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ORIGINAL ARTICLE

Prevalence and risk factors for prolonged mechanical ventilation in patients with congenital heart diseases undergoing cardiac surgery at a tertiary care center.

Ammad Hussain[1], Rajab Ali Khokhar[2], Mujeeb Ur Rehman[3], Zubair Ahmed[4], Veena Kumari[5], Saad Bader[6], Abdul Sattar Shaikh[7]

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ABSTRACT… Objective: To determine the prevalence and risk factors for prolonged mechanical ventilation (PMV) in patients with CHDs undergoing cardiac surgery at a tertiary care center of Karachi, Pakistan. **Study Design:** Cross-sectional study. **Setting:** Paediatric Cardiac Intensive Care Unit (PCICU) at National Institute of Cardiovascular Diseases, Karachi, Pakistan. **Period:** July 2022 to June 2023. **Material & Methods:** We analyzed patients who underwent open or closed heart surgery for CHDs. PMV was defined as duration of mechanical ventilation > 72 hours from the time of arrival to PCICU until extubation after cardiac surgery. Peri-operative factors were noted and their association with PMV was documented. **Results:** In a total of 184 patients who underwent surgeries for CHD, 105 (57.1%) were male while the overall mean age was 7.23±6.49 years. Post-surgery, PMV was documented in 17 (9.2%) patients. PMV was significantly associated with age (p=0.001), weight (p<0.001), cyanosis (p=0.005), TAPSE (p=0.011), and CPB time (p=0.003). Post-surgery, PMV was linked with metabolic acidosis (p=0.003), lactate (p=0.001), $AVDO_2$ (p<0.001), inotropic score (p=0.002), low cardiac output (p=0.005), LV dysfunction (p<0.001), acute kidney injury (p=0.002), sepsis (p<0.001), pneumonia (p=0.004), mortality (p=0.045), and PCICU stay (p<0.001). **Conclusion:** PMV was documented in 9.2% patients who underwent CHD repair. Age, weight, cyanosis, TAPSE, CPB time, metabolic acidosis, lactate, $AVDO_2$, inotropic score, low cardiac output, LV dysfunction, acute kidney injury, sepsis, and pneumonia were noted to be significant risk factors for PMV.

Key words: Cardiac Output, Cardiopulmonary Bypass, Cyanosis, Mechanical Ventilation, Metabolic Acidosis.

INTRODUCTION

Mechanical ventilation (MV) is an important management strategy in patients with congenital heart diseases (CHD) post cardiac surgery in the "pediatric cardiac intensive care unit (PCICU)". Prolonged mechanical ventilation (PMV) is linked with many serious complications in pediatric population irrespective of the underlying etiology.[1] The reported incidence of prolonged mechanical ventilation ranged from 3% to 22%.[2,3] All children undergoing cardiac surgery need MV in PCICU depending upon the underlying diseases and any associated complications.[4-7] PMV not only increase PCICU and hospitalization duration, but also puts extra burden on resource utilizations of the healthcare facilities as well.[6,7]

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Prompt identification of risk factors behind PMV in children undergoing surgery for CHDs can be challenging. Nevertheless, pinpointing these risk factors could potentially lead to adjustments in surgical and medical approaches, facilitating early extubation from mechanical ventilation.[8,9] This, in turn, can promote swift post-surgery mobilization, enhance cardiopulmonary function, and reduce both ICU and hospital stays.[10-12]

Limited research has been conducted on identifying risk factors associated with PMV in pediatric patients with CHDs undergoing cardiac surgery. The PMV has been pointed out to be linked to increase in-hospital mortality, elevated healthcare costs, and lower 5-year survival

1. FCPS (General Surgery), FCPS (Cardiac Surgery), Senior Registrar Pediatric Cardiac Surgery, National Institute of Cardiovascular Diseases, Karachi.
2. FCPS (Pediatric Medicine) MRCPI (Pediatric Medicine), Assistant Professor Pediatric Cardiac Intensive Care Unit, National Institute of Cardiovascular Diseases, Karachi.
3. FCPS (Pediatric Cardiology), Senior Registrar Paediatric Cardiology, National Institute of Cardiovascular Diseases, Karachi.
4. FCPS (Pediatric Cardiology), Senior Registrar Paediatric Cardiology, National Institute of Cardiovascular Diseases, Karachi.
5. FCPS (Pediatric Cardiology), Assistant Professor Paediatric Cardiology, National Institute of Cardiovascular Diseases, Karachi.
6. MRCS (General Surgery), FCPS (General Surgery), FCPS (Cardiac Surgery), Assistant Professor Pediatric Surgery, National Institute of Cardiovascular Diseases, Karachi.
7. FCPS (Pediatric Cardiology), Associate Professor Pediatric Cardiology, National Institute of Cardiovascular Diseases, Karachi.

Correspondence Address:
Dr. Mujeeb Ur Rehman
Department of Paediatric Cardiology
National Institute of Cardiovascular Diseases, Karachi.
mujeeburrehman113@gmail.com

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rates.[6] The duration of "postoperative mechanical ventilation (POMV)" is considered a crucial quality indicator due to its connection with complications and resource utilization. Discovering predictive factors for prolonged mechanical ventilation could potentially enhance the clinical management. This study aimed to determine the prevalence and risk factors for PMV in patients with CHDs undergoing cardiac surgery.

MATERIAL & METHODS

This cross-sectional study was conducted at PCICU at "National Institute of Cardiovascular Diseases", Karachi, from July 2022 to June 2023. Sample size of 184 was calculated keeping margin of error as 6%, confidence level 95% and the incidence of PMV as 22%.[3] We included patients who underwent open or closed heart surgery for CHDs. Those patients who had previous palliative surgeries for congenital heart defects were also included. Patients with genetic syndromes were excluded.

Study approval was acquired from the hospitals ethical and research committee (Reference number: ERC-130/2021). Informed and written consents were acquired from parents/guardians of all patients, explaining them the aims and procedures. A total of 184 patients fulfilling the inclusion criteria were analyzed. Standard protocols were adopted for all surgeries. All patients undergoing CHD surgeries were monitored for the first 48 hours by consultant PCICU (with more than 3 years of post-fellowship experience). Incidence of PMV and associated risk factors were recorded. PMV was defined as duration of mechanical ventilation > 72 hours arrival to PCICU until extubation after cardiac surgery. Pre-operative factors like patient's age at the time of surgery (in years), weight, sex, cardiac diagnosis, cyanosis, pre-operative left ventricular ejection fraction (%), pre-operative "tricuspid annular plane systolic excursion (TAPSE)", any previous surgery and history previous chest infections, were noted. Surgical repair techniques, cardiopulmonary bypass (CPB) time, aortic cross clamp (ACC) time, Inotropic support, inotropic score and postoperative LVEF, and right ventricular functions, were also noted. All the study data was noted a special proforma formed for this research.

Data analysis was done by SPSS version 26.0. Quantitative data was shown as mean and standard deviation (SD). Frequencies and proportions were given for categorical data. Comparisons between groups were made using the unpaired Student t-test. Chi-square test was used to compare the data considering $p<0.05$ as significant.

RESULTS

In a total of 184 patients who underwent surgeries for CHD, 105 (57.1%) were male and 79 (42.9%) female. The mean age and weight at the time of surgery were 7.23±6.49 years (ranging between 2 months to 30 years) and 19.55±12.84 kg (ranging between 4 to 58 kg). Cyanosis was present in 38 (20.7%) patients at the time of enrollment. Tetralogy of fallot, and isolated atrial septal defect were the most frequent types of CHDs, noted in 39 (21.2%), and 11 (6.0%) patients respectively. History of previous surgery was noted in 15 (8.2%) patients. The mean pre-operative LVEF and TAPSE were calculated to be 66.25±11.42% and 1683±4.40 mm respectively. Post-surgery, the mean duration of mechanical ventilation was 35.34±72.38 hours. PMV was documented in 17 (9.2%) patients. Table-I is showing stratification of pre-operative, intra-operative and post-operative factors with respect to PMV. PMV was found to have significant association with age (2.34±2.67 vs. 7.72±6.56 years, $p=0.001$), weight (8.19±3.38 vs. 20.71±12.89 kg, $p<0.001$), cyanosis (47.1% vs. 18.0%, $p=0.005$), TAPSE (13.38±3.39 vs. 17.16±4.95 mm, $p=0.011$), and CPB time (95.78±26.44 vs. 66.16±28.43 minutes, $p=0.003$), as shown in Table-I.

Table-II showing that PMV was significantly associated with metabolic acidosis ($p=0.003$), lactate ($p=0.001$), $AVDO_2$ ($p<0.001$), inotropic score ($p=0.002$), low cardiac output ($p=0.005$), LV dysfunction ($p<0.001$), acute kidney injury ($p=0.002$), sepsis ($p<0.001$), pneumonia ($p=0.004$), mortality ($p=0.045$), and PCICU stay ($p<0.001$).

Pre-surgery and Intra-Operative Variables		Prolonged Mechanical Ventilation		P-Value
		Yes (n=17)	No (n=167)	
Gender	Male	8 (47.1%)	97 (58.1%)	0.382
	Female	9 (52.9%)	70 (41.9%)	
Age (years)		2.34±2.67	7.72±6.56	0.001
Weight (kg)		8.19±3.38	20.71±12.89	<0.001
Cyanosis		8 (47.1%)	30 (18.0%)	0.005
History of previous surgery		1 (5.9%)	14 (8.9%)	0.720
LVEF (%)		66.71±6.38	66.21±11.80	0.875
TAPSE (mm)		13.38±3.39	17.16±4.95	0.011
Surgery type	Open	11 (64.7%)	141 (84.4%)	0.041
	Closed	6 (35.3%)	26 (15.6%)	
CPB time (minutes)		95.78±26.44	66.16±28.43	0.003
ACC time (minutes)		45.44±11.95	35.20±20.99	0.151

Table-I. Association of pre-operative and intra-operative factors with PMV (N=184)

Post-operative Factors	Prolonged Mechanical Ventilation		P-Value
	Yes (n=17)	No (n=167)	
Respiratory alkalosis	-	6 (3.6%)	0.427
Metabolic acidosis	4 (23.5%)	159 (95.2%)	0.003
Lactate (mmol/l)	4.82±2.14	2.94±1.56	0.001
$AVDO_2$	29.29±11.93	16.84±4.73	<0.001
Inotropic score	15.06±14.97	7.52±8.26	0.002
LVEF (%)	58.00±15.74	62.61±13.16	0.206
TAPSE (mm)	8.60±3.30	14.45±46.11	0.675
Low cardiac output	3 (17.6%)	5 (3.0%)	0.005
LV dysfunction	9 (52.9%)	13 (7.8%)	<0.001
Arrhythmias	1 (5.9%)	154 (92.2%)	0.778
Acute kidney injury	1 (5.9%)	-	0.002
Sepsis	5 (29.4%)	3 (1.8%)	<0.001
Pleural effusion	1 (5.9%)	6 (3.6%)	0.638
Pneumothorax	-	4 (2.4%)	0.519
Pneumonia	2 (11.8%)	2 (1.2%)	0.004
Diaphragm paralysis	-	2 (1.2%)	0.650
RV dysfunction	5 (29.4%)	55 (32.9%)	0.768
Mortality	1 (5.9%)	1 (0.6%)	0.045
PCICU stay (hours)	13.82±6.67	3.61±3.05	<0.001

Table-II. Association of post-operative factors with PMV (N=184)

DISCUSSION

In our study, 66.8% patients were successfully extubated within a 24-hour window subsequent to CHD surgery. Among the patients, 9.2% continued to require mechanical ventilation after 72 hours, while 4.3% patients remained ventilated beyond 7 days. Notably, these outcomes are aligned with previously reported ranges. A study from Saudi Arabia noted 65% of their patients undergoing CHD repair to have been extubated within 24 hours while 14.9% went on to be ventilated beyond 72 hours.[13] This is in congruence with varying figures reported in prior investigations, which noted PMV rates of 13.2%[14] after CHD surgery, 25%[15], and 35.4%[16] in other studies.

The early extubation and timely weaning of pediatric patients from mechanical ventilation post-CHD surgery yield manifold benefits.[17,18] These encompass swift mobilization, enhanced cardiopulmonary function, and reduced durations of both Pediatric Intensive Care Unit (PICU) stays and hospitalization.[19] Despite the intricacies surrounding the identification of factors contributing to delayed extubation, an understanding of high-risk patients and pertinent

preoperative, intraoperative, and postoperative risk elements can potentially guide tailored surgical and medical strategies. However, it's noteworthy that the literature on the definition and predictors of PMV exhibits variations across diverse studies.

While simple CHD surgery aligns with early extubation tendencies, it's intriguing to note that even complex CHD surgeries can facilitate extubation within 72 hours.[20] A study by Davis et al. highlighted that the complexity of the procedure and whether it is palliative or complete repair did not significantly impact the success of early extubation.[21] Although young age emerges as a recognized risk factor for PMV as was shown in this study (2.34±2.67 vs. 7.72±6.56 years, p=0.001), our study underscores the additional significance of weight and age as PMV risk factors, and these findings are similar to what has been identified earlier as well.[13] Factors such as compromised cardiac function remain universal contributors to PMV risk.[22]

Prolonged CPB time and ACC durations have been exhibited to have association with PMV previously[13], this research reported significant association of relatively increased CPB time with PMV but we did not find any significant linkage of ACC time with PMV. Szekely et al described an association between the duration of CPB and delayed extubation.[14] Some other researchers have revealed CPB and ACC time as no significant risk factors for PMV.[23,24]

The present study noted PMV to have significant connection with metabolic acidosis (p=0.003), lactate (p=0.001), $AVDO_2$ (p<0.001), inotropic score (p=0.002), low cardiac output (p=0.005), LV dysfunction (p<0.001), acute kidney injury (p=0.002), sepsis (p<0.001), pneumonia (p=0.004), mortality (p=0.045), and prolonged PCICU stay (p<0.001). Factors like delayed sternal closure, sepsis, and re-intubation have been identified as correlating with PMV in the past.[13,16,24] The presence of discrepancies among various studies in pinpointing risk factors underlines the complexity of this issue. A confluence of systemic and cardiopulmonary factors intertwines in PMV occurrences, and center-specific protocols tailored to individual risk profiles are warranted. This further underscores the imperative for dedicated investigation of these factors within each pediatric cardiology setting. Being a single center study, conducted on a relatively modest sample size were some limitations of this study.

CONCLUSION

PMV was documented in 9.2% patients who underwent CHD repair. Age, weight, cyanosis, TAPSE, CPB time, metabolic acidosis, lactate, $AVDO_2$, inotropic score, low cardiac output, LV dysfunction, acute kidney injury, sepsis, and pneumonia were noted to be significant risk factors for PMV. Early identification, consideration and management of these factors could lead to improved outcomes among patients undergoing CHD repairs.

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AUTHORSHIP AND CONTRIBUTION DECLARATION

No.	Author(s) Full Name	Contribution to the paper	Author(s) Signature
1	Ammad Hussain	Data Collection, Data analysis.	
2	Rajab Ali Khokhar	Data Collection, Drafting.	
3	Mujeeb Ur Rehman	Concept and Designing, Drafting.	
4	Zubair Ahmed	Data Collection.	
5	Veena Kumari	Data Collection.	
6	Saad Bader	Data Collection.	
7	Abdul Sattar Shaikh	Supervision, Critical Revisions.