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Original Research Article

Impact of duration of cardiopulmonary bypass on recovery after open heart surgery

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ABSTRACT

Background: Objective of the study was to examine the impact of cardiopulmonary bypass (CPB) duration on recovery from cardiac surgery.
Methods: This is an observational retrospective study. Data from adult cardiac surgical patients presented at Queen Alia Heart Institute (QAHI) in the duration between September 2023 and February 2024 was retrospectively analysed. The impact of CPB duration was examined. Patients were divided into groups according to CPB duration (0 to 60 minutes, 60 to 120 minutes, 120 to 180 minutes, 180 to 240 minutes and 240 to 300 minutes). For each group intra-operative and post-operative variable were examined. The intra-operative variables studied were need for blood transfusion, haemofiltration and intra-aortic balloon pump. The post-operative variables studied were duration of post-operative mechanical ventilation, intensive care unit (ICU) stay, hospitalization time and mortality.
Results: Consecutive data of 202 adult cardiac surgical patients (34 females and 168 males) was analysed. Average age of patients was 57.149 years. Average duration of CPB was 109.9 minutes (ranged from 29 to 300 minutes). Half of the patients (50.5%) had CPB duration between 1 and 2 hours. Blood transfusion was needed in 88 patients (43.6%). Haemofiltration was used in 32 patients (15.8%) and intra-aortic balloon pump (IABP) was used in 29 patients (14.4%). The average postoperative time of mechanical ventilation was 34 hours and the average ICU stay was 5.5 days. Chest re-exploration was needed in 30 patients (15%). Hospital stay was on average 12 days and in-hospital mortality was witnessed in 20 patients (9.9%). Patients who had CPB for less than one hour (17.3%) had the lowest incidence of blood transfusion (37.1%), lowest incidence of haemofiltration (8.6%), low incidence of IABP use (11%). They also had lowest incidence of chest re-opening (5.7%), shortest time of postoperative mechanical ventilation (13 hours) and shortest ICU and hospital stay (4.1 and 8.5 days, respectively). There was a significant increase in postoperative sternal re-opening and postoperative mortality when the duration of CPB exceeded 3 hours.
Conclusions: Duration of CPB is a key predictor of recovery and outcome of cardiac surgery. Shorter CPB time was associated with earlier extubation, less ICU stay and shorter hospitalisation time. Prolonged CPB was associated with higher rates of complications, delayed recovery, longer ICU stay, protracted hospitalisation and higher mortality rates.

Keywords: Cardiac, Cardiopulmonary bypass, Extubation, Hospitalisation, Recovery, Surgery

INTRODUCTION

Cardiopulmonary bypass (CPB) is a form of extracorporeal circulation (ECC) that temporarily replaces the circulatory function of the heart, the respiratory function of the lungs and allows temperature control of the blood during cardiac surgeries.[1] The CPB techniques includes diversion of the blood from the heart and lungs, to be rerouted to the CPB machine where it will be oxygenated, to have carbon dioxide removed and to be pumped back in a precise and controllable fashion to perfuse the body during heart surgeries.[2] Advances in

cardiac surgery have been possible because of CPB development. Historically, the first use of CPB on humans was by Doctor John Gibbon in 1952 for closure of an atrial septal defect (ASD).[3] For more than half a century of its use, the CPB has undergone major improvements due to advancements in biomedical engineering, medical and clinical sciences.[4] Despite the fact that CPB has enabled the delivery of complex cardiovascular surgical procedures and even with all the advancements in CPB and innovations in perfusion sciences, multitudes of adverse effects of CPB exist and persist.[5] Over the years, CPB has undergone immense modifications in the form of novel de-foaming agents, heparin coated circuitry, pressure and temperature monitoring, bubble detectors, ultrafiltration, miniaturised circuit design, integrated arterial filters with oxygenator and other; still it is not without its share of side effects and complications.[6] These include adverse effects of cannulation (aortic, atrial and bicaval), exposure to the CPB circuit, ischemia, emboli and hypo perfusion especially to the CNS, cognitive dysfunction, acute kidney injury (AKI), systemic inflammatory response syndrome (SIRS) involving activation of neutrophils, complement, kallikrein systems and release of tumour necrosis factor (TNF), myocardial stunning, acute lung injury (ALI), acute respiratory distress syndrome (ARDS) secondary to SIRS, neutrophil activation and decreased surfactant, ischemic gut, acalculous cholecystitis, hepatitis, or pancreatitis, and electrolyte disturbances.[7-9] In addition, CPB catastrophes may occur, including supply failure, disconnection, gas emboli, dislodgement or misplacement of the cannulae and their occlusion resulting high pressures and low flows.[10,11] Therefore, the duration of CPB is of paramount importance for an acceptable outcome that meets the expectations of patients and their families. Several literature reports and studies demonstrated that prolonged CPB duration independently predicts postoperative morbidity and mortality after cardiac surgery. Studies have also shown that despite improvements over time with regard to CPB; longer CPB time remains a significant factor determining post-operative mechanical ventilation, mediastinal blood loss, neurological injury, acute kidney injury, ICU and hospital length of stay, and in-hospital mortality. There is no agreement on the safe cut-off value for the safe duration of CPB.[12] In this research, we will study the impact of CPB duration on different clinical outcomes that include post-operative mechanical ventilation, mediastinal blood loss, blood transfusion requirements, ICU stay, surgical complications, length of hospitalisation, and in-hospital mortality.

METHODS

This is an observational retrospective study. Data from adult cardiac surgical patients presented at Queen Alia Heart Institute (QAHI) in the duration between September 2023 and February 2024 was retrospectively analysed. The impact of CPB duration on outcome of cardiac surgery was examined. Patients were divided into five groups according to CPB duration (0 to 60 minutes, 60 to 120 minutes, 120 to 180 minutes, 180 to 240 minutes and 240 to 300 minutes). For each group intra-operative and post-operative variable were examined. The intra-operative variables studied were needs for blood transfusion, need for haemofiltration and the need for intra-aortic balloon pump insertion. The post-operative variables studied were the post-operative mechanical ventilation time, ICU stay, hospitalisation time and mortality. Data was statistically analysed using Microsoft excel. Ethical committee approval obtained from the hospital's institutional review board (IRB).

RESULTS

This study comprises data of 202 cardiac surgical patients (34 females and 168 males). Average age of patients was 57.149 years. Average duration of CPB was 109.9 minutes (ranged from 29 to 300 minutes). Most of the patients (50.5%) had CPB duration between 1 and 2 hours (Figure 1). Blood transfusion was needed in 88 patients (43.6%). Haemofiltration was used in 32 patients (15.8%) and IABP was used in 29 patients (14.4%) (Figure 2).

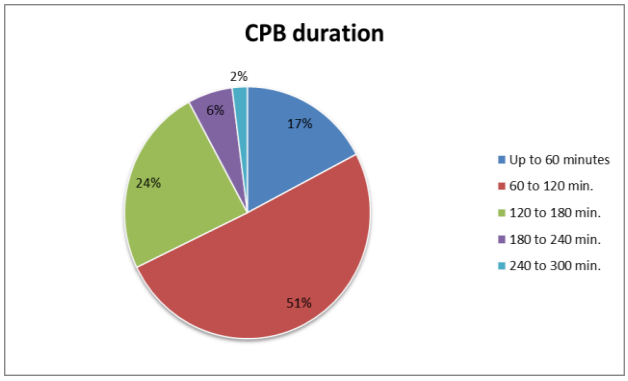

Figure 1: Cardiopulmonary bypass duration.

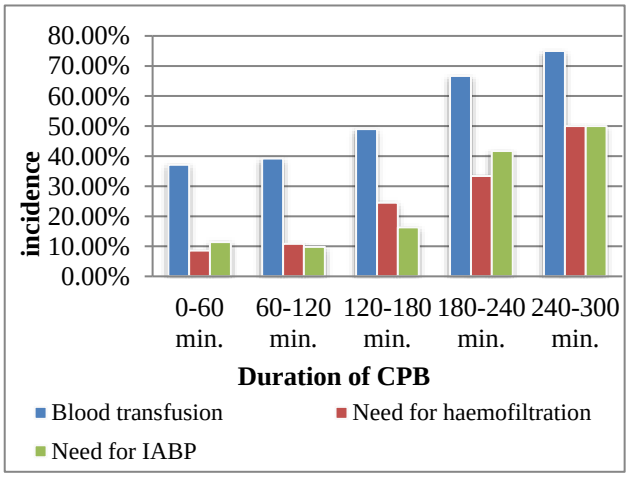

Figure 2: Impact of CPB duration on intra-operative characteristics.

The average postoperative time of mechanical ventilation was 34 hours and average ICU stay was 5.5 days. Chest re-

exploration (re-opening) was needed in 30 patients (15%). Hospital stay was on average 12 days and in-hospital mortality was witnessed in 20 patients (9.9%). Patients who had CPB for less than one hour (17.3%) had the lowest incidence of blood transfusion (37.1%), lowest incidence of haemofiltration (8.6%), low incidence of intra-aortic balloon pump (IABP) use (11%). They also had lowest incidence of chest re-opening (5.7%), shortest time of postoperative mechanical ventilation (13 hours) and shortest ICU and hospital stay (4.1 and 8.5 days, respectively) (Table 1). The longer the CPB time the higher the incidence of blood transfusion, need for haemofiltration, need for IABP, need for chest re-exploration and mortality. Moreover, the longer the CPB time; the longer was the time of postoperative mechanical ventilation, ICU stay and hospitalisation time (Figure 3). There was a sharp increase in postoperative chest re-opening (re-exploration) and postoperative mortality when the duration of CPB was more than 3 hours (Figure 4).

Table 1: Comparison of intra-operative and post-operative characteristics according to time of CPB.

Characteristics	00-60 min	60-120 min	120-180 min	180-240 min	240-300 min
Number of patients (%)	35 (17.3)	102 (50.5)	49 (24.2)	12 (5.9)	4 (2)
Incidence of blood transfusion	13 (37.1)	40 (39.2)	24 (49)	8 (66.7)	3 (75)
Incidence of haemofiltration	3 (8.6)	11 (10.8)	12 (24.5)	4 (33.4)	2 (50)
Incidence of IABP	4 (11.4)	10 (9.8)	8 (16.3)	5 (41.7)	2 (50)
Postoperative mechanical ventilation (hours)	12.78	22	34.1	99.5	203
Incidence of re-opening (%)	2 (5.7)	9 (8.8)	11 (22.4)	6 (50)	2 (50)
ICU stay (days)	4.1	5.4	5.5	7.3	12
Hospital stay (days)	8.5	13	12.8	13.9	18
In-hospital mortality	2 (5.7)	5 (4.9)	6 (12.2)	5 (41.7)	2 (50)

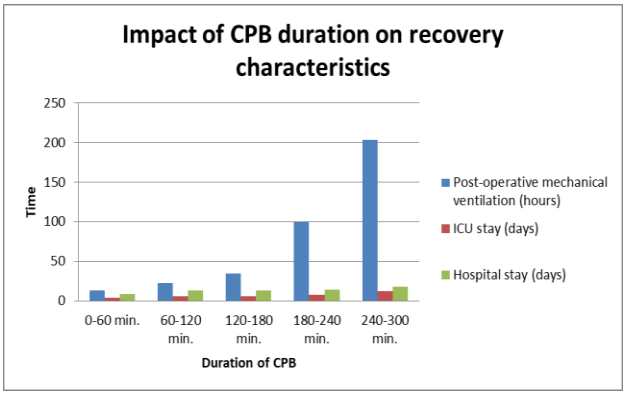

Figure 3: Impact of CPB duration on post-operative recovery.

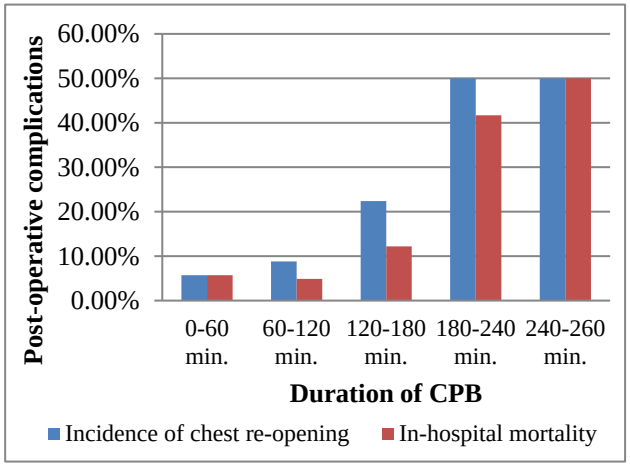

Figure 4: Impact of CPB duration on post-operative morbidity and mortality.

DISCUSSION

Heart surgery is distinguished from other types of surgery by the use of CPB machine. Although CPB has helped millions of patients undergoing heart surgeries; it is a non-physiological state with myriad of major complications on different body systems and organs, including cerebral, neurological, renal, lung, haematological, gastrointestinal, vascular and other. Therefore, we decided to study the impact of the duration of CPB on recovery parameters and overall outcome of cardiac surgery.

There is no global agreement on a cut-off value for safe or optimal duration of CPB. Madhavan et al found that CPB time of more than 180 minutes was a significant predictor of mortality.[13] Hu et al depicted that optimal cut-off duration of CPB was less than 160 min for ICU and in-hospital mortality.[14] Nadeem et al illustrated that CPB time duration acts to affect clinical outcomes adversely and is associated with prolonged postoperative mechanical ventilation.[15] Therefore, with the intention of finding the optimal limit of safe CPB duration, we conducted this retrospective observational study of 202 patients; we divided the patients into groups according to the duration of CPB and observed intraoperative and postoperative recovery parameters in each group. More than half of the patients in this study had a CPB duration of 60-120 minutes (Figure 1). Patients who had shortest CPB duration (less than 60 minutes) comprised 17.3% of the total study population and they had lowest incidence of blood (or blood product) transfusion, haemofiltration and shortest time of postoperative mechanical ventilation. They also had lowest incidence of postoperative chest re-opening (re-exploration), shortest intensive care unit (ICU) length of stay, shortest hospitalisation period and

lowest mortality rate. Patients who had duration of CPB between one and two hours had slightly higher needs of blood and blood products transfusions, slightly higher needs of intraoperative haemofiltration, higher rates of re-opening of sternum, longer average time to tracheal extubation, and slightly longer ICU and hospital length of stay (Table 1). However, for each extra hour of CPB time thereafter, there was a considerable increase in rates of blood transfusion, haemofiltration, need for IABP to facilitate weaning, higher re-opening rates and considerable delays in tracheal extubation, ICU discharge and hospital discharge. The in-hospital mortality rate increased with each hour increase in CPB duration, especially when the duration of CPB was above three hours (Figure 4).

Our study showed that each and every minute of CPB time had an impact on recovery and outcome of cardiac surgery. Patients with shorter CPB time during their surgery had faster recovery and lower mortality rates. On the other hand; longer duration of CPB was associated with delayed recovery manifested by prolonged time of postoperative mechanical ventilation, higher incidence of blood transfusions, more postoperative bleeding, higher incidence of re-sternotomy (reopening), and increased need of IABP to facilitate weaning from CPB, extended ICU stay, lengthened hospitalisation time and higher mortality.

Limitations of this study include the observational nature of the study, the relatively small number of patients and that it is a single centre study.

CONCLUSION

Duration of CPB is a significant predictor of recovery and outcome of cardiac surgery. Shorter CPB time was associated with earlier tracheal extubation, less ICU stay, shorter hospitalisation time and good outcome. On the other hand, prolonged CPB was associated with higher incidence of complications, delayed recovery, longer ICU stay, protracted hospitalisation and higher mortality rates.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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