Research Article

Predictors of Prolonged Mechanical Ventilation in Pediatric Patients After Cardiac Surgery for Congenital Heart Disease

Avisa Tabib,[1] Seyed Ehsan Abrishami,[1,*] Mohammad Mahdavi,[1] Hojjat Mortezaeian,[1] and Ziae Totonchi[1]

[1]Heart Valve Disease Research Center, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran

[*] *Corresponding author*: Seyed Ehsan Abrishami, Heart Valve Disease Research Center, Rajaie Cardiovascular Medical and Research Center, Valiasr Ave, Niayesh Blvd, Tehran, IR Iran. Tel: +98-9132951707, E-mail: atrialtdco@gmail.com

Abstract

Background: The duration of mechanical ventilation (MV) is one of the most important clinical factors which predict outcomes in pediatric cardiac surgery. The prolonged mechanical ventilation (PMV) following cardiac surgery is a multifactorial phenomenon and there are conflicts regarding its predictors in pediatric population between different centers.

Objectives: The current study aimed to describe PMV predictors in patients undergoing cardiac surgery for congenital heart disease in a tertiary center for pediatric cardiovascular diseases in Iran.

Patients and Methods: From May to December 2014, all pediatric patients (less than a month – 15 years old) admitted to pediatric Intensive Care Unit (PICU) after congenital heart surgeries were consecutively included. The PMV was defined as mechanical ventilation duration more than 72 hours as medium PMV and more than seven days as extended PMV. The demographic data and variables probably related to PMV were recorded during the PICU stay.

Results: A total of 300 patients, 56.7% male, were enrolled in this study. Their mean age was 32 ± 40 months .The median duration (IQR) of MV was 18 hours (8.6 - 48 hours). The incidence of PMV more than 72 hours and seven days was 20% and 10.7%, respectively. Younger age, lower weight, heart failure, higher doses of inotropes, pulmonary hypertension, respiratory infections and delayed sternal closure were independent predictors of PMV in multivariate analyses.

Conclusions: The results of this study indicated that PMV predictors could be specific for each center and a good administration program is needed for each pediatric cardiac surgery center for the preoperative management of patients undergoing congenital heart surgeries.

Keywords: Mechanical Ventilation, Cardiac Surgery, Congenital Heart Disease

1. Background

Children who undergo cardiac surgery for congenital heart diseases are high risk for significant post-operative morbidity and mortality. The improvement in pediatric intensive care, results in better survival in such patients(1-7). The duration of mechanical ventilation (MV) is one of the most important clinical factors which predicts outcomes in pediatric cardiac surgery (1-13).The improvement in MV protocols and early extubation shortens the intensive care unit (ICU) stay and results in less complications and improved outcomes (14-16) .Hence, there is a need to identify and quantify clinical predictors of prolonged mechanical ventilation (PMV).Predictors of PMV after pediatric cardiac surgery are investigated in several studies (1-13). Parameters such as the clinical condition of the patients and underlying disorders, factors related to surgical and anesthetic techniques, the postoperative ICU management protocols and certain postoperative complications including renal failure can influence the length of intubation (1-13).

Identification of these parameters in each center could guide clinicians to choose the best management protocol. On the other hand there are some conflicts regarding the predictors among different medical centers.

2. Objectives

The current study aimed to describe PMV predictors in patients undergoing cardiac surgery for congenital heart disease in a tertiary center for pediatric cardiovascular diseases in Iran.

3. Patients and Methods

The study was conducted from May to December 2014 at Rajaie cardiovascular, medical and research center, the center of excellence for pediatric cardiology and cardiovascular surgeries in Tehran, Iran. After approval of the study by the institutional research and ethics committee,

all pediatric patients (less than a month – 15 year old) admitted to pediatric ICU (PICU) after corrective or palliative cardiovascular surgery for congenital heart disease were consecutively included and patients who remained on mechanical ventilation for $\geq$ 72 hours and/or $\geq$ 7 days were defined as medium and extended prolonged mechanical ventilation (PMV) respectively. Children with neuromuscular disorders and flappy babies were excluded.Although the definition of PMV is arbitrary, in many similar studies extubation was usually achievable within three days even after complex cardiac procedures and PMV is defined as a mechanical ventilation duration more than 72 hours for medium PMV and seven days for extended PMV ([1], [3]). The demographic and clinical data and the variables probably related to PMV were recorded during the PICU stay. The recorded data included age, gender, weight, type of congenital heart disease, presence of pulmonary hypertension (mean pulmonary artery pressure more than 25 mmHg documented by catheterization or echocardiography), history of previous cardiac surgery, history of MV before surgery, surgical technique (palliative or corrective, on pump or off pump, etc.), intra operative variables including aortic cross clamp and cardiopulmonary bypass time, postoperative variables (inotropes type, dosage and duration and vasoactive inotropic score), laboratory data and complications including sepsis, heart failure, renal failure, respiratory complications, re intubation and death.

3.1. Calculation of Vasoactive Inotropic Score

The following inotropic agents were used in the current practice: dopamine, dobutamine, epinephrine, norepinephrine and milrinone. VIS was calculated as described by Davidson et al. and Gaies et al. ([17]-[19]).VIS (μg/kg/min) = dopamine dose (μg/kg/min) + dobutamine dose (μg/kg/min) + 100 $\times$ epinephrine dose (μg/kg/min) + 10 $\times$ milrinone dose (μg/kg/min) +10,000 $\times$ vasopressin dose (μg/kg/min) + 100 $\times$ Norepinephrine dose (μg/kg/min)

3.2. Statistical Analysis

IBM SPSS Statistics 19.0 for Windows (IBM Corp., Armonk, NY, USA) was used for all the statistical analyses. All variables were assessed for normal distribution using Kolmogorov Smirnov test. Categorical variables were expressed as number and percentage and quantitative variables as mean (standard deviation) or median (interquartile range) for the variables not normally distributed. Student t-test or Mann–Whitney U test were used, as appropriate, to compare quantitative variables. Categorical data were compared by chi-square test. Binary logistic regression analysis was used for multivariate analysis. The

Spearman's rank correlation coefficient was used to assess the correlation between not normally distributed interval variables. P < 0.05 was considered significant.

4. Results

From May to December 2014, 300 patients, 56.7% male, were included in this study. The median (IQR) of age was 15 (5 - 39) months (from 10-day to 14-year-old). Thirty-three (11%) of patients were neonate and 139 (46.3%) patients were categorized as cyanotic congenital heart disease .Tetralogy of Fallot (TOF) was the most common diagnosis. 61 (20.3%) patients had a history of palliative surgeries (shunts or pulmonary artery banding) and 15(5%) patients had undergone redo operation. Table 1 depicts demographic and clinical findings of the study population.

4.1. Mechanical Ventilation Duration

The median duration (IQR) of MV was 18 hours (8.6 - 48 hours). From 2.5 hours to 43 days. The incidence of early extubation ($\leq$ 6 hours after cardiac surgery) was 13.5% and 69.3% were extubated within 24 hours after surgery. Sixty (20%) patients remained on MV for more than 72 hours and 32 (10.7%) of them were mechanically ventilated for more than seven days. As expected the duration of ICU stay was more prolong and mortality was higher in patients with PMV (Table 2).

4.2. Predictors of PMV

Table 3 depicts a comparison between patients with and without PMV regarding demographic and clinical variables.

As shown in Table 2, age, weight, presence of cyanotic heart disease, pulmonary hypertension (PH) and mechanical ventilation before surgery were associated with PMV. PMV was also more prevalent in patients undergoing surgery for complex congenital heart lesions.There was no association between gender, history of surgery (palliative, corrective, and redo surgery) and PMV (P > 0.05). The hypothermia was used during surgery in 61.3% of the patients, no association was found between using hypothermia and mechanical ventilation duration more than 72 hours .However, MV duration more than seven days was associated with hypothermia during surgery (P = 0.005) Although there was no correlation between the on pump or off pump surgery and PMV, cardiopulmonary bypass time (CPB time) and aortic cross clamp (AOX) time were significantly longer among patients with PMV (P < 0.001). As expected the CPB and AOX time were also longer in patients who developed heart failure (HF) manifestations. The median (IQR) of CBP time was 79 (55 - 114) versus 125 (72.5 - 169)

Table 1. Demographic Characteristics and Surgical Data of Study Population

Variables	Values
Age, mo, mean (Interval)	15 (5-39)
Weight, kg, mean (SD)	11 (9.7)
CBP time, min, mean (interval)	81 (56-120)
AOX time, min, mean (interval)	50 (30 - 75)
ICU stay, h, mean (interval)	72 (48 -144)
MV duration, h, mean (interval)	18 (8.75-48)
Gender, No. (%)	
Male	170 (56.7)
Female	130 (43.3)
Type of congenital anomaly, No. (%)	
Cyanotic	139 (46.3)
Non-cyanotic	161 (53.7)
Congenital heart disease, No. (%)	
Tetralogy of Fallout	73 (24.3)
VSD + PH	69 (23)
ASD	25 (8.3)
CAVSD	23 (7.7)
Single ventricle + PS,TA	29 (9.7)
DORV + PS	10 (3.3)
TGA	32 (10.7)
TAPVC	6 (2)
Aortic coarctation + AS + MS	16 (5.3)
PDA + PH	8 (2.7)
Other anomalies	9 (3)
Pulmonary hypertension	129 (43)
History of operation, No. (%)	
Palliative	61 (20.4)
No history	223 (74.6)
Redo operation	15 (5)
Off pump	81 (27)
On pump	219 (73)
Hypothermia during surgery, No. (%)	
Mild	183 (61)
Moderate	1 (3)
Severe	0
Preoperative MV	14 (4.6)

Abbreviations: AOX, aortic cross clamp; AS, aortic stenosis; ASD, atrial septal defect; CAVSD, complete atrioventricularseptal defect; CBP, cardiopulmonary bypass; DORV: double outlet right ventricle; ICU, intensive care unit; MS: mitral stenosis; MV: mechanical ventilation; PDA, pedusductusarteriosus; PH, pulmonary hypertension; PS, pulmonary stenosis; TA, truncusarteriosus; TAPVC, total anomalous pulmonary venous connection; TGA, transposition of great arteries.

Table 2. Comparison of the Complications Between Patients With and Without Prolonged Mechanical Ventilation[a]

Variable	Mechanical Ventilation D					
	$\geq$ 72 hr, N = 60	$\geq$ 72 hr, N = 240	P Value	$\geq$ 7 Days, N = 32	< 7 Days, N = 268	P Value
Age (months)[a]	6 (0.6- 30)	24 (11 - 61.5)	< 0.001	2 (0.6 - 12)	24 (11 - 60)	< 0.001
Weight (Kg)[a]	6.5 (3.5-10.3)	10 (7.9 - 15)	< 0.001	4.1 (3.2-9.7)	10 (7.5-14.5)	< 0.001
Gender (No%)						
Male	40 (66.7)	130 (54.2)	0.08	21 (65.5)	149 (55.6)	0.2
Female	20(33.3)	110 (45.8)	0.2	11 (34.4)	114 (44.4)	0.2
Type of congenital anomaly						
Cyanotic	38 (63.3)	101 (42.1)	0.003	25 (78.1)	114 (42.5)	< 0.001
Non-cyanotic	22 (36.7)	139 (57.9)		7 (21.9)	154 (57.5)	
Congenital heart Disease			0.003			0.003
Tetralogy of fallot	10 (16.7)	63 (26.3)		5 (15.6)	68 (25.4)	
VSD + PH	14 (23.3)	55 (22.9)		2 (6.3)	67 (25)	
ASD	0	25 (10.4)		0	25 (9.3)	
CAVSD	3 (5)	20 (8.3)		3 (9.4)	20 (7.5)	
Single ventricle+PS, TA	7 (11.7)	22 (9.2)		5 (15.6)	24 (9)	
DORV+PS	3 (5)	7 (2.9)		2 (6.3)	8 (3)	
TGA	17 (28.3)	15 (6.3)		10 (31.3)	22 (8.2)	
TAPVC	2 (3.3)	4 (1.7)		2 (6.3)	4 (1.5)	
Aortic coarctation + AS + MS	2 (3.3)	14 (5.8)		1 (3.1)	15 (5.6)	
PDA + PH	1 (1.7)	7 (2.9)		1 (3.1)	7 (2.6)	
Other anomalies	1 (1.7)	8 (3.3)		1 (3.1)	8 (3)	
Pulmonary hypertension (No%)	33 (55)	96 (40)	0.03	14 (43.8)	115 (42.9)	0.9
History of operation			0.1			0.3
Palliative	14 (23.3)	47 (19.7)		6 (18.8)	55 (20.6)	
No history	44 (75)	179 (73.3)		26 (81.3)	197 (73.8)	
Redo operation	2 (3.3)	13 (5.4)		0	15 (5.6)	
Off pump	21 (35)	60 (25)	0.1	13 (40.6)	68 (25.4)	0.06
On pump	39 (65)	180 (75)		19 (59.4)	200 (74.6)	
CBP time (minutes)[a]	119 (64 - 176)	75 (54 - 110)	< 0.001	140 (77 - 172)	78 (55 - 115)	0.007
AOX time (minutes)[a]	73 (40 - 166)	43.5 (25.7 - 70)	0.003	76 (45 - 90)	44 (26 - 70)	0.02
Hypothermia during surgery			0.08			0.005
Mild	33 (84.6)	150 (83.3)		15 (78.9)	168 (84)	
Moderate	1 (2.6)	0		1 (5.3)	0	
Severe	-	-		-		
Preoperative MV	6 (10)	8 (3.3)	0.02	4 (12.5)	10 (3.7)	0.02
ICU stay (hours) [a]	264 (192 - 456)	48 (48 - 72)	< 0.001	372 (29 4- 626)	48 (48 - 96)	< 0.001
MV duration (hours)[a]	164 (88 -288)	12 (8 - 20.2)	< 0.001	288 (240 - 528)	14 (8 - 24)	< 0.001

Abbreviations: LV: left Ventricle; PH: Pulmonary Hypertension; RV Right Ventricle.
[a] Data are presented as No. (%).

Table 3. Comparison of Demographic, Clinical and Surgical Characteristics Between Patients With and Without Prolonged Mechanical Ventilation

Complications[a]	Mechanical Ventilation Duration					
	$\geq$ 72 hr	< 72 hr	P Value	$\geq$ 7 Days	< 7 Days	P Value
Delayed sternal closure	19 (32)	8 (3.3)	< 0.001	12 (37.5)	15 (5.6)	< 0.001
Re-intubation	25 (41.7)	11 (4.6)	< 0.001	11 (34.4)	25 (9.3)	< 0.001
Heart failure	20 (33.3)	17 (7.1)	< 0.001	14 (43.8)	23 (8.6)	< 0.001
RV failure	14 (23.3)	5 (2.1)		10 (31.3)	9 (3.4)	
LV failure	1 (1.7)	10 (4.2)		1 (3.1)	10 (3.7)	
RV+LV failure	5 (8.3)	2 (0.8)		3 (9.4)	4 (1.5)	
Residual anomaly	21 (35)	50 (21)	0.02	12 (37.5)	59 (22)	0.05
Sepsis	9 (15)	3 (1.3)	< 0.001	7 (21.9)	5 (1.9)	< 0.001
Positive blood culture	7 (11.7)	0	< 0.001	5 (15.6)	2 (0.7)	< 0.001
Respiratory complications	43 (71.7)	88 (36.7)	< 0.001	28 (87.5)	103 (38.4)	< 0.001
Pneumonia	19 (31.7)	3 (1.3)	< 0.001	18 (56.3)	4 (1.5)	< 0.001
Pneumothorax	5 (8.3)	3 (1.3)	0.002	3 (9.4)	5 (1.9)	0.01
Atelectasis	8 (13.3)	3 (1.3)	< 0.001	4 (12.5)	7 (2.6)	0.01
Pleural effusion	31 (51.7)	79 (33.1)	0.008	18 (56.3)	92 (34.5)	0.01
Pleural hemorrhages	4 (6.7)	4 (1.7)	0.03	2 (6.3)	6 (2.2)	0.01
Postoperative PH	22 (36.7)	56 (23.3)	0.03	12 (37.5)	66 (24.6)	0.1
Renal failure	4 (6.7)	1 (0.4)	0.001	3 (9.4)	2 (0.7)	< 0.001
Reoperation for bleeding	4 (6.7)	5 (2.1)	0.06	2 (6.3)	7 (2.6)	0.2
Lactate Level $\geq$ 4.2	16 (31)	15 (7.1)	< 0.001	12 (46.2)	19 (8)	< 0.001
Death	16 (26.7)	19 (7.9)	< 0.001	12 (37.5)	23 (8.6)	< 0.001

Abbreviations: AS, aortic stenosis; ASD, atrial septal defect; Aox, aortic cross clamp; Cavsd: complete atrioventricularseptal defect; CBP, cardiopulmonary bypass; dorv: double-outlet right ventricle; ICU, intensive care unit; Ms, mitral stenosis, MV, mechanical ventilation; PDA, pedus ductus arteriosus; PH, pulmonary hypertension; PS, pulmonary stenosis; TA, t runcus arteriosus; TAPVC, total anomalous pulmonary venous connection; TGA, transposition of great arteries.
[a] Data presented as median (IQR).

minutes in patients without and with HF respectively, and the median (interquartile range) of AOX time was 44 (26.7 - 70) versus 73 (35 - 100) minutes in patients without and with HF respectively (P < 0.001 for both CBP and AOX time). The complications of surgery are shown in Table 3. As expected the PMV was associated with more complications and mortality. Among all complications only reoperation for bleeding had no association with PMV in this study (P > 0.05).The lactate level was significantly correlated with PMV. As shown in Table 2, 31% and 46% of patients with PMV more than 72 hours and seven days had a high lactate level (> 4.2) which were significantly higher than those of the patients not on PMV (P < 0.001). Table 4 shows inotropes used in the study population. There was an association between the numbers of inotropes and mechanical ventilation duration (P < 0.001). Patients with PMV received more inotropes. Fifty three percent of the patients, extubated before 72 hours were on only one inotrope whereas 43.3% of the patients with PMV received at least three different inotropes.

Regarding the inotrope dosages and intubation duration, there was only a weak correlation between milrinone dose and intubation duration (Spearman's rho = 0.22, P = 0.001).However, VIS was significantly correlated with intubation duration (Spearman's rho = 0.5, P < 0.001) and was higher among patients remaining on MV more than 72 hours or seven days (Table 4). VIS was also moderately correlated with the duration of ICU stay (Spearman's rho = 0.4, P < 0.001).

4.3. Independent Predictors of PMV

A multivariate logistic regression model was applied to determine the independent predictors of PMV and showed delayed sternal closure, sepsis, re-intubation, VIS and the number of inotropes were independent predictors for MV more than 72 hours. According to the multivariate analysis younger age, lower weight, the presence of pulmonary hypertension before surgery and presence of some complications such as heart failure, respiratory complications and renal failure accompanied by delayed sternal closure, VIS and the number of inotropes can be considered as independent predictors of mechanical ventilation more than seven days. (Tables 5 and 6).

5. Discussion

In the current study about 70% of the patients were extubated within 24 hours after cardiac surgery. The MV median was 18 hours, 20% of the patients had a MV duration more than 72 hours and the incidence of MV duration more than seven days was about 11% in the study population which was similar to those of the previous reports.

The incidence of PMV in young children after congenital heart surgery was 10% - 19% (4), and in adult population after cardiovascular surgery was 3% - 22% (20). The incidence of PMV in Shi et al. (3) and Szekely et al. (1) were 35.4% and 25% respectively, and in the study by Polito et al. (6) 11% of pediatric patients undergoing cardiac surgery remained intubated for more than seven days.Recently, early extubation is being considered as a safe strategy after cardiac surgery in many centers (1-13). However, there are conflicting data regarding the definition and the predictors of PMV in different studies (1-9). It is shown that even after complex heart surgeries, extubation is usually achievable before 72 hours (1). In the study by Davis et al.(8) 47% of pediatric patients were extubated within 24 hours after the cardiac surgery. In their study heart failure and pulmonary hypertension were suggested as the main reasons for failed early extubation. The median duration for MV in the study by Marwali al. was 12 hours (0 - 25 days) (2). Results of the current study showed that delayed sternal closure, sepsis, re-intubation, VIS and numbers of inotropes would be independent predictors for MV more than 72 hours. The independent predictors of MV for more than a week were age, weight, pulmonary hypertension before surgery and presence of some complications such as heart failure, respiratory complications and renal failure accompanied by delayed sternal closure, VIS and numbers of inotropes. Although univariate analyses show similarities in the predictors for PMV between different studies (1-13), the multivariate analyses show that independent predictors would somehow be different in different centers. One possible reason for these differences could be differences in institutional protocols in the preoperative and ICU management of pediatric patients after cardiac surgery. However, some factors such as age, pulmonary hypertension, infections particularly respiratory infections and heart failure were common among different investigations (1-9).In a similar study by Shi et al.(3) nosocomial pneumonia, fluid imbalance and low cardiac output syndromes were independently associated with PMV (MV ≥ 72 hours). Marwali et. al.(2) reported that younger age, longer cardiopulmonary bypass time and greater severity of congenital anomaly could be independently associated with PMV. Szekely et al.(1) considered that the MV duration more than 61 hours and seven days as medium and long PMV, respectively. They concluded that the presence of complications such as heart failure, infection, renal failure and arrhythmias were independent predictors for both medium and long PMV. Young age is known as an important predictor of PMV and ICU stay (1, 2, 5, 21, 22). The incidence of PMV in infants undergoing surgery for congenital heart disease is estimated 10%-19% (4). Shu et al. showed a failed extubation rate of 13.2% after car-

Table 4. Comparison of Inotropes Type, Dosages and Vasoactive Inotropic Score Between Patients with and Without Prolonged Mechanical Ventilation

	Mechanical Ventilation Duration									
	≥ 72 hr, N = 240		≥ 72 hr, N = 60		P Value		≥ 7 Days, N = 268		≥ 7 Days, N = 32		P Value
Inotrope	NO (%)	Dose[a]	NO (%)	Dose[a]		NO (%)	Dose[a]			
Milrinone	172 (72)	0.5 (0.5 - 0.5)	46 (76.7)	0.5 (0.5 - 0.5)	0.4	194 (72.4)	0.5 (0.5 - 0.5)	24 (75)	0.5 (0.5-0.5)	0.7
Dopamine	18 (7.5)	6 (5 - 7.5)	25 (41.7)	5 (5 - 7.5)	< 0.001	30 (11.2)	6 (5-7.5)	13 (40.6)	5 (5-7)	< 0.001
Dobutamine	14 (5.8)	5 (5-7)	27 (45)	5 (5-7)	< 0.001	22 (8.2)	5 (5 - 7.5)	19 (59.4)	5 (5-10)	< 0.001
Epinephrine	67 (27.9)	0.05 (0.05-0.10)	42 (70)	0.1 (0.05-0.1)	< 0.001	83 (31)	0.01 (0.01-0.1)	26 (81.3)	0.10 (0.05-0.1)	< 0.001
Norepinephrine	3 (1.3)	0.05 (0.05-0.10)	-	-	-	3 (1.1)	0.05 (0.05-0.01)	-	-	-
VIS		5 (5 - 10)		15 (10 - 22.5)	< 0.001		5 (5 - 10)		18.5 (10 - 25)	< 0.001

Abbreviation: VIS: Vasoactive Inotropic Score.
[a] The drug dosage in microgram/kilogram/minutes presented as median (IQR).

Table 5. Multivariable Analysis to Investigate the Adjusted Associations Between Prolonged Mechanical Ventilation and Some Predictors

	Coefficient (β)	P Value	Odd Ratio (CI 95%)
VIS	-0.125	.012	0.883 (0.801 - 0.973)
Delayed sternal closure	-2.951	.001	0.052 (0.01 - 0.280)
Reintubation	-3.076	.000	0.046 (0.01 - 0.205)
Sepsis	-3.061	.069	0.047 (0.002 - 1.26)
Inotrope using	2.426	.000	11.3 (3.5 - 36.6)

Table 6. Multivariable Analysis to Investigate the Adjusted Associations Between Prolonged Mechanical Ventilation and Some Predictors

	Coefficient (β)	P Value	Odd Ratio (CI 95%)
Age	0.163	.007	1.2 (1.04 – 1.32)
Weight	-1.040	.004	0.35 (.17 - .71)
PH	4.530	.007	92.8 (3.5 - .2448)
VIS	-0.169	.026	0.84 (.73 – .98)
Delayed sternal closure	-2.366	.042	0.09 (.01 - .9)
Heart failure	3.870	.005	47.9 (3.1- .735)
Respiratory complications	-7.473	.028	0.001 (.0001 - .45)
Renal Failure	-2.877	.071	0.06 (.002 - .1.3)
Inotrope using	2.126	.008	8.4 (1.7 - .40.6)

Abbreviations: PH; Pulmonary hypertension, VIS; vasoactive inotropic score.

diac surgery for CHD in pediatric patients with a mean age of 6±4 months (4). They also showed that preoperative pulmonary hypertension and postoperative pneumonia were independent factors to predict failed extubation (4). The infants with CHD are physiologically different from the older children or the adults. They may be low birth weight, malnourished and most of them have a history of frequent infectious episodes because of depressed immunity. Therefore, they tend to have limited cardiorespiratory reserve and are prone to PMV (1, 2, 5, 21, 22). Many investigators suggest preoperative pulmonary hypertension and respiratory complications including postop pneumonia as important and independent risk factors for failed extubation in children undergoing cardiac surgery for CHD (4, 5, 9). After corrective surgery of congenital anomalies in patients with left-to-right shunt the pulmonary arterial pressure decreases, partially or totally. However, these patients are prone to pulmonary hypertensive crisis after surgery which may be due to hypoperfusion of pulmonary tissue during cardiopulmonary bypass .The pulmonary compliance will decrease in patients with pulmonary hypertension crisis and prone them to respiratory complications

and PMV (4, 5).Cardiac dysfunction is another important predictor for PMV after congenital heart disease surgery. (2, 3) Many children with congenital heart anomalies, particularly those with complex ones have limited cardiac reserve which may get worse during CPB (22).The occurrence of heart failure and low output state syndrome after congenital heart surgery is multi factorial and depends on the severity of cardiac dysfunction before surgery, aortic cross clamp time, CPB time and myocardial preservation measures during surgery (1, 3). With persistence, the heart failure clinical manifestations, and discontinuing the inotrope support will be difficult and using multiple and high dose inotropes might induce more myocardial damages (1, 3, 22). Although CPB and AOX time were not independently associated with PMV in the current study, using multiple inotropes, VIS and presence of heart failure were independent predictors of PMV.The presence of conflicting data regarding the independent PMV predictors shows that complex systemic and cardiopulmonary interactions contribute to this issue and it is impossible to have a universal list of risk factors for this multifactorial phenomenon. Authors believe that the possible predictors should be assessed in each center and each pediatric cardiology center should have its own protocol in the perioperative management of these patients.

5.1. Study Limitations

The study considered different age groups all together (neonate to 15 years).It was better to perform a subgroup analysis. Some risk factors mentioned in other studies such as nutritional status and other therapeutic interventions were not considered (antibiotics, non-invasive ventilation, diuretics, etc.). In conclusion, younger age, lower weight, the presence of heart failure and using higher doses of inotropes and several complications particularly respiratory infections would be considered as important factors to predict PMV in children undergoing cardiac surgery for congenital anomalies. The results of the current study indicate the need for a good administration program to direct specific protocols for the preoperative management of patients undergoing congenital heart surgeries. Further studies are recommended to assess the role of different therapeutic measures of this issue.

Acknowledgments

Footnote

References

1. Szekely A, Sapi E, Kiraly L, Szatmari A, Dinya E. Intraoperative and postoperative risk factors for prolonged mechanical ventilation after pediatric cardiac surgery. *Pediatr Anesth: Curr Pract.* 2006;**16**(11):1166–75. doi: 10.1111/j.1460-9592.2006.01957.x.

2. Marwali EM, Budiwardhana N, Sastroasmoro S, Pudjiadi A, Haas NA. Prediction model for length of intubation with assisted mechanical ventilation in pediatric heart surgery. *Intensive Care Med.* 2013;**16**(3):74–82.

3. Shi S, Zhao Z, Liu X, Shu Q, Tan L, Lin R, et al. Perioperative risk factors for prolonged mechanical ventilation following cardiac surgery in neonates and young infants. *Chest.* 2008;**134**(4):768–74. doi: 10.1378/chest.07-2573. [PubMed: 18625673].

4. Shu Q, Shi S, Zhang XH, Shi Z, Tan LH, Zhang ZW, et al. Risk factors of failed extubation after open-heart surgery in infants. *World J Pediatr.* 2005;**1**(1):72.

5. Ip P, Chiu CS, Cheung YF. Risk factors prolonging ventilation in young children after cardiac surgery: Impact of noninfectious pulmonary complications. *Pediatr Crit Care Med.* 2002;**3**(3):269–74. [PubMed: 12780968].

6. Polito A, Patorno E, Costello JM, Salvin JW, Emani SM, Rajagopal S, et al. Perioperative factors associated with prolonged mechanical ventilation after complex congenital heart surgery. *Pediatr Crit Care Med.* 2011;**12**(3):e122–6. doi: 10.1097/PCC.0b013e3181e912bd. [PubMed: 20625334].

7. Roodpeyma S, Hekmat M, Dordkhar M, Rafieyian S, Hashemi A. A prospective observational study of paediatric cardiac surgery outcomes in a postoperative intensive care unit in Iran. *J Pak Med Assoc.* 2013;**63**(1):55–9. [PubMed: 23865132].

8. Davis S, Worley S, Mee RB, Harrison AM. Factors associated with early extubation after cardiac surgery in young children. *Pediatr Crit Care Med.* 2004;**5**(1):63–8. doi: 10.1097/01.PCC.0000102386.96434.46. [PubMed: 14697111].

9. Harrison AM, Cox AC, Davis S, Piedmonte M, Drummond-Webb JJ, Mee RB. Failed extubation after cardiac surgery in young children: Prevalence, pathogenesis, and risk factors. *Pediatr Crit Care Med.* 2002;**3**(2):148–52. [PubMed: 12780985].

10. Barash PG, Lescovich F, Katz J, Talner NS, Stansel HC. Early extubation following pediatric cardiothoracic operation: A viable alternative. *Ann Thorac Surg.* 1980;**29**(3):228–33. doi: 10.1016/s0003-4975(10)61872-3.

11. Schuller JL, Bovill JG, Nijveld A, Patrick MR, Marcelletti C. Early extubation of the trachea after open heart surgery for congenital heart disease. A review of 3 years' experience. *Br J Anaesth.* 1984;**56**(10):1101–8. [PubMed: 6433948].

12. Dunning J. A validated rule for predicting patients who require prolonged ventilation post cardiac surgery. *Eur J Cardiothorac Surg.* 2003;**24**(2):270–6. doi: 10.1016/s1010-7940(03)00269-0.

13. Mittnacht AJ, Thanjan M, Srivastava S, Joashi U, Bodian C, Hossain S, et al. Extubation in the operating room after congenital heart surgery in children. *J Thorac Cardiovasc Surg.* 2008;**136**(1):88–93. doi: 10.1016/j.jtcvs.2007.11.042. [PubMed: 18603059].

14. Brown KL, Ridout DA, Goldman AP, Hoskote A, Penny DJ. Risk factors for long intensive care unit stay after cardiopulmonary bypass in children. *Crit Care Med.* 2003;**31**(1):28–33. doi: 10.1097/01.CCM.0000046068.19048.86. [PubMed: 12544989].

15. Pagowska-Klimek I, Pychynska-Pokorska M, Krajewski W, Moll JJ. Predictors of long intensive care unit stay following cardiac surgery in children. *Eur J Cardiothorac Surg.* 2011;**40**(1):179–84. doi: 10.1016/j.ejcts.2010.11.038. [PubMed: 21227714].

16. Egbe AC, Nguyen K, Mittnacht AJ, Joashi U. Predictors of Intensive Care Unit Morbidity and Midterm Follow-up after Primary Repair of Tetralogy of Fallot. *Korean J Thorac Cardiovasc Surg.* 2014;**47**(3):211–9. doi: 10.5090/kjtcs.2014.47.3.211. [PubMed: 25207217].

17. Davidson J, Tong S, Hancock H, Hauck A, da Cruz E, Kaufman J. Prospective validation of the vasoactive-inotropic score and correlation to short-term outcomes in neonates and infants after cardiothoracic surgery. *Intensive Care Med.* 2012;**38**(7):1184–90. doi: 10.1007/s00134-012-2544-x. [PubMed: 22527067].

18. Gaies MG, Jeffries HE, Niebler RA, Pasquali SK, Donohue JE, Yu S, et al. Vasoactive-inotropic score is associated with outcome after infant cardiac surgery: an analysis from the Pediatric Cardiac Critical Care Consortium and Virtual PICU System Registries. *Pediatr Crit Care Med.* 2014;**15**(6):529–37. doi: 10.1097/PCC.0000000000000153. [PubMed: 24777300].

19. Gaies MG, Gurney JG, Yen AH, Napoli ML, Gajarski RJ, Ohye RG, et al. Vasoactive-inotropic score as a predictor of morbidity and mortality in infants after cardiopulmonary bypass. *Pediatr Crit Care Med.* 2010;**11**(2):234–8. doi: 10.1097/PCC.0b013e3181b806fc. [PubMed: 19794327].

20. Siddiqui MM, Paras I, Jalal A. Risk factors of prolonged mechanical ventilation following open heart surgery: what has changed over the last decade?. *Cardiovasc Diagn Ther.* 2012;**2**(3):192–9. doi: 10.3978/j.issn.2223-3652.2012.06.05. [PubMed: 24282717].

21. Monteverde E, Fernandez A, Poterala R, Vidal N, Siaba Serrate A, Castelani P, et al. Characterization of pediatric patients receiving prolonged mechanical ventilation. *Pediatr Crit Care Med.* 2011;**12**(6):e287–91. doi: 10.1097/PCC.0b013e3182191c0b. [PubMed: 21499185].

22. Traiber C, Piva JP, Fritsher CC, Garcia PC, Lago PM, Trotta EA, et al. Profile and consequences of children requiring prolonged mechanical ventilation in three Brazilian pediatric intensive care units. *Pediatr Crit Care Med.* 2009;**10**(3):375–80. doi: 10.1097/PCC.0b013e3181a3225d. [PubMed: 19325502].