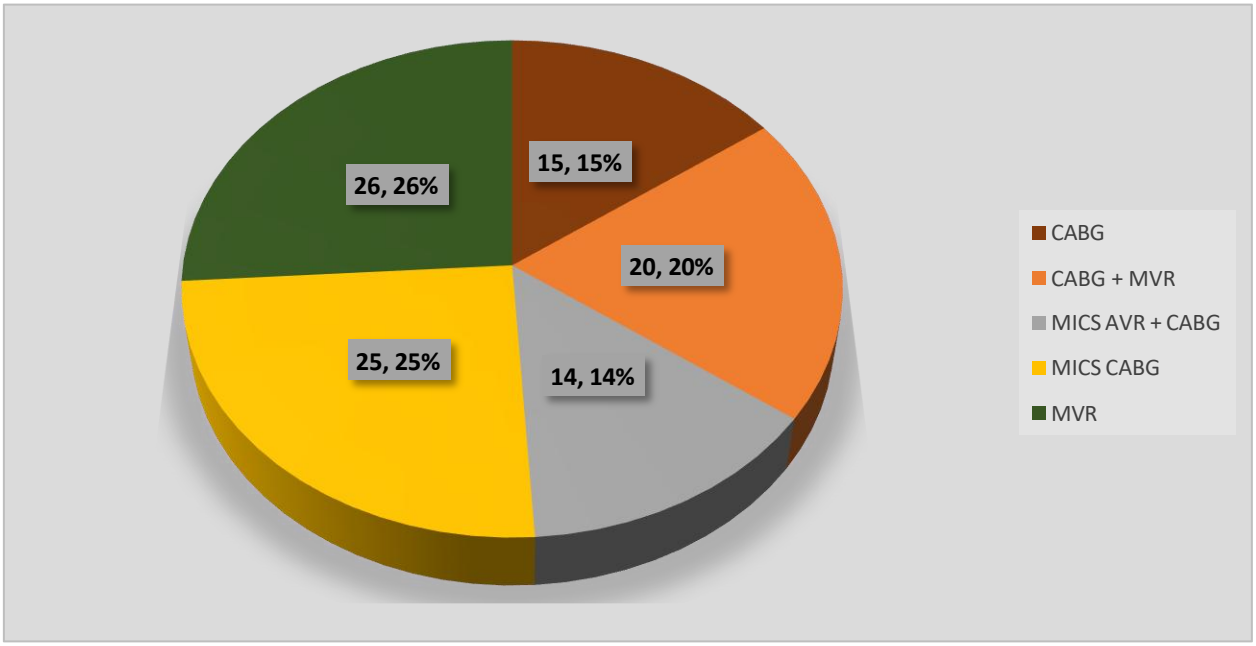
RESULTS

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%)

Figure 1: 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-1)

Intraoperative Aortic Cross-Clamp and CPB Duration

The mean aortic cross-clamp time among study participants was significantly prolonged in complex cardiac procedures compared to isolated surgeries. Patients with prolonged ACC duration demonstrated longer cardiopulmonary bypass time and increased postoperative ventilatory support requirements.

The mean CPB duration was also elevated in patients with prolonged cross-clamp exposure, suggesting increased intraoperative complexity and ischemic burden.

Comparison Between Patient Groups

Patients with prolonged postoperative recovery demonstrated increased aortic cross-clamp duration compared to patients with earlier extubation. The mean cross-clamp duration was 71.96 ± 48.54 minutes in the delayed recovery group compared with 58.61 ± 53.36 minutes in the stable recovery group. Although the difference did not reach statistical significance in univariate comparison ($p = 0.221$), prolonged ACC duration showed a clinically important trend toward delayed extubation.

Similarly, extubation time was significantly prolonged in patients with delayed postoperative recovery (10.41 ± 4.41 hours) compared with patients demonstrating earlier extubation (8.29 ± 4.97 hours) (p = 0.03).

Table 2: *Comparison of Intraoperative Aortic Cross Clamp 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
Extubation time (hrs)	8.29 ± 4.97	10.41 ± 4.41	0.03

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.

Table 3: *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%)	
	CABG+MVR	5 (16.1%)	15 (21.7%)	
	MICS AVR+CABG	4 (12.9%)	10 (14.5%)	0.324
	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%)	

Multiple logistic regression analysis was performed to evaluate predictors of delayed postoperative extubation. Among all perioperative variables analyzed, aortic cross-clamp time was identified as the only statistically significant independent predictor of delayed extubation.

The adjusted odds ratio for aortic cross-clamp duration was 0.985 (95% CI: 0.976–0.994; p = 0.002). In contrast, age and CPB duration did not demonstrate statistically significant associations with extubation delay after adjustment for confounding variables.

Table 4: ***Association of perioperative factors of Aortic Cross Clamp and 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

DISCUSSION

The present study determined the association between the aortic cross-clamp (ACC) time and the extubation time in the post-operative period in adult patients undergoing cardiac surgery under cardiopulmonary bypass (CPB). Results showed that longer durations of ACC were correlated with longer postoperative ventilatory recovery and higher rate of delayed extubation.

Aortic cross-clamping is an integral part of cardiac surgery, but ischemic exposure of the heart during the application of a cross-clamp may be a major source of myocardial and systemic injury. In the present study, patients with delayed postoperative recovery had a longer duration of the ACC than patients who recovered earlier. In addition, regression analysis revealed that duration of the ACC was an independent predictor of delayed extubation, underscoring the clinical significance of reducing ischemic time during the cardiac surgery procedure [9,11].

There are several physiological mechanisms that may account for this association between prolonged ACC duration and delayed extubation that was observed. Aortic cross clamping causes global myocardial ischemia, causing metabolic stress, ATP depletion, intracellular acidosis and calcium accumulation. Cardioplegia and hypothermia offer myocardial protection but extended ischemic exposure can result in

marked myocardial dysfunction. After clamping, reperfusion worsens the oxidative stress, activates inflammation and dysfunctions the ventricular performance. These adjustments can delay the hemodynamic stabilization after surgery and make the ventilatory support more prolonged [9,11-12].

The findings of this study confirm earlier findings of other studies that shown that longer ischemic time in cardiac surgery has a negative impact on recovery. Multiple investigators have found prolonged duration of the ACC to be correlated with mechanical ventilation, low cardiac output syndrome, longer length of stay in the intensive care unit, renal dysfunction, and a higher incidence of postoperative morbidity. Overall, the current results confirm a role for ACC duration as an important factor in postoperative respiratory recovery [10,14,16,20].

The systemic inflammatory response by CPB is mediated by the interaction of blood with extracorporeal surfaces, hemodilution and oxidative stress. With a long CPB, a long ACC, inflammatory injury may be more severe, and result in pulmonary endothelial dysfunction, altered gas exchange and decreased lung compliance. Such changes in physiology can vary significantly for extubation following surgery [13,15].

Patients with longer recovery had longer extubation times than the patients with earlier recovery in the present study. Furthermore, patients who received prolonged operative stress and ischemic time exhibited a significantly higher rate of delayed extubation $\geqslant$8 hours. Based on these findings, it can be concluded that the duration of ACC may directly affect the stabilization of the breathing after surgery and ventilatory dependence.

Early extubation is a vital part of fast-track cardiac anesthesia programmes, and is linked to better patient outcomes, reduced hospital costs, reduced ventilator-associated complications, and a shorter time in the intensive care unit. On the other hand, delayed extubation leads to pulmonary infections, weakness of respiratory muscles, long length of stay in the ICU and postoperative morbidity. Thus, it is clinically important to determine factors that can be modified in the operating room that are associated with delayed extubation [5,17,19-20].

Based on the results of this study, it is recommended to shorten the duration of aortic cross-clamp time and therefore, promoting earlier extubation after cardiac surgery.

Minimization of ischemic burden and optimization of cardiopulmonary function after surgery could be improved by optimization of surgical techniques, improved myocardial preservation strategies and careful management during surgery.

Limited numbers of cardiac centers and limited numbers of patients were used in the study and this may restrict the generalizability of the findings. Some differences in the complexity of the surgery, anesthetic management, myocardial protection, and postoperative intensive care unit (ICU) care protocols may also have contributed to differences in extubation outcomes. Moreover, the present study did not address the long-term postoperative complications and death rates.

The authors do not underestimate the value of the results obtained in their study, even if it is limited by the above constraints, because of the clinical relevance of their findings in the association of prolonged aortic cross-clamp time with delayed postoperative extubation. These results could be extended and expanded in future multi-center studies with bigger number of patients and additional peri-operative factors that might influence the recovery of ventilation following surgery.

CONCLUSION

This study showed that longer aortic cross-clamp (ACC) times during heart surgery lead to longer tube removal times after surgery in adults. Longer ACC durations seem to slow down how fast people recover their breathing and heart functions afterward.

This delay could be because of extended lack of blood flow to the heart during surgery. It might make the heart work less well, spark more inflammation, and mess up normal breathing, which means people need ventilators longer.

These findings point out that ACC time is a big deal in surgery, impacting how quickly someone gets better right after the procedure. Shortening ACC time through improved techniques and care could mean getting the breathing tube out faster and improving results. More big studies across different centers would help confirm these findings and learn about other things that affect breathing recovery after heart surgery.

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