

Utilization of mechanical ventilators in low resource Faculty: a cross sectional study

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Abstract

Background

Few studies are available from Africa on the use of mechanical ventilation (MV) in the pediatric intensive care unit (PICU). Knowledge of the outcome of patients on MV is critical for better use of resources and clinical decision making. We aimed to see the outcome and pattern of patients treated in a pediatric intensive care unit in a teresery hospital, which is the first study to evaluate an Ethiopian PICU.

Methods

A cross-sectional study with retrospective data collection was employed. Data were abstracted from the patients' medical records by trained health professionals. SPSS version 21 software was used for data entry and analysis. The reports were depicted descriptively using measures of central tendency, dispersion, and displayed through tables and graphs.

Results

There were 536 patients admitted during the study period. 202 (41.2%) incidence of mechanical ventilation (MV) rate 63.6% of the participants were males and 130 (59.1%) died. The most common indication for the initiation of MV was respiratory problems 46 (20.9%). we identified 30.59/1000 ventilator days developed complications. Ventilator-associated pneumonia accounted for 18.6% of the complications with 20.9/1000 ventilator days. Survival of medical cases was better than the surgical cases (including trauma); [AOR = 0.13, 95% CI(0.04–0.413)] and those who have MV for more than 3 days are 79% more likely to die than those of less than 3 days ventilated; ($p = 0.003$). Those who have multi-organ dysfunction syndrome die more likely than the other group of patients; [AOR = 0.181, 95% CI (0.08, 0.412)] and the patient who had high PIM II severity score had higher mortality rate; [AOR = 35, 95% CI (1.7, 11)].

Conclusions

In the current study, the mortality rate of mechanically ventilated pediatric patients was high. Severity score, multi-organ dysfunction syndrome, length of stay, and being a surgical patient increased the risk of mortality. Adequate education of PICU staff on the use of mechanical ventilator and prevention of complications as well as the use of severity score is necessary.

Background

Mechanical Ventilation (MV) is a life-supporting strategy used at the time of either impending or acute respiratory failure with the aims of improving gas exchange and decreasing work of breathing (1, 2).

Given the high load of respiratory problems being the primary reason for admission to the intensive care unit in low resource countries (LRIC), there is a need for proper use of MV (3–8).

There is a disparity of available resources like mechanical ventilators and trained health providers between the LRIC and high resource income countries (HRIC). Most ICUs have no adequate available resources in LRIC (3). The percentage of children receiving MV in PICUs ranges from 17–64% in developed countries where PICUs are a well-established discipline of medicine (2). There is a great scarcity of data from African countries regarding the use of MV in PICUs. The incidence of utilizing MV in children in Egypt was 32.8% (9). The study in Nepal showed that out of the 16 pediatric ICUs, 32% had only one functioning mechanical ventilator and another 38% had two ventilators, the other units had 3–6 ventilators (10).

Despite its important role, MV is associated with poor outcomes and might lead to complications like shock, ventilator-associated pneumonia (VAP), pulmonary hemorrhage, pneumothorax, atelectasis, and also side effects of medications (e.g. sedatives and analgesia) (2,11). Many studies in developing countries have revealed that the mortality rate ranges from 40–60% in mechanically ventilated children. A study in the PICU of Aga Khan University Hospital in Pakistan found that the mortality rate among mechanically ventilated patients was 30.5% and the complication rate was 9.4% (1). A report from Nepal revealed a 34.1% mortality rate (10).

The scarce resources in Ethiopia made physicians choose very difficult rationing bedside decisions because of a lack of resources like intensive care beds and mechanical ventilators (12). The information on patient characteristics and outcomes in patients requiring MV is critical for better use of resources and clinical decisions for the limited pediatric intensive care unit (PICU) (13, 14). However, this information is not dealt with in our setting. Therefore, the present study aimed to assess the characteristics and outcomes of mechanically ventilated pediatric patients in Tikur Anbessa specialized referral hospital, Addis Ababa, Ethiopia.

Methods

Setting and Study Period

The study was conducted from September 2016 to February 2018 at Tikur Anbessa Specialized Hospital which is the largest referral and teaching hospital in Addis Ababa, the capital city of Ethiopia. The hospital used to manage children either in adult medical or surgical ICU. Starting from 2012 the first two pediatric emergency and critical care physicians for a country established a separate four-bed ICU in 2012 which is the first PICU in Ethiopia. These two physicians cover both emergency and intensive care units during the day and on-call during the night while the nights are covered by pediatric residents. Nurse to patients ratio is 1: 2. There is no respiratory therapist.

Each PICU bed has mechanical ventilation and equipped with a monitor along with end-tidal CO₂ monitoring. This unit shares a portable X-ray machine with the adult ICU which is in the next door. We use Philip V200 mechanical ventilator for respiratory support in our PICU. Mechanical ventilation in all

patients was initiated through an Endotracheal tube. The modes of MV mostly used were synchronized intermittent mandatory ventilation (SIMV) either volume (SIMV or pressure limited, or SIMV with pressure support (PS), assist control pressure-controlled ventilation AC/PCV assist control volume-controlled ventilation AC/VCV. The other parameters set depending on the patient's condition as FIO₂, PEEP, PIP, and VT. Monitoring the subjects on MV was done with clinical examination but arterial blood gas not available PaO₂ is estimated from the saturation of oxygen and PaCO₂ with Entidal carbon dioxide monitor, and oxygen saturation was continuously recorded through a pulse oximeter. A chest X-ray was ordered on demand. Chest physiotherapy is done by a nurse and rarely with a physiotherapist. Subject weaning was initiated after improving clinical condition, criteria of extubation were, when the need of FIO₂<0 .4 and depend on the clinical examination.

All children during mechanical ventilation were getting intermittent doses of diazepam and morphine (which mostly available in PO form) as sedation and analgesia mostly. Thiopental and propofol are used rarely for status epilepticus cases and very rarely midazolam and fentanyl are rarely used as it is not available. Sometimes ketamine and Sedation of perfusion rarely continuous infusion is used because of the lack of infuser pumps. The neuromuscular blocking agent was never used.

Participants and Sampling Technique

All pediatric patients who were mechanically ventilated in the pediatric ICU of TASH for at least 24 hours during the study period were included whereas those patients with incomplete charts and lost charts were excluded from the study.

Study Design

Institutional based cross-sectional study design was employed by using a review of the patient's medical charts.

Data Collection Tools and Procedures

The instrument used to collect the data for this study was a structured data abstraction tool developed from the literature review. The tool has three parts: Socio-demographic characteristics of the participants, characteristics of mechanically ventilated patients, and patient outcome.

Data Analysis

Data were checked for completeness and coded manually and entered into SPSS version 21 for analysis. Both descriptive and analytical statistical procedures were utilized. Descriptive statistics like percentage, mean, median, standard deviation, and interquartile range (IQR) were used for the presentation of characteristics of mechanically ventilated patients; and tables and graphs were also used for data presentation. Binary and multivariable logistic regression models were used with 95% CI and p-value less than 0.05 taken as significant.

Operational Definition

Ventilator-associated pneumonia was diagnosed in patients on MV for more than 48 hours with a new persistent infiltrate on chest radiograph and at least 3 of the following; fever, leucopenia or leukocytosis, increased sputum production, rales, cough or worsening gas exchange (8).

Ethical Consideration

The ethical clearance was obtained from Addis Ababa University, College of Health Sciences, Departments of Emergency Medicine and Pediatrics, and Child Health Research and publication Committee. Additionally, the confidentiality of all the data was seriously respected by not mentioning patients' identifiers in the questioner and unauthorized individuals were not allowed to access the data which was collected by using a password-protected computer.

Results

There were 537 patients admitted to the PICU in two and a half years and 220 patients met the inclusion criteria. Most of the study subjects (39.1 %) were younger than 1 year and 63.6% of the participants were males (**Table 1**)

Table 1: Clinical characteristics of the study population.

Variable		Frequency	Percent (%)
Age	< 1	86	39.1
	1-5	74	33.6
	6-12	60	27.3
Sex	Male	140	63.6
	Female	80	36.4
Length of stay in days(SD =13.33, mean=9.33)	1-3 days	93	42.3%
PIM 2 Score	4-7days	63	28.6%
	>8days	64	29.1%
	Range (1-91) SD=23.9	Mean=20	

Clinical presentation

The source for admission to PICU was from the pediatric emergency department (102; 46.4%), from the operation room (57; 25.9%), from inpatient units (47; 21.4%), and from another hospital (14; 6.4%). Regarding the general indication of PICU admission, 160 (72.7%) were medical patients and 60 (23.7%) were surgical patients. From 149 (67.7%) of the children who were screened for HIV and 4 (1.8%) were positive. The most common indication for the initiation of mechanical ventilation was respiratory problems 46 (20.9%) and the mean weight in kilogram was 12.73 ± 9.12 (mean \pm SD) and Glasgow Coma Scale (GCS) of patients at admission was <8 in 73 (33.2%).

Table 2: Etiology of admission of the study population.

Variable (n, %)		Frequency	Percent
Neurology (41,18.7)	Status epilepticus	12	5
	Brain abscess	6	2.7
	Traumatic brain injury	6	2.7
	Meningitis	7	3.2
	Stroke	4	1.8
	Brain tumor	3	1.4
	Intra cranial hemorrhage	2	0.9
Respiratory (46, 20.9)	Spinal cord injury	1	0.5
	Pneumonia	15	6.8
	Tuberculosis	8	3.6
	FBA	6	2.7
	Apnea	4	1.8
	Aspiration pneumonia	4	1.8
	Lung contusion	2	0.9
	PCP	2	0.9
	HAAD	1	0.5
	HAP	1	0.5
	PTE	1	0.5
Cardiac (29, 13.2%)	Pulmonary edema	1	0.5
	Severe croup	1	0.5
	Post cardiac arrest	14	6.4
	Congenital heart disease	10	4.6
Sepsis (34, 15.5%)	Congestive heart failure	3	1.4
	SVT	2	0.9
Renal (10, 4.5%)	34	15.5	
Neuromuscular (19, 8.6%)	Acute renal failure	6	2.7
	Chronic renal failure	4	1.8
Superior mediastinal mass	Gulian Barrie syndrome	19	8.6
		5	2.3

Malignancy (8, 3.6%)	Anterior mediastinal mass	2	0.9
	Tumor lysis syndrome	1	0.5
Other (33, 15%)	Post- operation	28	12.7
	Poisoning	2	0.9
	Diabetic ketoacidosis	1	0.5
	Uremic encephalopathy	2	0.9

FBA: foreign body aspiration PTE: Pulmonary thromboembolism, HAP: Hospital-acquired pneumonia, HAAD: Hyperactive airway disease, PCP: Pneumocystic carni pneumonia. SVT: Supraventricular tachycardia

Mode of ventilation and Weaning Method

The access to airways was through endotracheal tubes in most cases, while 6 cases were tracheostomized (2.7%). Regarding the modes used at the initiation of mechanical ventilation, SIMV + PS , SIMV/VSV , AC/PCV , AC/VCV, and BIPAP/CPAP were used in 80%, 8.6%, 4.5% , 3.2 %, 3.6% of cases respectively. The duration of MV ranged from (1-90) days with a median of 4.4 with IQR (2-10.3). The weaning methods recorded for this patients were CPAP alone 54(24.5%), direct oxygen trial 14(6.4%), PS with CPAP 12(5.5%), and unplanned accidental extubation 3(1.4%).

Complications

Complication occurred in 60 (27.3%) patients that is 30.55 per 1000 ventilation days, categorized as VAP 41(18.6%) (20.9/ 1000 ventilation days), Pneumothorax 15 (6.8%) (7.6 /1000 ventilation), atelectasis 11(5%) (5.6/1000 ventilation) and post-extubation stridor 1(0.5%) (0.5 ventilation). More than one complication occurred in 8 (3.6%) patients. About half (57.3%) of the patients developed multiple organ dysfunction Syndrome (MODS).

Outcome of patients

Among the total study participants, 130(59.1%) died where sepsis was the leading cause of death 59 (26.8%). From the survivors, 75(34.1%) transferred to the ward, 12(5.5%) left the hospital against medical advice and 3 (1.4%) were discharged (**Table 3**).

Table 3: Outcome of mechanically ventilated pediatric patients in TASH PICU, (n=220) 2018.

Variable		Frequency	Percent
Outcome	Survived	90	39.9
	Not survived	130	59.1
Cause of death	Sepsis	59	26.8
	ARDS	30	13.6
	Brain death	17	7.7
	Intractable heart failure	12	5.5
	Other**	13	5.9

**Renal failure, Surgical site bleeding, Tension pneumothorax, Blocked ETT, Intracranial hemorrhage.

Logistic Regression Results

Medical cases survived better than the surgical cases (including trauma); [AOR= 0.13, 95% CI(0.04-0.413)] and those who have mechanical ventilation for more than 3 days were 79% more likely to die than those with less than 3 days of ventilation; (p=0.003). The patients without MODS were more likely to survive than those with MODS [AOR= 0.181, 95% CI (0.08, 0.412)]. The patients who had a high PIM II score had a higher death rate [AOR= 4.35, 95% CI (1.7, 11)] (**Table 4**).

Table 4: Logistic regression analysis of associated factors with mortality in mechanically ventilated pediatric patients in TASH pediatrics ICU (n=220) 2018.

Variable	Final Outcome		COR(95 % CI)	AOR(95%CI)
	Survivor (n)	Non survivor (n)		
Age	< 1 year	31	55	1.27 (0.64,2.49)
	1-5 year	34	40	0.84 (0.42,1.67)
	6-12 year	25	35	1
Sex	Female	32	48	0.94(0.54, 1.64)
	Male	58	82	1
	Medical	48	112	5.44(2.933,10.730)* 0.127(0.37,0.413)**
Type of cases	Surgical	42	18	1
	Neurology	18	23	0.61(0.248, 1.49)
Admission diagnosis	Respiratory	18	28	0.61(0.26.1.41)
	Cardiac	11	18	0.45(0.18, 1.14)
	Sepsis	6	28	0.20(0.07,0.58)*
	Neuromuscular	15	4	3.42(0.97, 11.96)*
	Malignancy	2	6	0.30(0.055,1.67)
	Renal	2	10	0.20(0.07,0.58)*
	Other	23	10	1
	Respiratory failure	3	15	25(2.10, 29.28)*
	Cardiovascular	27	34	6.29(0.69,7.14)* 7.149(1.30,39.48)
Indication for MV	Neurology	55	80	7.27(0.83,63.97)
	Other(post op)	5	1	1
	1-3 days	26	67	0.2 (0.11,0.43) 0.19(0.068,0.57)**
	4-7	23	40	0.32(0.156,0.67) 0.26(0.09,0.77)**
Length of stay on MV	> 8	41	23	1
	SAM	6	6	1.0(0.167,5.98)
	Malignancy	14	23	0.609(0.131,2.83)

	HIV	1	3	0.33(0.023,4.736)	
	CHD	10	17	0.588(0.12,2.81)	
	Renal	1	3	0.33(0.23,4.7)	
	Other	4	4	1	
Modes MV	SIMV/VCV	7	12	2.9(0.59,.14.06)*	
	AC/PCV	2	8	4.3(0.51,36.9)*	
	AC/VCV	1	6	0.24 (0.2421,0.05)*	
	BIPAP/CPAP	6	2	1	
CPR before admission	Yes	12	27	1	
	No	78	103	1.7(0.81,3.57)	
Complication of mechanical vent	Yes	33	26	0.44(0.24, 0.8)*	
	No	57	103	1	
MODS	No	61	33	1	0.181 (0.08,0.412)**
	Yes	29	97	6.18 (3.417.11.18)*	
PIM II SCORE	0-9	54	50	0.417 (0.24, 0.72)*	4.35(1.7, 11)**
	9-91	36	80	1	

Mean and SD) (20, 23.9), MIN/MAX (1-91)

*P value < 0.2 for COR, ** P value <0.05 for AOR

Discussion

The COVID pandemic exposed the burden and need for a mechanical ventilator globally. This scarcity is much exaggerated in Africa where fewer than 2,000 working ventilators in public hospitals available across 41 African countries, compared with more than 170,000 in the U.S. Ten countries in Africa have no ventilator at all(14). There is scarce available data from African countries regarding the use of MV in the intensive care unit in particularly in pediatrics. Even if most data's from resource-limited setting are underreported; there are a high burden and mortality of respiratory failure in LRIC compared to HRIC, the provision of mechanical ventilators help save lives if implemented in a thoughtful fashion (14). This is the first study in Ethiopia to look for characteristics and short-term outcomes of mechanically ventilated children as it is important to know how this scarce resource being used.

There were 536 Patients admitted during the study period with 202 (41.2%) supported by mechanical ventilation. In a previous study in Gondar university ie the Northern part of Ethiopia 10% of pediatric ICU

admissions required MV (15) on the other hand children admitted to the general ICU of the university hospital southeastern part of Ethiopia (Jimma) it was 37% (16). Both these are lower than the current study. This could be Tikur Anbessa is last referral hospital in Ethiopia where more complicated cases and also e Gondar hospital used 1 ventilator and Jimma used shared the general ICU that might have a role also. Other studies reported a varying incidence of MV use in PICU: 30% in 16 United States PICUs (17); in Egypt of 32.8% (9), 34.6% in an Italian study (18), 50.7% in Pakistan (1) and 52% in Sri Lanka (19).

This study identified that respiratory (20.9%) was the most common indication for admission. A Prospective cohort Brazil and retrospective follow up study in Turkey and another multicenter study showed acute respiratory failure was a primary reason for MV 59.18%, and 72%, 64.8% respectively (4, 20, 21). However, our finding differs from a study done in a prospective observational study in Cairo in which the main indication for MV was neurologic cases 38.9% (9) and the discrepancy might be due to respiratory diseases like pneumonia that are common in Ethiopia and is one of the top causes of mortality in the country for children younger than 5 years of age (22).

This study found that SIMV was the most commonly used MV mode (80.0%). Similarly, the retrospective review in Pakistan (1) and prospective descriptive study in India (2), Egypt (9), Turkey (21), and Bangladesh(23) reported the commonest ventilator mode to be SIMV (21). Several published reports also found that SIMV the most commonly used mode of MV in multiple PICUs in the USA (17). The weaning method employed was CPAP alone 24.5% whereas the study of the group from Cairo showed that pressure support (PS) with CPAP was the preferred method of weaning in 74.7% of the cases (9). The difference could be due to the preference of the physicians and patients' capacity of maintaining their saturation on both methods.

The length of MV support in this finding showed a median of 4.4 days [IQR 2-10.3] and a mean of 9.3 (\pm 13.33). The duration of MV ranged from 4–9 days in other reports. The median duration of MV was 3.1, 4.5, 5, 9 days in London Ontario (24), in Italian (18), Latin America (6), and in Cairo (9) respectively. This variation could be due to the variation in the reason for admission.

In the present study, we identified 60 (27.3%) and 30.59 /1000 ventilator days developed complications. Though it is lower than the reported in Cairo (39.9%) and also 40% in Principi et al (24). This study showed VAP of 18.6% with 20.9/ 1000 ventilator days which is similar to Meligy et al where VAP had accounted for 20.19 per 1000 ventilation days(9). Higher values VAP also reported in (36.2%) India (2) and Egypt (31.8/1000) ventilator-days (24). The atelectasis occurred in 5% in this study which is similar to (4.6%) in Pakistan (1) and (4.4%) in Egypt (9).

Logistic regression analysis reflected, predictors of mortalities were the presence of MODS; higher severity score, surgical rather than medical cases (including trauma), and prolonged duration of MV. Our MODS rate of 57.3% of the cases higher than studies done in (7.6%) India (2) and (41.3%) Egypt (9). The higher discrepancy in our study might be due to delayed admission to PICU, a limited early resuscitation practice in our setting which is a crucial method of preserving organs from failing. Prolonged MV more than 3 days were 79% more likely to die than those of less than 3 days ventilated; ($p = 0.003$). This is similar to

the Pakistan study where prolonged mechanical ventilation (> 10 days) is an important predictor of mortality (1). Similarly, those who are on MV died more in Italian study than those who are not MV (18).

Higher Severity score showed higher mortality in our study and which is similar to multiple other studies. Surgical cases die more than the medical case because we included those severe traumatic injuries in this list. This study revealed that the mortality rate was 59.1% which is higher than in Czech Republic 3.5% (27), in Italy 6.7% (18), in Sri Lanka 27.6% (19), in Pakistan 30.3% (1), India 43.8% (2) and in Egypt study (9) respectively. Also it is higher than from Faris et al from international study of 36 Picus of seven countries 15.6% (28). The report in developed countries ranged from 1.6–15% (4–7, 17, 18, 27). Sepsis (26.8%) and ARDS (13.6%) were among the common causes of mortality in our study Dahlem et al also showed the same (29).

This higher rate of mortality with severe PIM score and MORD speak about late admission of PICU patients because of the limited PICU bed and ventilators, delayed recognition and resuscitation of critically ill children, lack of PICU trained enough staff who covers undividedly ICU both during and night. As the previous study showed the standardized mortality ratio (SMR) improved significantly with intensivist care compared to non-specialist care (30) therefore there is a huge need for training of the pediatric intensivists. The limited knowledge of health providers on the use and management of mechanical ventilator; unavailability of basic tests for mechanical ventilators like blood gas and lack of syringe pumps to administer sedation and other necessary drugs all these needs to improve the outcome of ventilated children.

Limitations Of The Study

Secondary data were used for this study; so that it was difficult in getting all the necessary data which are important for the study like anthropometry measurements. None of the patients had a blood gas analysis.

Conclusion

This study identified that the mortality rate of mechanically ventilated pediatric patients in Tikur Anbessa specialized hospitals. The main reason for the initiation of MV at PICU was respiratory failure and predictor of mortality are higher PIM II score, prolonged duration of MV, the presence of MODS; the surgical case with nonmedical score were significant predictors of PICU mortality.

Abbreviations

ARDS: Acute respiratory distress syndrome, CPAP: Continuous positive airway pressure, ETT: Endotracheal tube, FIO₂: Fraction of inspired oxygen, ICU: Intensive care unit, IVH: Intraventricular hemorrhage, MODS: Multiple organ dysfunction syndromes, MV: Mechanical ventilation, PEEP: Peak end-expiratory pressure, PICU: Pediatric intensive care unit, PS: Pressure support, SIMV: Synchronized intermittent mandatory ventilation, SPSS: Statistical package for social sciences, US: United States, VAP: Ventilator-associated pneumonia

Declarations

Ethics approval and consent to participate

The ethical clearance was obtained from Addis Ababa University, College of Health Sciences, Departments of Emergency Medicine, and Department of Pediatrics and child health research and publication committee.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interest

We have no competing interest.

Funding statement

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Authors' contribution

TH: selected topic, help writing of the proposal , analyzed the data and wrote the manuscript, **NT:** wrote a draft of the proposal, collected data, and review the manuscript, **WT:** assisted in the design of critical review of the proposal and edited the final manuscript .All authors read and approved the final draft of the manuscript for publication.

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