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Original Article

Impact of Cardiopulmonary Bypass Time and Aortic Cross Clamp Time on Immediate Post-Operative Outcomes in Patients with Congenital Heart Disease Undergoing Open Heart Surgery

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ABSTRACT

Objective: to find out the impact of cardiopulmonary bypass time (CPBT) and aortic cross-clamp time (ACCT) on immediate post-operative outcomes in patients with congenital heart disease (CHD) undergoing open heart surgery at a tertiary care centre.

Study Design: Prospective longitudinal study.

Place and Duration of the Study: Department of Paediatric, Cardiac Intensive Care Unit, National Institute of Cardiovascular Diseases (NICVD), Karachi Pakistan, from Jul to Dec 2021.

Methodology: We enrolled 104 patients of both genders up to any age with CHD undergoing open heart surgeries. At the time of admission, age, gender, body weight, presence of cyanosis and types of CHDs were noted. Duration of mechanical ventilation, pediatric cardiac intensive care unit (PCICU) stay, and mortality was recorded. Baseline characteristics and post-surgery parameters were compared about CPBT and ACCT.

Results: Of 104 patients, 58(55.8%) were males. Overall, the mean age was 7.9±5.1 years. Cyanosis was noted in 34(32.7%) cases. Mean CPBT was 74.6±42.9 minutes, while the mean ACCT was 43.5±29.5 minutes. Most types of CHDs were noted to be tetralogy of Fallot (ToF) 28(26.9%). An increase in the duration of CPBT and ACCT was found to have a significant association with post-surgical morbidity (p<0.001).

Conclusion: Increased cardiopulmonary bypass time and aortic cross-clamp time were found to have a significant association with post-surgical morbidity and outcomes among cases undergoing open heart surgeries for congenital heart diseases.

Keywords: Cardiopulmonary bypass time, aortic cross-clamp time, congenital heart disease.

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INTRODUCTION

The global incidence of congenital heart disease (CHD) is estimated to be between 3-10 per 1000 live births.[1,2] Local data from Pakistan have estimated around 40000 live births with CHD every year.[3] Data from China revealed the incidence of CHD as 8.0/1000 live births.[4] Recent advancements have seen a major decline in the mortality rates among cases of CHD.[5,6]

Peri-operative risk stratification of CHD cases depends upon the types of CHD and the surgical proceduress. In the past, age, gender, number of procedures performed, amount of surgeries being performed by the healthcare facility, extent of cardio-pulmonary bypass time (CPBT), aortic cross-clamp time (ACCT), post-surgery major organ dysfunction, prolonged duration of mechanical ventilation and increased length of hospital stay were some of the most significantly associated factors with mortality among patients undergoing surgery for CHDs.[7,8]

In recent years, determining the impact of CBPT or ACCT on cardiac surgery outcomes has been a topic of interest, and prolonged CBPT and prolonged ACCT have been labelled to be very important factors influencing mortality and post-surgery complications.[9,10] No local data is available regarding the impact of CBPT or ACCT on the outcomes of patients undergoing open heart surgeries for congenital heart diseases, so the present study was planned to find out the impact of CPBT and ACCT on immediate post-operative outcomes in children with congenital heart diseases undergoing open heart surgery at a tertiary care centre. The findings of this study provide vital information about the influence of CPBT and ACCT on the immediate outcomes of patients undergoing open heart surgeries for CHDs at a prominent cardiac healthcare facility in Pakistan.

METHODOLOGY

The prospective longitudinal study was conducted at Department of Paediatric Cardiology National Institute of Cardiovascular Diseases (NIC VD), Karachi, Pakistan, from July to December 2021. Approval from the Institutional Ethical Committee was taken (ERC-004/2021; Dated: 03/09/2021).

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Inclusion Criteria: Patients of either gender, up to any age with CHD undergoing open heart surgeries were included from the study.

Exclusion Criteria: We also did not include patients planning to undergo closed heart surgeries.

Informed and written consent was acquired from patients/parents/guardians/caregivers. According to the non-probability purposive sampling technique, we enrolled all patients fulfilling inclusion/exclusion criteria during the study period and no specific sampling size calculations were done.

At the time of admission, age, gender, body weight, presence of cyanosis and types of CHDs were noted. Standard surgical procedures were performed as per the requirement of the types of CHDs. The CPBT and ACCT were noted in all cases. Post-surgery, all cases were monitored for the development of any complications. Duration of mechanical ventilation, pediatric cardiac intensive care unit (PCICU) stay, and mortality was recorded. Cardiopulmonary bypass time was categorised as normal (<60 minutes), mildly normal (60-100minutes), moderately prolonged (100-140 minutes) or severely prolonged (>140minutes).[11] Aortic cross-clamp time was categorised as normal (<30 minutes), mildly prolonged (30-60 minutes), moderately prolonged (60-90 minutes), largely prolonged (90-120 minutes) or very prolonged (>120 minutes).[12]

SPSS-23.0 was used for the data analysis. Qualitative data was represented in frequency and percentages. Quantitative data was highlighted as mean and stan-dard deviation (SD). Baseline characteristics and post-surgery parameters were compared about different categories of CPBT and ACCT. To compare qualitative data, the chi-square test was used while analysis of variance (ANOVA) was employed to compare quantit-ative variables, considering p of value<0.05 was as significant.

RESULTS

Of 104 patients, 58(55.8%) were male. The mean age was 7.9±5.1 years (7 months to 22 years). Cyanosis was noted in 34(32.7%) cases at enrollment. Mean CPBT was 74.6±42.9 minutes (ranging between 20 to 381 minutes) while mean ACCT was 43.5±29.5 minutes (ranging between 3 to 218 minutes). The CPBT was normal in 34(32.7%), mildly prolonged in 49 (47.1%), moderately prolonged in 19(18.3%) and severely prolonged in 2(1.9%) cases. Table-I is showing characteristics of cases undergoing open heart surgery for CHDs.

Table-I: Baseline Characteristics of Cases Undergoing Open Heart Surgery for Congenital Heart Diseases (n=104)

Characteristics	Number (%) / Mean±SD
Gender	
Male	58(55.8%)
Female	46(44.2%)
Age in years	7.9±5.1
Weight in kg	22.1±13.5
Cyanosis	34(32.7%)
Cardiopulmonary Bypass Time in minutes	74.6±42.9
Cardiopulmonary Bypass Time Categories	
Normal	34(32.7%)
Mildly Prolonged	49(47.1%)
Moderately Prolonged	19(18.3%)
Severely Prolonged	2(1.9%)
Aortic Cross Clamp Time in minutes	43.5±29.5
Aortic Cross Clamp Time Categories	
Normal	39(37.5%)
Mildly Prolonged	38(36.5%)
Moderately Prolonged	24(23.1%)
Largely Prolonged	2(1.9%)
Very Prolonged	1(1.0%)

Most types of CHDs were noted to be tetralogy of Fallot (ToF), atrial septal defect (ASD) and ventricular septal defect (VSD) in 28(26.9%), 23(22.1%) and 20 (19.2%) cases respectively, (Table-II).

Table-II: Types of Congenital Heart Diseases (n=104)

Congenital Heart Diseases Types	Number (%)
Tetralogy of Fallot	28(26.9%)
Atrial Septal Defect	23(22.1%)
Ventricular Septal Defect	20(19.2%)
Mitral Valve Replacement	4(3.8%)
Atrial Regurgitation+Mitral Regurgitation	3(2.9%)
Tetralogy of Fallor+Atrial Septal Defect	3(2.9%)
Mitral Regurgitation	3(2.9%)
Atrioventricular Septal Defect	2(1.9%)
Ventricular Septal Defect+Patent ductus arteriosus	2(1.9%)
Others*	12(11.5%)

**All other CHD types with a single patient*

An increase in the duration of CPBT was found to have a significant association with the presence of cyanosis (p=0.008), increased ACCT (p<0.001), increased levels of post-sur-gery lactate (p<0.001), presence of acidosis (p<0.001), increased levels of AVDO2 (p<0.001), higher inotropic score (p<0.001), post-surgery low cardiac output syn-drome (p<0.001), post-surgery hypotension (p<0.001), arrhythmias (p<0.001), the occurrence of post-surgery acute kidney injury (p=0.026), sepsis (p<0.001), acute liver injury (p<0.001), right ventricular dysfunction (p<0.001), increased duration of mechanical ventilation (p=0.011),

increased duration of PCICU stay (p<0.001) and mortality (p<0.001), as shown in Table-III.

Table-III: Association of Pre-Surgery and Post-Surgery variables with Cardiopulmonary Bypass Time (n=104)

Study Variables	Cardiopulmonary Bypass Time				*p*-value
	Normal (n=34)	Mildly Prolonged (n=49)	Moderately Prolonged (n=19)	Severely Prolonged (n=2)	
Gender					
Male	17(50.0%0	28(57.1%)	13(68.4%)	0	0.236
Female	17(50.0%)	21(42.9%)	6(31.6%)	2(100.0%)	
Age in years (Mean±SD)	7.6±4.3	7.5±5.2	9.0±5.3	12.5±9.5	0.390
Weight in years (Mean±SD)	21.5±11.4	21.6±14.6	23.7±12.6	30.0±20.0	0.774
Cyanosis	5(14.7%)	18(36.7%)	11(57.9%)	0(0%)	0.008
Aortic Cross Clamp Time					
Normal	30(88.2%)	9(18.4%)	0(0%)	0(0%)	<0.001
Mildly Prolonged	4(11.8%)	34(69.4%)	0(0%)	0(0%)	
Moderately Prolonged	0(0%)	6(12.2%)	18(94.7%)	0(0%)	
Largely Prolonged	0(0%)	0(0%)	1(5.3%)	1(50.0%)	
Very Prolonged	0(0%)	0(0%)	0(0%)	1(50.0%)	
Post-Surgery Lactate (Mean±SD)	3.4±1.4	4.4±2.1	5.3±1.8	9.0±1.0	<0.001
Acidosis	3(8.8%)	2(4.1%)	6(31.6%)	2(100%)	<0.001
AVDO2 (Mean±SD)	19.5±5.3	22.4±4.4	24.5±8.3	45.0±0	<0.001
Inotropic Score (Mean±SD)	10.0±16.0	11.3±8.0	15.1±6.9	25.0±0	<0.001
Low Cardiac Output syndrome	1(2.9%)	2(4,1%)	3(15.8%)	2(100%)	<0.001
Hypotension	1(2.9%)	7(14.3%)	2(10.5%)	2(100%)	<0.001
Arrhythmias	1(2.9%)	4(8.2%)	3(15.8%)	2(100%)	<0.001
Acute Kidney Injury	1(2.9%)	2(4.1%)	1(5.3%)	1(50.0%)	0.026
Sepsis	1(2.9%)	0(0%)	0(0%)	1(50.0%)	<0.001
Acute Liver Injury	1(2.9%)	2(4.1%)	1(5.2%)	2(100%)	<0.001
Left Ventricular Dysfunction	2(5.9%)	7(14.3%)	4(21.1%)	1(50.0%)	0.176
Right Ventricular Dysfunction	3(8.8%)	17(34.7%)	12(63.2%)	0(0%)	<0.001
Mortality	0(0%)	1(2.0%)	0(0%)	1(50.0%)	<0.001
Duration of Mechanical Ventilation in hours (Mean±SD)	22.9±84	16.8±14.8	25.5±14.7	143.5±126.5	0.011
Duration of ICU Stay in days (Mean±SD)	3.8±8.1	3.9±2.8	4.0±1.5	28.5±11.5	<0.001

An increase in the duration of ACCT was noted to have a significant association with increased age (p =0.003), higher body weight (p=0.011), the presence of cyanosis (p=0.003), increased levels of post-surgery lactate levels (p<0.001), presence of acidosis (p=0.001), increased levels of AVDO2 (p<0.001), post-surgery low cardiac output syndrome (p=0.001), post-surgery hypotension (p=0.004), arrhythmias (p=0.002), the occurrence of post-surgery acute kidney injury (p<0.001), sepsis (p<0.001), acute liver injury (p<0.001), left ventricular dysfunction (p=0.006), right ventricular dysfunction (p<0.001), increased duration of mechanical ventilation (p<0.001), increased duration of PCICU stay (p<0.001) and mortality (p<0.001) as shown in Table-IV.

DISCUSSION

In this study, we observed that increased duration of CPBT and ACCT was found to have a significant association with post-surgical morbidity and mortality. Contrary to our findings, a study from Saudi Arabia by Mehmood *et al.* analysing 413 cases undergoing cardiac surgeries found no significant association between CPBT and ACCT with the post-surgery duration of mechanical ventilation or length of hospital stay.[10] Polito and colleagues also found no significant linkage between CPBT and post-surgery duration of mechanical ventilation. The difference between our findings and Polito *et al.* [11] as well as Another study by Szekely et al. noted a significant association between CPBT and post-surgery mechanical ventilation duration. Szekely *et al.* considered a shorter threshold for the duration of mechanical ventilation.[12]

The present study is the 1st that categorised CPBT as normal, mildly prolonged, moderately prolonged and severely prolonged. We also categorised ACCT as normal, mildly prolonged, moderately prolonged, largely prolonged and very prolonged to get better insights into the relationship of various characteristics. In literature, researchers have reported increased CPBT

Table-IV: Association of Pre-Surgery and Post-Surgery variables with Aortic Cross Clamp Time (n=104)

Study Variables	Aortic Cross Clamp Time					*p*-value
	Normal (n=39)	Mildly Prolonged (n=38)	Moderately Prolonged (n=24)	Largely Prolonged (n=2)	Very Prolonged (n=1)	
Gender						
Male	18(46.2%)	22(57.9%)	17(70.8%)	1(50.0%)	0(0%)	0.285
Female	21(53.8%)	16(42.1%)	7(29.2%)	1(50.0%)	1(100%)	
Age in years (Mean±SD)	8.5±4.9	6.0±4.1	9.2±5.4	10.0±9.9	22.0±0	0.003
Weight in years (Mean±SD)	24.3±14.7	17.1±8.8	24.4±13.9	34.0±33.9	50.0±0	0.011
Cyanosis	5(12.8%)	15(39.5%)	14(58.3%)	0(0%)	0(0%)	0.003
Post-Surgery Lactate (Mean±SD)	3.6±1.4	4.5±2.4	4.9±1.8	6.5±2.1	10.0±0	<0.001
Acidosis	3(7.7%)	1(2.6%)	7(29.7%)	1(50.0%)	1(100%)	0.001
AVDO2 (Mean±SD)	19.6±4.9	23.0±4.7	23.9±7.9	31.5±19.1	45.0±0	<0.001
Inotropic Score (Mean±SD)	10.3±15.2	11.7±9.0	14.0±6.8	15.0±14.1	25.0±0	0.557
Low Cardiac Output syndrome	1(2.6%)	2(5.3%)	3(12.5%)	1(50.0%)	1(100%)	0.001
Hypotension	1(2.6%)	7(18.4%)	2(8.3%)	1(50.0%)	1(100%)	0.004
Arrhythmias	1(2.6%)	3(7.9%)	4(16.7%)	1(50.0%)	1(100%)	0.002
Acute Kidney Injury	1(2.6%)	2(5.3%)	1(4.2%)	0(0%)	1(100%)	<0.001
Sepsis	1(2.6%)	0(0%)	0(0%)	0(0%)	1(100%)	<0.001
Acute Liver Injury	1(2.6%)	2(5.3%)	1(4.2%)	1(50.0%)	1(100%)	<0.001
Left Ventricular Dysfunction	1(2.6%)	8(21.1%)	3(12.5%)	1(50.0%)	1(100%)	0.006
Right Ventricular Dysfunction	6(15.4%)	10(26.3%)	16(66.7%)	0(0%0	0(0%)	<0.001
Mortality	0(0%)	1(2.6%)	0(0%)	1(50.0%)	0(0%)	<0.001
Duration of Mechanical Ventilation in hours (Mean±SD)	21.5±79.6	18.8±16.1	21.5±15.5	16.5±0.7	270.0±0	<0.001
Duration of ICU Stay in days (Mean±SD)	3.6±7.7	4.0±3.0	4.0±1.9	9.5±10.6	40.0±0	<0.001

to be a significant predictor of ICU stay duration and overall hospitalisation length among children and adults.[13-16] In the present study, we noted various post-surgical morbidities like low cardiac output, arrhythmias, acute kidney injury or sepsis. These must have contributed to the duration of PCICU stay and mechanical ventilation. Xu *et al.* report CPBT as an independent predictor of acute kidney injury among patients undergoing thoracic aortic surgery.[9] It is established that post-surgical infections, glycemic controls, and cardiac events are known risk factors for the prolongation of ICU stay and overall length of hospitalisation.[17,18] With recent advancements in the betterment of gas exchange membrane quality and machine interface surfaces, the chances of insult influence by CPBT or ACCT are reduced. By applying the categorisation of CPBT and ACCT, we found a better association of post-surgical morbidities that no previous study explored. Further studies involving a larger set of patients and categorisation of CPBT and ACCT are required to confirm the findings of this study further.

Our study had some limitations as well. As we had only noted immediate outcomes of patients undergoing open heart surgeries for CHDs, further prospective studies involving long-term follow-ups should be planned to explore the long-term impact of CPBT and ACCT. As mortality was reported in only 2 cases, we could not find any significant associations between mortality and different pre-operative, peri-operative and post-operative factors involved.

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CONCLUSION

Increased cardiopulmonary bypass time and aortic cross-clamp time were found to have a significant association with post-surgical morbidity and outcomes among cases undergoing open heart surgeries for congenital heart diseases.

Conflict of Interest: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

NA & RAK: Data acquisition, data analysis, critical review, approval of the final version to be published.

MR & ASS: Study design, drafting the manuscript, data interpretation, critical review, approval of the final version to be published.

HB & RS: Critical review, conception, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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