Review

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Mechanical Ventilation in Children - A Challenge

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SUMMARY

Mechanical ventilation is a life saving adjunct to the treatment of critically ill children. In order to assess the usefulness of mechanical ventilation amongst our sick children, this study was carried out at the Paediatric Intensive Care Unit at Shaikh Zayed Hospital, Lahore. A total of 464 paediatric patients were included in the study. The study was carried out for a period of 6 years (1st January 1994 to 30th December 1999). The overall percentage of paediatric admissions to ICU requiring mechanical ventilation in our study was 23.5%. 68% of the patients who required MV, were under one year of age, with median age of 26 months. Males out-numbered females with male to female ratio of 2:1.5. A majority (66.8%) of patients who required MV were received in PICU in critically ill condition. The average duration of endoctracheal intubation and mechanical ventilation in our study was 6 days while the average duration of stay in PICU was 9 days. The need for MV in our study was indicated by hypoxia (10%), hypercarbia (46%) frequent apnoea (19%) and/or respiratory arrest (26%). Amongst the major indications for MV in our setup were central nervous system (CNS) conditions (29.3%) infectious diseases (26.2%) and respiratory conditions (22.6%). Maximum survival was documented for CNS conditions (46.3%), while 43% patients belonging to the respiratory and gastrointestinal diseases survived. Highest mortality was documented with haematology/oncology (91.6%), infectious diseases (88%) and cardiovascular diseases (81.2%). Our study reveals an overall high mortality rate of 63% associated with mechanically ventilated children but the important finding was that out of the critically sick children admitted to PICU 37% could be saved because mechanical ventilation provided time and support to these children for their specific treatment to prove effective.

INTRODUCTION

Acute respiratory failure (ARF) continues to be a major problem in paediatric critical care[1,2]. It is defined as the inability of the respiratory system to deliver adequate oxygen or to remove CO2 from the pulmonary circulation thereby leading to arterial hypoxia, hypercapnia or both[2]. In practical terms respiratory failure is present when the PaO_2 is <7 kPa (55 mmHg) or the $PaCO_2$ is >7 kPa (55 mmHg)[3]. It is a common paediatric problem and is responsible not only for morbidity in children but also a high death rate[3].

As far as the management of respiratory failure is concerned, patients with hypoxemia induced by respiratory failure may respond to supplemental oxygen administration alone. But severe ventilation perfusion (V/Q) mismatches often do not respond to anything but aggressive airway management and mechanical ventilation[2,4-10]. Mechanical ventilation is one of the major supportive modalities used in critical care[4,6]. It can be a life-saving intervention in patients with seriously impaired pulmonary gas exchange[5,8]. Increased compliance of an infants chest wall, the growing number of alveoli until approximately the age of 8 years and the small size of airways make paediatric ventilation challenging[2].

In Pakistan the facility of mechanical ventilation is available in limited numbers and in tertiary care medical centres only. Paediatric Intensive Care Unit (PICU) at Shaikh Zayed Hospital, Lahore (SZH) is one of the few units

where this facility is provided to sick children. In order to assess the usefulness of this treatment modality in our setup this prospective study was conducted at the PICU at Shaikh Zayed Hospital from January 1994 to December 1999.

AIMS AND OBJECTIVES

The main aims and objectives of the study were to assess the utility of mechanical ventilation in terms of the following:

1. Indications of mechanical ventilation.
2. Outcome (assessed during hospitalization).

PATIENTS AND METHODS

All patients admitted to the Paediatric Intensive Care Unit (PICU, SZH) needing mechanical ventilation (MV) were included in the study. The study population, therefore, included 464 patients with age group range of one day to 15 years. These patients were then prospectively followed until discharge from PICU. A thorough history and physical examination was performed in each case to establish the primary diagnosis. The study population was categorized into two groups according to the severity of illness on admission. Accordingly a patient was labelled as "critical" if he/she fulfilled one or more of the following criteria:

a) Shock and circulatory collapse.
b) Hypothermia
c) Disseminated intravascular coagulation (DIC)
d) Respiratory failure (Apnoea / respiratory arrest)
e) Coma grade III or IV (Glasgow coma scale less than 8 for all ages)
f) Evidence of more than one organ failure.

If the child who was sick-enough to be admitted to PICU but did not fulfil any of the above criteria he/she was categorized as "serious".

The parameters used to indicate need for endotracheal intubation and MV included one or more of the following;

1. Type I respiratory failure: indicated by severe hypoxemia, i.e. a PaO_2 value of less than 50 mmHg with a normal to low $PaCO_2$ showing no improvement despite high FiO2 of 0.9 to 1.0 liters delivered through face mask or oxyhood.
2. Type II respiratory failure: indicated by hypercarbia, i.e. a $PaCO_2$ value of more than 55 mmHg with severe hypoxemia i.e. a PaO_2 value of less than 50 mmHg despite high inhaled FiO_2 of 8.0 to 1.0 liters delivered through face mask or oxyhood and other supportive measures to improve ventilation.
3. Frequent apnoea.
4. Respiratory arrest, impending or evident.

Endotracheal intubation was performed routinely via the oral route in all the cases. The internal diameter and the insertion length of the endotracheal tube were chosen according to the age and weight of the child. An uncuffed endotracheal tube was used in all the cases. A nasogastric tube was inserted in majority of cases to allow gastric deflation, drainage of secretion and entral nutrition. The endotracheal tube (ETT) position was confirmed by a chest radiograph. In patients who needed prolonged MV (more than 21 days) endotracheal tube was replaced by tracheostomy and MV was continued by this route. Mechanical ventilation was provided by two ventilator types i.e. Siemens (Servo Ventilator 900C) and Newport Breeze (E150 Ventilator) Artificial humidification was provided for ventilated patients with humidifier (Fisher and Paykel-MR370, MR340) attached to each ventilator. The type of mechanical ventilation used in the study population was either pressure-cycled or volume-cycled. The modes used for mechanical ventilation were either assist control or synchronized intermittent mandatory mechanical ventilation (SIMV). The ventilatory settings were recorded on initiation of ventilation, during the illness and at the time of a complication. Weaning was tried either with the use of intermittent trials of spontaneous breathing alternating with SIMV or by the use of CPAP (continuous positive airway pressure). Sedation, anaesthetics or muscle relaxants were used in very few selected cases who did not synchronize with mechanical ventilation, while drugs like Dexamethasone I/V and Salbutamol nebulized were used in the majority of cases during weaning. During extubation, chest physiotherapy was instituted in most cases.

A data sheet was attached to the medical record of each patient on admission and their age, sex, weight, main diagnosis, severity of illness on admission, indication for mechanical ventilation, endotracheal tube route, size and its type, type of

ventilator and mode of mechanical ventilation, use of humidifier and drugs during MV, ventilatory settings, method of weaning, drugs used during and after extubation, duration of endotracheal intubation, duration of tracheostomy (if done) and duration of mechanical ventilation and stay in PICU were noted. Serial clinical and radiological assessments of patients included serial thorough physical examination, pulse oxymetry, arterial blood gas analysis and chest roentgenograms. Along with this the patients were investigated and treated for the primary diagnosis as per requirement of the case. The outcome in terms of morbidity and mortality in each case during their stay in PICU was recorded. Later this information was correlated to assess the usefulness of mechanical ventilation in sick children in our setup.

RESULTS

The study population consisted of 464 paediatric patients which constituted 23.5% of the total cases admitted to the paediatric ICU at Shaikh Zayed Hospital. The age range of our patients was 1 day to 15 years with an average age of about 26 months (Fig. 1). A majority (69.6%) were males with a male to female ratio of 2:1.5. According to the defined criteria mentioned earlier 154 patients (33.19%) were categorized as "serious" on admission while 310 patients (66.8%) of the study population were "critically ill". The average length of stay in PICU was 9 days with a stay range between 8 hours to 68 days (Table 1).

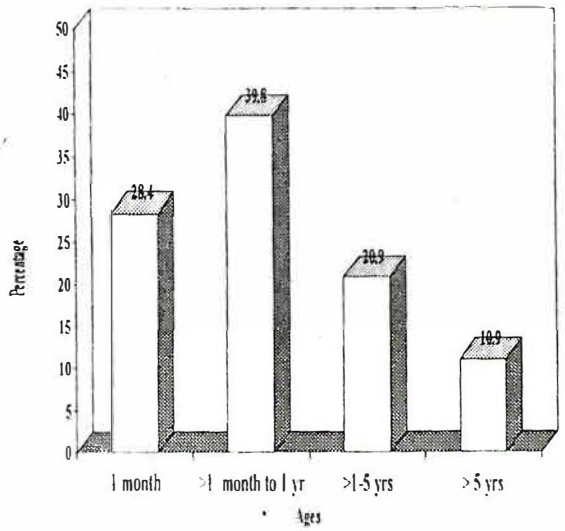

Fig. 1: Age distribution in study population.

Table 1: Total duration of stay in PICU (n=464)

Duration	*Number*	*Percent*
< 1 day	106	22.8
1 day - 3 days	116	25
> 3 days - 10 days	156	33.6
> 10 days - 30 days	74	15.9
> 30 days	12	2.7
Total	464	100.0

As regards **indications** for endotracheal intubation and mechanical ventilation, the results of the study depicted that 46 cases (10%) had type I respiratory failure while a much larger percentage i.e. 45% (212 cases) had type II respiratory failure as an indication of mechanical ventilation. Frequent apnoea was documented in 87 case (19%) while in 119 patients (26%) mechanical ventilation was initiated due to respiratory arrest (Table 2).

Table 2: Indications for endotracheal intubation and mechanical ventilation (n=464)

Indications	*Number*	*Percent*
Type I Respiratory failure (PaO_2 < 50 mmHg)	46	10
Type II Respiratory failure ($PaCO_2$ > 55 mmHg) (PaO_2 > 50 mmHg)	212	45
Frequent apnoea	87	19
Respiratory arrest (impending or evident)	119	26
Total	464	100

When the study population was distributed according to the **primary diagnosis** it was found that maximum patients ventilated in our study belonged to conditions of the central nervous system 136 (29.3%). This was closely followed by the

infectious diseases which accounted for 122 (26.4%) of the cases. 107 (23%) of the patients had primary disease of the respiratory system, 32 (6.9%) of cardiovascular system, 14 (3%) of gastrointestinal system, 9 (1.9%) of genitourinary system, 12 (2.6%) of haematology/oncology and 15 (3.2%) related to surgery or surgical conditios.

Table 3: Distribution of cases according to the primary diagnosis (n=464)

System involved	*Number*	*Percent*
Central nervous system	136	29.3
Infectious diseases	122	26.4
Respiratory system	107	23
Cardiovascular system	32	6.9
Gastrointestinal system	14	3
Genitourinary system	9	1.9
Haematology and oncology	12	2.6
Surgical condition	15	3.2
Miscellaneous	17	3.7
Total	464	100.0

As regards the **route of ventilation** orotracheal route was used in all (100%) the cases (in order to insert the endotracheal tube. In 10 patients (2.15%) who needed prolonged mechanical ventilation (beyond 3 weeks) ventilation via the tracheostomy tube was carried out.

Of the total 357 cases (77%) received "pressure cycled" MV while 107 cases, i.e., (23%) received "volume cycled" MV, pressure cycled MV was used mainly in the younger age group (Table 4).

The most commonly used **ventilatory mode** was synchronized intermittent mandatory ventilation (SIMV) (82%), while assist control mode (A/C) was used in 18% of cases. Continuous positive airway pressure (CPAP) was used for **weaning** in 72.5% of cases while intermittent trials of spontaneous breathing were used as a weaning technique in 27.6% of cases. 171 patients (37%) were successfully extubated after variable periods of mechanical ventilation The process of extubation was facilitated by the use of drugs (27.6%) during and in the immediate post extubation periods. Intravenous dexamethasone (3 doses) was used in 26.7% along with salbutamol nebulized in 31.9% of cases, while in 86% case intravenous Aminophylline was used to facilitate extubation. Chest physiotherapy was used in the majority of ventilated patients.

Table 4: Correlation of age with type of mechanical ventilation (n=464)

Age	*Total*	*Pressure cycled*		*Volume cycled*	
		No.	*%*	*No.*	*%*
Birth - 1 month	140	140	100	0	0
> 1 month - 1 yr	169	163	97	6	3
> 1 yr - 5 yrs	104	43	41.3	61	58.6
> 5 yrs	51	0	0	51	100
Total	464	346	74.6	118	25.4

A total of 68785 ventilation hours were recorded in a total of 464 cases with maximum duration of MV of 63 days and a minimum duration of 2.5 hours (range = 2.5 hours to 63 days). The average **duration of mechanical ventilation** in our study was 6.17 days. 106 (22.8%) cases received MV for less than 24 hours; 116 (25%) cases were ventilated in duration range of 1-3 days; 156 (33.6%) cases were ventilated > 3 to 10 days duration and 69 (14.8%) cases received MV between duration range of more than 10 days to 30 days. A total of 17 patients (3.6%) were ventilated for more than 30 days (Fig. 2).

As far as **outcome** of our ventilated patients is concerned 171 (37%) out of a total of 464 cases survived while 293 (63%) patients expired despite use of mechanical ventilation (Fig. 3). Maximum cases survived in conditions of the CNS (46.3%) closely followed by the gastrointestinal system (42.8%), while 41% patients survived in the respiratory system conditions. From the infectious diseases category 31.1% cases survived while 11.1% from genitourinary system and 8.3% from haematology/oncology group survived. Survival of 26% was noted for paediatric surgery patients and 47.05% for miscellaneous group (Table 5).

When outcome in our study population was correlated with the severity of illness on admission it was found that amongst the 155 (33.4%) patients

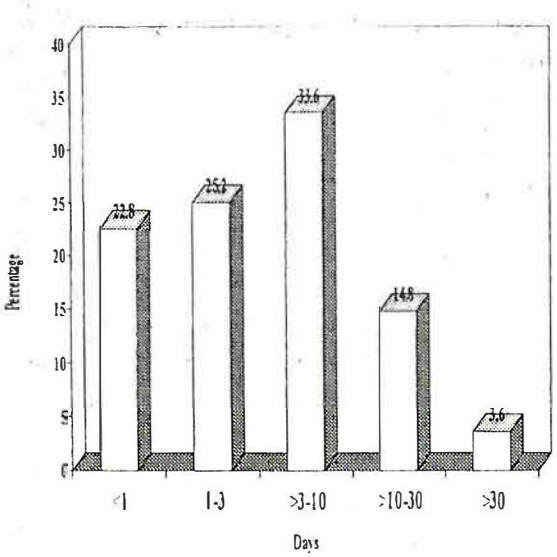

Fig. 2: Total duration of mechanical ventilation (n=646).

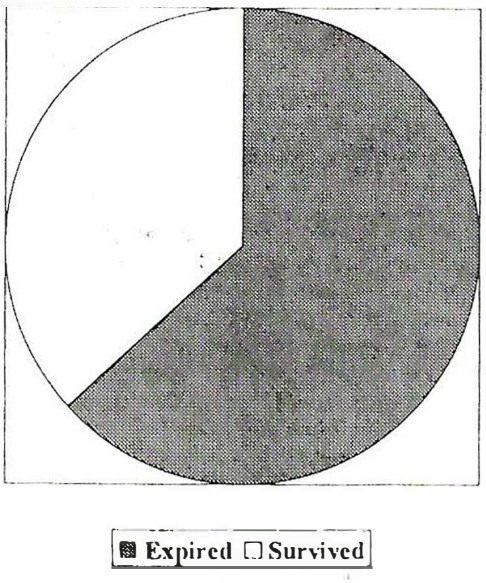

Fig. 3: Age distribution in study population (n=464).

Table 5: Correlation of primary diagnosis with outcome (n=464)

Systemic involved	Total	Survived No.	Survived %	Expired No.	Expired %
Central nervous system	136	63	13.5	73	15.7
Infectious disease	122	38	8.1	84	18.1
Respiratory system	107	44	9.4	63	13.5
Cardiovascular system	32	6	1.3	26	5.6
Gastrointestinal system	14	6	1.3	8	1.7
Genitourinary system	9	1	0.21	8	1.7
Haematology and oncology	12	1	0.21	11	2.3
Surgical patients	15	4	0.86	11	2.3
Miscellaneous	17	8	1.72	9	1.9
Total	464	171	36.8	293	63

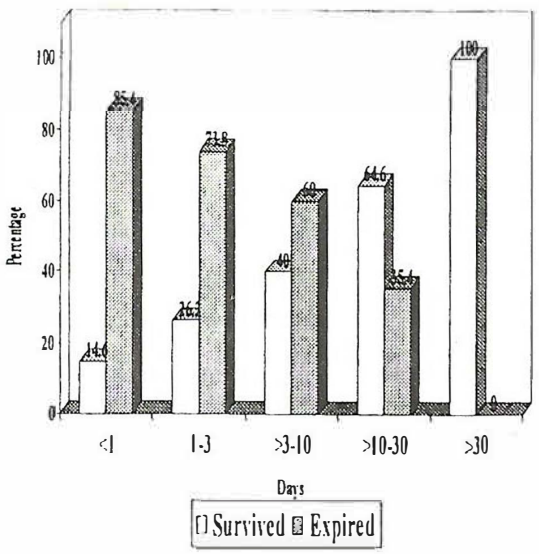

Fig. 4: Total duration of mechanical ventilation.

whose condition was "serious" on admission 119 (76.7%) cases survived and only 36 (23%) cases expired. On the other hand, those patients who were labelled as "critical" on admission (309 = 66.5% cases) only 59 (19%) survived and the majority i.e. 250 (80.9%) cases expired (Table 6). When the total duration of mechanical ventilation in each case was correlated with outcome it was found that mortality was very high among patients who were put on mechanical ventilation for short periods of time (probably for terminal care) while percentage of survivors was very high among patients who needed mechanical ventilatory support for long durations of time (Fig. 4). Statistically, among the

116 patients who were ventilated for less than 24 hours duration only 17 (14.6%) survived while 99 (85%) expired. 130 patients received ventilation for a period range of 1 to 3 days. Out of these patients 34 (26%) survived and 96 (73.8%) expired. Among 34 patients who received MV for a duration range between more than 3-10 days 64 (40%) cases survived and 96 (60%) cases expired.

When correlation was made between age and the final outcome, out of a total of 131 patients who were within first month of age only 30 (22.9%) cases survived. Between 1 month to 1 year of age only 87 (45%) cases and 35 (36.8%) cases survived in the age group category of 1 year to 5 years (Fig. 5). Important finding was survival rate of 60.7% in patients above 5 years of age.

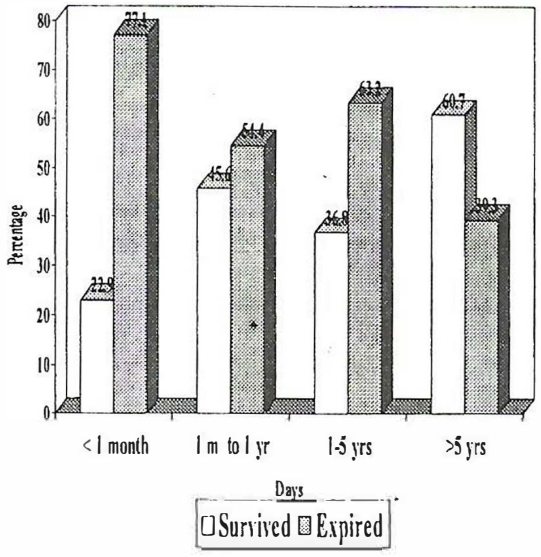

Fig. 5: Correlation of age with outcome.

As regards condition at discharge amongst survivors in our study population 83.3% cases were discharged in stable condition. Out of the rest one case (2.4%) was oxygen dependent and one case (2.4%) was discharged with tracheostomy tube still in place. 5 (11.9%) cases had residual sequalae at discharge which were primarily pertaining to the main diagnosis rather than a complication of mechanical ventilation. These were in the form of reduced muscle power in limbs and trunk hemiplagia, cranial nerve palsies and other neurological deficits etc.

DISCUSSION

The usefulness of endotracheal intubation and mechanical ventilation in paediatric critical care has been emphasized repeatedly[2-13]. The overall percentage of paediatric admissions to ICU requiring MV in our study was 23.5%. The corresponding percentages from the Western literature vary from 28 to 58%[14,15]. The predominant group of patients receiving MV at PICU at Shaikh Zayed, Hospital (SZH) were in the first year of life (68%). In comparison to this the median age for MV has been reported to be 10 months in a prospective cohort study done on 500 mechanically ventilated children, out of a total study population of 869 patients admitted to a paediatric ICU[14]. Males greatly out numbered females with a ratio of 2:1.5 but this ratio was comparable with a male to female ratio of 2:1 for all admissions to PICU at SZH during the study period. Therefore, it is concluded that there was no specific correlation between male sex and need for mechanical ventilation.

As regards the condition on admission a greater percentage of patients (66.8%) in our study population were critically ill on admission. This is probably due to the fact that majority of these patients were referred cases from other hospitals and from other cities of Pakistan. In addition to this fact, in our setup, a large number of parents bring their children to a medical facility very late during illness due, probably, to lack of education, interest or inability to recognize signs of serious illness. People, in Pakistan, which is an underdeveloped country, often have to travel long distances to reach a tertiary care medical centre like Shaikh Zayed Hospital, which incurs a lot of expense and inconvenience on the family. So the decision to come to the hospital is made late, only after all the other avenues have been tried.

The average duration of stay in our PIUC population was 9 days. This is in comparison to ICU stay of 6-20 days from other studies[15-17].

The average duration of endotracheal intubation and MV was 7 days. In comparison to this a study published in Archives of Diseases in childhood, reveals a mean duration of MV of 105 hours (4.3 days)[18]. Other studies quote mean duration of MV as 70.4 hours[19], 42 hours[20], 48 hours[21] and 7.0±2.6 days[16,17,22,23]. Longer duration of stay in ICU is explained on the fact that the

majority of patients admitted to PICU are received with serious illnesses and, therefore, require prolonged admissions.

As regards indications, endotracheal intubation and MV are performed for potentially life-threatening conditions such as upper airway obstruction and respiratory failure[13]. Additionally, a large number of patients are intubated electively during anaesthesia before surgery and the post operative period. The study results reveal that in our setup need for MV was indicated by hypoxia (10%), hypercarbia (46%), frequent apnoea (19%) and/or respiratory arrest (26%). These criteria were present either singly or in combination. These are the traditional criteria for MV mentioned in the text and in various studies[3]. Amongst the indications for MV in our setup maximum patients mechanically ventilated in our study belonged to the CNS group (29.3%) (pyomeningitis, encephalitis, tuberculous meningitis, Guillain Barre' syndrome and seizure disoders, etc), while figures of 26.4% for infectious diseases and 23% for respiratory conditions become prominent (Pneumonia, acute laryngotracheo-bronchitis, pulmonary tuberculosis, status asthmaticus, diphtheria, respiratory distress syndrome, thoracic emphysema, tracheo-oesophageal fistula and aspiration syndrome etc). This is at variance with experience of the West where respiratory conditions are the primary indication for MV[14,24].

Another important fact that emerged from our study was that maximum survival (46.3%) was documented for the Central nervous system which was closely followed by respiratory conditions with survival rate of 43%. The highest mortality was found in the haematology/oncology group followed closely by infectious diseases and cardiovascular disease. The figures reported from an Australian study cited alone confirm the better survival rates associated with respiratory conditions[14]. But in contrast to our results this study reveals a much less mortality associated with cardiovascular conditions. The high mortality associated with cardiovascular conditions in our setup is most likely due to the paucity of paediatric cardiology and cardiac surgery facilities in Pakistan. The high mortality rates associated with infectious diseases group and the fact that infectious diseases emerge out as a prominent indication for MV in our study is understandable as infectious diseases are more common in this part of the world.

Review of literature reveals that the mortality rate for acute respiratory failure (ARF) in children remained high for the past decade despite the use of conventional mechanical ventilation[1,25-36]. Since 1990, mortality rates in the range of 50% to 75%[29], 40% to 75%[33] 42.7%[24], 34-51%[16] and 35-67%[31] have been reported. The reasons for this discouraging observation are unknown but may be worsening disease conditions or limitations of conventional positive pressure ventilation or both. State of the art reviews concerning the mechanisms of ventilator induced lung injury caused by high positive pressure and large tidal volumes have been published[14,37,38]. Because of the known limitations and detrimental effects of conventional ventilation therapy alternative methods of respiratory support, such as high frequency jet ventilation high frequency oscillation, inverse-ratio ventilation, permissive hypercapnia and non-invasive ventilation have been examined[7,17,33,34,39]. To date, however, no variation or modification of positive pressure ventilation has been shown in a randomized controlled study to improve outcome[24].

As regards outcome, our study reveals a high mortality rate of 63%. The important facts which emerge from the results of this study are: a) Mortality of 80.6% was documented when patients condition on admission was "critical". b) The children who were ventilated for "shorter periods" had a relatively higher mortality rates as compared to 100% survival in patients who received ventilation for more than 30 days. c) The "younger" the age at admission the poorer the outcome. So if we take out terminally ill patients, i.e. those who died within the first 12-24 hours of admission to PICU the mortality figures come down by 99 patients to 57.26%. This fact drives our attention to formulate strict criteria for admission to PICU for MV. The question arises whether critically ill patients should be put on MV for terminal care or not ? Mortality rate of 77% for neonates and 63.5% for infants have been documented in our study. This is related to the larger percentage of critically sick children, arriving in late and often terminal stages as well as to the lack of ancillary support and lack of experience with mechanical ventilation.

CONCLUSION

Mechanical ventilation is one of the major supportive modalities used in critical care all over

the world, but this treatment modality is being used in very limited number of sick children in Pakistan and even in few tertiary care medical centres. Despite the limitations of a greater percentage of critically sick children arriving late, the overall survival is 37%. This modality should therefore be encouraged with provision of ancillary support, training of pediatric residents and support of respiratory therapists.

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