PROFILE OF CHILDREN VENTILATED IN PAEDIATRIC INTENSIVE CARE UNIT OF A TERTIARY CARE HOSPITAL

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CERTIFICATE

This is to certify that the dissertation titled, **"Profile of children ventilated in Paediatric Intensive Care Unit of a Tertiary Care Hospital**" submitted by Dr. A.R Mullai Baalaaji, to the Faculty of Paediatrics, The Tamilnadu Dr. M.G.R Medical University, Chennai, in partial fulfillment of the requirements for the award of M.D. Degree (Paediatrics) is a bonafide research work carried out by him under our direct supervision and guidance, during the academic year 2008-2011.

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DECLARATION

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CONTENTS

INTRODUCTION

Ventilatory support is an essential and a common form of therapy in Pediatric Critical Care Unit. In recent years, this modality has evolved into a highly specialized discipline (1). The term mechanical ventilation refers to various artificial means used to support ventilation and oxygenation (2).

Natural spontaneous ventilation occurs when the respiratory muscles (diaphragm, intercostal muscles) create negative intrathoracic pressure, in part by expanding the rib cage, leading to lung expansion, which pulls air into the alveoli and allows gas exchange to occur. In contrast, ventilation is achieved in intubated patients by delivering compressed gas to the lungs by positive pressure ventilation.

During positive pressure ventilation, the flow of gas during inspiration and expiration is driven by the airway pressure gradient between the airway opening and the alveoli. During inspiration, the airway opening pressure is greater than alveolar pressure, thereby driving gas into the lungs and inflating them. Expiration is usually passive and occurs because, at the end of inspiration, alveolar pressure becomes greater than airway pressure (3).

History of ventilators

Hippocrates (460-375 BC) wrote the first description of endotracheal intubation in his book –'Treatise on Air'- "One should introduce a cannula into the trachea along the jaw bone so that air can be drawn into the lungs". Paracelsus (1493-1541) used 'Fire Bellows' connected to a tube inserted into patient's mouth as a device for assisted ventilation. This was the first study (1550) which credited him with the first form of mechanical ventilation. From the mid 1800-1900s, a large number of devices were invented that provided ventilation by applying negative pressure around the body or thoracic cavity – these devices came to be known as negative pressure ventilators or 'iron lungs'.

During the Scandinavian polio epidemic of 1952, many principles of positive pressure ventilation began to be defined - including the use of cuffed tubes, periodic sigh breaths and weaning by reduction of assisted breaths. After polio epidemics, the 1960's became an era of respiratory intensive care. Positive pressure ventilation with the use of an artificial airway replaced the bulky and cumbersome negative pressure ventilators. A mechanical change of substantial importance in the late 1960's and early 1970's that shaped the present era of artificial ventilation was the introduction of Positive End Expiratory Pressure (PEEP). Two modes of ventilation, Assisted Ventilation (AV) and

Controlled Mechanical Ventilation (CMV) came together in a single piece of equipment and the modern era of multiple choice respiratory support was thus born. From the "iron lungs" used in the past, primarily to treat respiratory paralysis in poliomyelitis, modern day ventilators have evolved into micro-processor based sophisticated devices capable of a large number of functions with many alarms to make them as safe as possible for the patient.

Common terminologies used in ventilation

- Peak Inspiratory Pressure (PIP) is the point of maximum airway pressure.
- Positive End Expiratory Pressure (PEEP) is the pressure maintained in airways at the end of expiration.
- Mean Airway Pressure (MAP) is a measure of average pressure to which the lungs are exposed during the respiratory cycle.
- Ventilator frequency is the number of breaths delivered by the ventilator per minute.
- FiO2 denotes the fraction of oxygen in the inspired air.
- The change in lung volume during the inspiratory period is defined as the tidal volume (TV) (4).

There are two primary methods for positive pressure ventilation.

1) Pressure controlled ventilation: This allows a clinician to set the PIP and PEEP. The PIP is maintained throughout the Inspiratory time. Lung volume rises until it reaches its capacity at that PIP or until the ventilator cycles into expiration.

2) Volume controlled ventilation: Here, Tidal volume is preset as a product of setting flow and Inspiratory time. Airway pressure rises throughout inspiration and reaches its peak when the entire tidal volume is delivered.

Indications for mechanical ventilation

1) Respiratory distress and failure

The primary indication for institution of assisted ventilation is respiratory failure. Respiratory distress or failure is the primary diagnosis in 50% of children admitted to the pediatric intensive care unit and is a common cause of cardiopulmonary arrest in children (4).The unique anatomic and physiologic characteristics of the respiratory tract in children and infants make them vulnerable to respiratory failure.

Respiratory failure is defined as the inability of the respiratory system to fulfill the gas exchange needs of the patient – oxygenation, ventilation or both. Inadequate oxygenation is subjectively defined as

PaO2 of less than equal to 60 mm Hg in room air. Inadequate ventilation is defined as PaCO2 more than 45 mm Hg in the absence of chronic hypercapnia. Impending respiratory failure characterised by progressive respiratory distress, rapidly rising PaCO2, or fatigue of respiratory muscles is a relative indication for mechanical ventilation.

Rapid assessment of airway, breathing, circulation and disability is important in a child with suspected respiratory failure (5), and age specific vital signs (Table – 1) help us to identify critical illness in such children.It is important to understand that the decision to intubate, is based on clinical signs of respiratory failure such as altered sensorium, increased work of breathing, bradypnea or apnea, and not on blood gases.

TABLE – 1 : AGE SPECIFIC VITAL SIGNS(6)

Age	Respiratory rate per minute	Heart rate per minute	Blood pressure mm Hg
0- 3 months	35 - 55	100 - 150	65 - 85/45 - 55
3- 6 months	30 – 45	90 – 120	70 – 90/50-65
6-12 months	25 – 40	80 – 120	80 – 100/55-65
1-3 years	20 – 30	70 – 110	90 – 105/55-70
3-6 years	20 – 25	65 – 110	95 –110/60-75
6-12 years	14 – 22	60 – 95	100 – 120/60-75
12 years	12 – 18	55 – 85	110 – 135/65-85

The causes of ventilatory pump failure are decreased respiratory centre output due to CNS disorders, phrenic nerve injury, decreased muscle strength or endurance, increased work of breathing, increased ventilatory requirements and increased carbon dioxide production.The common clinical indications include pneumonia, bronchiolitis, lung hemorrhage, laryngotracheobronchitis.

2) Cardiovascular dysfunction

Shock is an acute, dramatic syndrome, characterised by inadequate circulatory provision of oxygen, so that the metabolic demands of vital organs and tissues are not met (7). An initial insult triggers shock, thus disrupting blood flow to end-organs, leading to inadequate tissue perfusion. The body's compensatory mechanisms are initiated to maintain perfusion to vital organs, leading to compensated shock. If left untreated, hypotensive shock develops, causing tissue damage that leads to multisystem organ dysfunction and death(8). Early recognition and stepwise execution of therapeutic interventions are essential as each additional hour of persistent shock increases the risk of mortality by 2 folds (9).

Positive pressure ventilation reduces the work of breathing, decreases lactic acid production by respiratory muscles during circulatory shock, and also decreases the oxygen demand of the heart

(10), and thus is utilised in the management of children with shock along with other supportive measures.

3) Neurological and neuromuscular disorders

Acute neurologic deterioration with numerous causes may require ventilation for many reasons. They may result in decreased ventilatory drive, loss of airway protective reflexes, decreased ventilatory effort as a result of muscle weakness (11). Mechanical ventilation may also be provided in disorders with raised intracranial pressure to optimally ventilate the child (12). The common causes include CNS infections, tumours, head trauma, Guillain-Barre syndrome, snake envenomation and poisoning.

Rapid Sequence Intubation

Airway management is the most important priority in the care of critically ill children, and tracheal intubation is frequently the primary life saving intervention. Although it is possible to intubate infants who are awake without sedation, analgesia, or paralysis, analgesia is recommended to reduce metabolic stress, discomfort and anxiety. Rapid sequence intubation (RSI) is the standard of care in emergency airway management for intubations not anticipated to be difficult. RSI can be defined as ‘the virtually simultaneous administration of a sedative (induction) agent and a neuromuscular blockade agent for the purpose of intubation'(13). This renders the patient rapidly unconscious and flaccid in order to facilitate emergent endotracheal intubation and to minimize the risk of aspiration (14).

Ventilation can be either invasive or non invasive.

Non Invasive Ventilation (NIV)

Non invasive ventilation refers to providing ventilation through upper airway using mask or similar devices which are known as interfaces. NIV is based on the cyclical application of a positive pressure (or volume) to the airways (15). Non invasive ventilation uses the intact upper airway, preserves the airway defence mechanisms and allows the patient to eat, drink and speak. However, they can be used only in older and co-operative children (16).

Invasive ventilation

In conventional ventilation, ventilation is provided through either endotracheal tube or tracheostomy or laryngeal mask airway bypassing the upper airway.

Commonly used modes of ventilation

1. *Controlled Mechanical Ventilation (CMV):* In this mode, the ventilator controls all the ventilation while the patient has minimal or no respiratory effort.

2. *Assist Control Ventilation (ACV):* In this mode, the patient initiates the breathing. However, if he/she fails to initiate the breathing within a prescribed time, the ventilator triggers the breathing and provides a controlled breath as in CMV, thus ensuring a guaranteed minute ventilation.

3. *Intermittent Mandatory Ventilation (IMV):* It is essentially a combination of spontaneous breathing and CMV. A modified circuit provides a continuous flow of gas that allows the patient to breathe spontaneously with minimal work of breathing. At a predetermined frequency, the ventilator provides a positive pressure breath to the patient (17).

4. *Synchronized Intermittent Mandatory Ventilation (SIMV*): When IMV is synchronised to the patient's inspiratory efforts, it is referred to as SIMV breath (18).

5. *Pressure Support Ventilation (PSV):*In this mode, the patient triggers the breath as in assisted ventilation. Therefore, this mode is applicable only to spontaneously breathing patients. Once initiated, the ventilator delivers air and gas mixture at a preset positive pressure in the ventilatory circuit. Patients determine their own inspiratory time and tidal volume. It is mainly used as a weaning mode and may be tolerated better than SIMV by some patients (19).

6. *Pressure Control Ventilation (PCV):* This is a time-initiated, pressure-limited and time-cycled mode intended for patients requiring total mechanical ventilatory support. Most ventilators also allow patient triggering of these breaths, producing pressure assisted breaths (pressure assist control ventilation).

7. *Airway Pressure Release Ventilation (APRV):* This is a pressure-limited, time-cycled ventilation, in which the preset pressure limit is equal to the level of CPAP required and the PEEP is usually ambient pressure, or a selected lower airway pressure (20).

8. *Pressure Regulated Volume Control(PRVC):* This is a control mode, which delivers a set tidal volume with each breath at the lowest possible peak pressure (21).

9. *Continuous Positive Airway Pressure(CPAP):* CPAP is best described as PEEP during spontaneous respiration. Infants with severe respiratory disease develop grunting which is a compensatory mechanism to elevate physiologic PEEP, preventing alveolar collapse. In spontaneously breathing patients, CPAP can be administered through a valve or water column in the expiratory circuit. Most ventilators are, however, equipped with a CPAP mode, which can be administered through tight fitting mask, nasopharyngeal catheter, nasal prongs or through endotracheal tube.

10. *High frequency ventilation(HFV):* They are characterised by supraphysiologic ventilatory frequencies (>60 cycles/min) and low tidal volumes. Four distinct methods are high frequency positive pressure ventilation, high frequency oscillatory ventilation, high frequency jet ventilation, high frequency chest wall oscillation (22).

Initiation and Maintenance of ventilation

Before starting ventilation, it is standard practice to ensure that the ventilator be clean and patient circuit be sterilized. The patients' baseline data is recorded. During spontaneous breathing, inspired air is warmed and almost completely humidified as it passes through the upper airways (23). Since the upper airways are bypassed, the inspired gas should be humidified to achieve a relative humidity of close to 100% (24).

Adequacy of ventilation is assessed by the degree of excursion of chest wall, the presence of breath sounds bilaterally and the improvement in the general condition of the child. Ventilation should be started in the control mode with 100% oxygen to correct hypoxia and bring blood gas values towards normal (25). Ventilator parameters *viz*., rate, volume and/or pressures, FiO_2 and appropriate alarms are set to desired level. The initial settings primarily depend on the nature of the lung disease.

TABLE – 2 : INITIAL VENTILATOR PARAMETERS (4)

Parameters	Normal lung	Restrictive diseases	Obstructive diseases
Tidal volume	8 – 12 ml/kg.	10- 12 ml/kg	10- 12 ml/kg
Rate (breaths/min)	Infants - 30 Toddlers – 20 Adolescents - 16	Higher rates	Lower rates
PIP	20-25 cm H_20	Higher	Higher
PEEP	2-4 cm H_20	Higher	Lower

Monitoring of a patient on ventilator

While the child is on mechanical ventilation, the patients have to be meticulously monitored.Monitoring may be non invasive such as repeated cardiopulmonary assessment, pulse oximetry, x rays, ECG, capnography, non invasive blood pressure monitoring, or invasive such as blood gases, central venous pressures, arterial blood pressure. However excellent may be the information provided by respiratory monitors, it cannot replace careful bedside clinical examination. In addition, fluid balance, intake and output, weight of children should be monitored daily. Close monitoring allows titration of therapies to optimise patient ventilator interactions and aid in weaning from the ventilator (26).

A record of FiO2, tidal volume, peak inspiratory pressure, mean airway pressure and any alterations made in the ventilator settings have to be documented.

Sedation, Analgesia and Muscle relaxants

Sedatives and muscle relaxants are often needed to enable effective ventilation (25). These medications can be used on an intermittent dosing schedule or as a continuous infusion . In most patients, sedation alone is sufficient. Muscle relaxants are needed in patients requiring maximal ventilatory support and higher oxygen concentrations. It is important to understand that agitation and 'fighting with ventilator' frequently results from tube related complications or hypoxemia and correcting them often obviates the need for further sedation requirement.

Tracheostomy

In chronically ventilated patients (more than 2-4 weeks), it is better to maintain the airway through a tracheostomy tube, since it is more comfortable, protects the airways and larynx, allows oral feeding and is less likely to be obstructed or inadvertently dislodged. Frequent suctioning, continuous humidification and meticulous wound toilet are necessary for care of the tracheostomy**.**

Weaning from mechanical ventilation

Weaning is defined as liberation from mechanical ventilation while spontaneous breathing is allowed to assume the responsibility for effective gas exchange (27). During weaning, the emphasis is on ways of enhancing the return of full diaphragmatic function and discontinuation of mechanical ventilation (28).

Criteria to be met before initiating weaning

1. Underlying disease process is improving.
2. Alert mental status – GCS > 11
3. Good cough and gag reflexes.
4. Spontaneous respiratory effort.
5. Core temperature < 38.5 ^{0} C.
6. No clinical need for increased ventilatory support in the past 24 hours.
7. Hemodynamic stability

    CRT < 3 sec.

    Heart rate normal.

    Systolic blood pressure normal.

    No need for further vasoactive agents.

8. No acidosis.

   pH 7.32 – 7.47

   $PaCO_2 < 50$ mm Hg.

9. Parameters of oxygenation.

   $PaO_2 > 60$ mmHg with FiO_2 of 0.50

   PIP < 20 cm water

   PEEP ≤ 7 cm water

The most commonly used weaning trials are T-piece, CPAP and pressure support trials (29).

Children who have been ventilated for a period of less than 2-3 days and who were in good health prior to respiratory failure may usually be weaned from ventilator and allowed to breathe spontaneously. However, those patients who have been ventilated for a longer period need to be weaned gradually by allowing increasing periods of time for spontaneous ventilation over a period of several days. Throughout weaning, vitals must be closely monitored and blood gases must be checked at the end of each weaning period off the ventilator (30).

Complications of ventilation

As a complex and invasive technology, mechanical ventilation is fraught with numerous adverse outcomes, both iatrogenic and unavoidable (31). Mechanical ventilation can no longer be viewed simply as a harmless support modality that is employed to keep patients alive while disease-specific treatments are used to ameliorate the underlying pathology (32). Mechanical ventilation can be lifesaving, but more than 50% of complications in conditions that require intensive care are related to ventilatory support, particularly if it is prolonged (33). These need to be anticipated and managed promptly:

1. *Airway Complications:* Accidental tracheal extubation or obstruction of the tracheal airway by mucus or blood are potentially life threatening complications.They can be prevented by proper airway care, adequate humidification of the inspired gas, physiotherapy of the chest and frequent suction. Prolonged intubation may lead to vocal cord damage, post-extubation subglottic stenosis, tracheal granuloma and fibrotic bands.

2. *Pulmonary Complications:* Most of the adverse physiological responses to positive pressure ventilation result from inappropriately high mean airway pressure (34). Sudden hypoxemia or deterioration in the circulatory status in a patient on mechanical ventilation warrants immediate examination to exclude tension pneumothorax. The danger of pneumothorax is increased and interstitial emphysema may occur when peak inspiratory pressure exceeds 40 cm water or when the end

expiratory pressure exceeds 15 cm water. Barotrauma can be minimized by maintaining low inspiratory pressures and tidal volume with minimum peak end expiratory pressure compatible with adequate ventilation.

3. *Ventilator Induced Lung Injury:* Ventilation is associated with the development of pulmonary tissue injury due to epithelial and endothelial damage, lung capillary permeability alterations (35).

4. *Oxygen toxicity:* Prolonged exposure to high concentration of oxygen can damage the alveolar capillary membrane and produce congested edematous lungs with intra alveolar hemorrhage and exudates (36). Oxygen toxicity is suggested by increasing alveolar-arterial oxygen difference in the absence of pulmonary fluid accumulation. Use of the lowest concentration of inspired oxygen to prevent hypoxemia is the best method to avoid pulmonary oxygen toxicity. General consensus indicates that $FiO_2 < 0.5$ can usually be tolerated satisfactorily.

5. *Ventilator Associated Pneumonia:* Ventilator-associated pneumonia is defined as nosocomial pneumonia in mechanically ventilated patients that was not present at the time of intubation, and occurs 48 hours after intubation. It is the second most common cause of nosocomial infections, next only to blood stream infections (37) and is a major risk factor for mortality in

ICU settings. Nosocomial pneumonia is caused by a wide spectrum of bacterial pathogens. They may also be polymicrobial and are rarely due to viral and fungal pathogens in immunocompetent host (38).

6. *Other Complications:* PEEP increases the intrathoracic pressure and reduces systemic venous return and cardiac output. These effects may cause serious consequences in patients with pre existing hypovolemia. They are overcome usually by fluid boluses to increase blood volume with or without inotropic agents. In this respect, a patient treated with mechanical ventilation must be followed by the pediatric intensive team and in a PICU (39).

In conclusion, judicious use of ventilation when indicated, is essential along with very close monitoring of these critically ill children for a successful outcome.

REVIEW OF LITERATURE

A Prospective cohort study of all consecutive patients admitted to a high-complexity PICU who were placed on mechanical ventilation for 24 hours or more, between October 1st, 2005 and March 31st, 2006 was done by da Silva et al in Brazil (40).A total of 35.7% received mechanical ventilation for 24 hours or more. Participants had a median age of 32 months. A large majority of the sample was male (61.23%). The major indication for mechanical ventilation was acute respiratory failure (59.18%), followed by acute decompensation of chronic pulmonary disease (22.45%) and a lowered level of consciousness (16.33%). Among patients with acute respiratory failure, 62% had severe sepsis / septic shock . Pressure ventilation modes were standard. Rapid sequence intubation was routinely performed with pre-oxygenation, administration of a sedative agent, an analgesic, and a paralyzing agent. The airway was achieved by orotracheal intubation, in most cases. There was no nasotracheal intubation. A total of 5 patients were previously tracheostomized, while another 3 were tracheostomized after 3 weeks of mechanical ventilation.

A retrospective study was conducted by Kendirli et al in Turkey, in which the records of patients who had mechanical ventilation in the PICU during a follow-up period between January 2002-May 2005 were looked up (41). Ninety-one patients (22.3%) were treated with mechanical ventilation. Ages of all patients were between 1-180 (median-8) months. The mechanical ventilation time was 18.8±14.1 days. Indications for mechanical ventilation were as follows: respiratory failure (64.8%), cardiovascular failure (19.7%), central nervous system disease (9.8%) and safety airway (5.4%). Tracheostomy was performed in four patients. The complication ratio of mechanically ventilated children was 42.8%, and diversity of complications were as follows: 26.3% atelectasis, 17.5% ventilator-associated pneumonia, 13.1% pneumothorax, 5.4% bleeding, 4.3% tracheal edema, and 2.1% chronic lung disease. The mortality rate of mechanically ventilated patients was 58.3%, but the overall mortality rate in the PICU was 12.2% .

A retrospective study was conducted at the PICU of a tertiary care teaching hospital at New Delhi by Indrajit Majumdar et al (42). A total of 100 male and 41 female children were included in the study. Age of the children ranged from 3 days to 18 years with a median age of 10 months. Diseases of the Central nervous system (40.4%) and respiratory system (36.8%) accounted for the majority of cases. Gastrointestinal (4.3%) or cardiovascular system (4.9%) was the primary diagnosis in much fewer cases. None of the patients had required manual bag and mask ventilation for more than 30 minutes prior to ventilation. Adequate premedication with midazolam and vecuronium was used for all patients prior to intubation. All the patients were ventilated with volume controlled or pressure regulated volume controlled ventilation. Overall mortality in the ventilated children was 24% .

A prospective study was conducted by Benjamin PK et al at Children's Hospital, Boston where 204 consecutive patients admitted to the multidisciplinary intensive care unit of the hospital were prospectively studied for complications of mechanical ventilation (43). Patients ranged in age from newborn to 24 years. Sixty-three percent were male. Average length of ventilation was 5.2 days. Overall survival rate was 91.7%. Endotracheal complications were: pre-necrosis (13 %), endotracheal tube retaping complications (6%), tube plugging (1%), and self-extubation (3%). Ventilator complications were: alarm failures (6.5%), ventilator failures (0.7%), and circuit problems (7%). Medical complications were: massive gastric distension (8.8%), right upper lobe collapse (4.4%), pneumothorax (4.4%), subcutaneous air (1.5%), and pneumoperitoneum (1%).

Secondary analysis was done from existing data set of all children intubated and mechanically ventilated from 16 PICUs in the United States by Robinder.G.Kemani et al (44). Thirty percent of children in a cross-section of the PICUs were endotracheally intubated. Of the children who received ventilation, 22% had cyanotic congenital heart disease; 26% had respiratory failure but not bilateral pulmonary infiltrates on chest radiograph; 8% had chronic respiratory disease; 7% had upper airway obstruction; and 5% had reactive airway disease .

STUDY JUSTIFICATION

Around 800 children are treated in the pediatric intensive care unit of the hospital every year, hence it is an ideal place to study the various characteristics of children who are ventilated.

There are not many publications in India in this subject. Scarcity of Indian literature in this topic stresses the importance of analysing this data.

The choices of type of ventilation, mode, ventilatory settings depends upon the individual condition and the experience of the unit. So, we wanted to study the various aspects of ventilated children such as demographic data, clinical indication for initiation of ventilation, duration of ventilation required, methods of weaning that were employed, complications that ensued and outcome of the children.

Analysing these data will be helpful to formulate better guidelines to improve the survival of the patients.

AIM OF THE STUDY

- To study the etiological and clinical profile of children ventilated in PICU and various complications and outcome of these children.

METHODOLOGY

Study design

Descriptive study

Study place

Pediatric intensive care unit , Institute of child health and hospital for children, Egmore, Chennai.

Study period

October 2008 to August 2009.

Study population

Children from 1 month to 12 years.

Inclusion criteria

Children more than 30 days and less than 12 years who are ventilated in Pediatric Intensive Care Unit either manually or mechanically.

Exclusion criteria

- Children ventilated for less than 12 hours .
- Children who were ventilated outside the hospital and referred for further care.

Manoeuver

Patients in the age group of one month to 12 years admitted in PICU during the study period, who fulfill the inclusion criteria were included in the study.

Cardiopulmonary assessment was done and entry made in the data sheet. All sick children were initially evaluated in the Pediatric Emergency Department of the hospital and initial stabilization of the patient including intubation when needed, fluid resuscitation, inotrope initiation were carried out accordingly. According to availability of bed in the PICU, the children were admitted there. When there was no bed available in PICU, the child would be shifted to the concerned medical units, and managed there, and later shifted to PICU as and when vacancy arose.

The choice of mechanical ventilation was based on availability of ventilators. If there were no available ventilators, the children were on manual ventilation by the caregivers of the child for variable time, until ventilator became available. Once the ventilators were available, the children were managed on mechanical ventilator. The children were monitored clinically, with periodic cardiopulmonary assessment, Oxygen saturation and with arterial blood gases whenever indicated and feasible.

The eligible children were registered for the study and the following particulars collected :

- Patient details.
- Cardiopulmonary status prior to intubation (heart rate, respiratory rate, blood pressure, oxygen saturation).
- Intubation details:

  Whether the child was intubated in Emergency department or in pediatric ward or in PICU.

  Size of ET tube used – appropriate size or lower.

  RSI protocol used or not.
- Need for inotropes
- Ventilation details:

  Invasive or non invasive ventilation

  Manual or mechanical ventilation

  Duration of ventilation

  Need for re intubation and the reason

  Weaning methods

- Complications:

  Nosocomial Pneumonia

  Pneumothorax

  Post extubation stridor

  Collapse/atelectasis

  Pressure sores

- Outcome:

  Discharge

  Death

  Against medical advice

Case Definitions used

Septic shock

The clinical diagnosis of septic shock was made in children with suspected infection with hypothermia or hyperthermia, and clinical signs of decreased perfusion including decreased mental status, prolonged capillary refill time of >2 seconds (cold shock) or flash capillary refill (warm shock), diminished (cold shock) or bounding (warm shock) peripheral pulses, mottled cool extremities (cold shock), or decreased urine output of <1ml/kg/hr (45).

Status epilepticus

Status epilepticus was defined as recurrent or continuous seizure activity lasting longer than 5 minutes in which the patient does not regain baseline mental status .

Acute encephalopathy

Alteration in neurological status for which no cause could be identified despite available investigations, or due to early death, such as when the child had expired prior to coming to the exact diagnosis.

Viral hemorrhagic fever

Compatible clinical history with signs of capillary leak such as hemoconcentration, serous effusions, hypoalbuminemia, bleeding tendencies.

Nosocomial pneumonia in ventilated children

Nosocomial pneumonia in ventilated patients that was not present at the time of intubation, and occurs after 48 hours.

Extubation

Extubation was defined as the removal of an endotracheal tube.

Extubation failure

Requirement for reintubation within 48 hours after extubation.

STATISTICAL ANALYSIS

Statistical analysis was done using SPSS version 11.0 for windows. Categorical data were expressed as absolute counts and percentages. Continuous data were expressed as mean and standard deviation.

For the variables in qualitative form, chi square test was used in the univariate analysis to observe the association between the study variables and the outcome. Data were considered significant at p value of <0.05.

OBSERVATIONS

Total number of PICU admissions during the study period was 615.

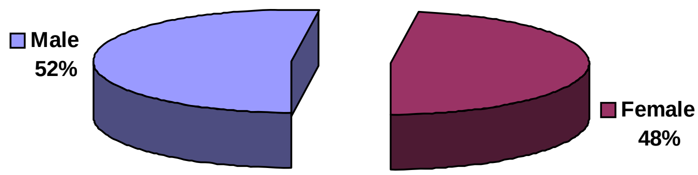
A total of 30.9% of the PICU admissions (190 cases) satisfied the inclusion criteria and were included in the study.

TABLE – 3 : AGE DISTRIBUTION OF CHILDREN

Age in months	No. of cases	Percentage
1 to 12	88	46.3%
13 to 60	64	33.7%
More than 60	38	20.0%
Total	190	100.0%

Infants contributed to 46.3% of the children who were treated with artificial ventilation in PICU during the study period.

CHART – 1 : SEX DISTRIBUTION OF CHILDREN



A total of 99 males and 91 females were included in the study. The ratio of males to females in the study was 1.09:1.0.

CHART – 2 : AGE AND SEX DISTRIBUTION

The following bar diagram gives the age and sex distribution of the study cohort.

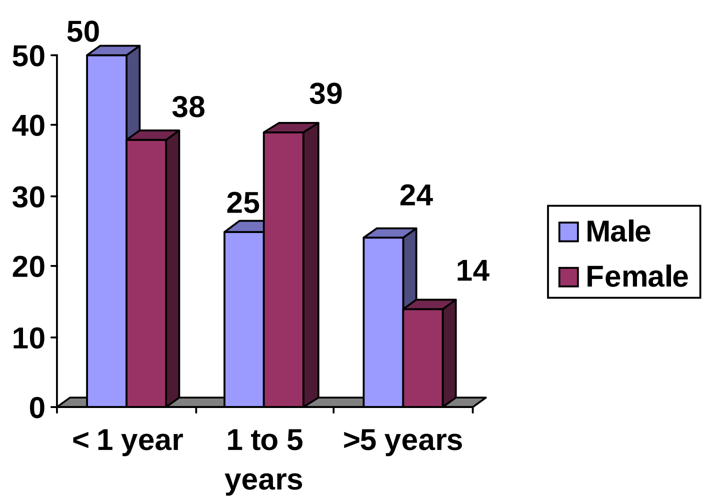
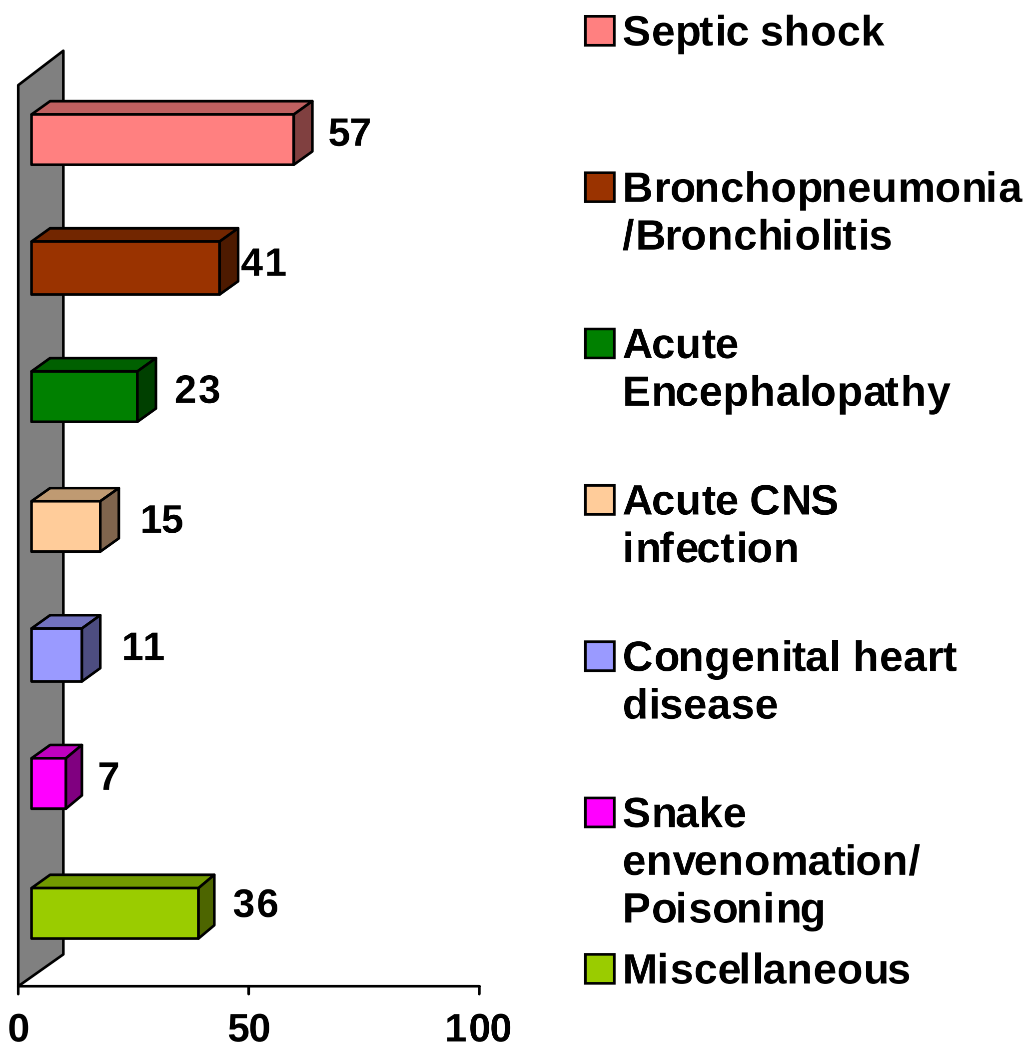


CHART – 3 : CLINICAL DIAGNOSIS

The bar diagram shows the various etiologies for which children were Ventilated in the PICU.



Miscellaneous category included Guillain-Barre syndrome, submersion injury, status epilepticus, Diabetic keto-acidosis, Intracranial bleed among others.

TABLE – 4 : TYPES OF VENTILATION

Artificial ventilation can be either invasive delivered through endotracheal tube or non-invasive delivered through a tight fitting face mask.

Type	No.of cases	Percentage
Invasive	188	98.9%
Non-invasive	2	1.1%
Total	190	100%

It is evident that invasive ventilation (98.9%) far exceeded the use of non–invasive ventilation (1.1%) in our PICU.

TAABLE – 5 : INTUBATION DETAILS

Place of intubation	No.of cases	Percentage
Emergency Department	144	76.6%
Pediatric ward	21	11.2%
Pediatric Intensive Care Unit	23	12.2%
Total	188	100%

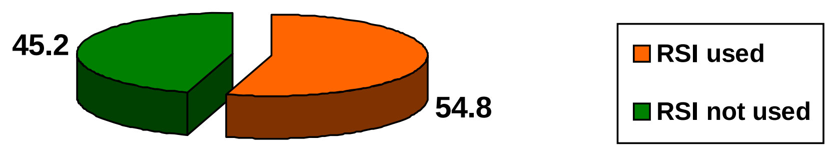
Majority of the children (76.6%) who were ventilated in the PICU required intubation on arrival at the Emergency Department itself.

TABLE – 6 : INDICATIONS FOR INTUBATION

Indications	No.of cases	Percentage
Circulatory (1)	71	37.8%
Respiratory (2)	38	20.2%
Neurological (3)	65	34.6%
(1) + (2)	7	03.6%
(1) + (3)	5	02.7%
(2) + (3)	2	01.1%
Total	188	100%

The commonest clinical indication for intubation was circulatory dysfunction which included septic shock, congenital heart disease with cardiogenic shock and others (37.8%). Neurological causes were next common and included status epilepticus, neuromuscular diseases and raised intracranial pressure (34.6%). Respiratory causes including bronchopneumonia and bronchiolitis were the third common cause requiring artificial ventilation (20.2%).

CHART – 4 : DRUGS USED FOR INTUBATION



Rapid Sequence Intubation (RSI) was done in 103 children (54.8%), whenever intensivist was available. All the other chidren were intubated using a combination of sedative and/or analgesic.

TABLE – 7 : TUBE SIZE USED FOR INTUBATION

Endotracheal tube size that had to be used was derived from the formula: ET Size = 4 + Age in years / 4 for uncuffed tubes and Age in years + 4 / 3 for cuffed tubes (46). Whenever difficult airway was anticipated in view of stridor, the children were intubated with a smaller size endotracheal tube.

Tube size used	No.of cases	Percentage
Appropriate	185	98.4%
Small	3	1.6%
Total	188	100%

Majority of children (98.4%) were intubated using endotracheal tubes that were appropriate for the age. Two children with airway obstruction required smaller size tubes.

TABLE – 8 : ROUTE OF INTUBATION

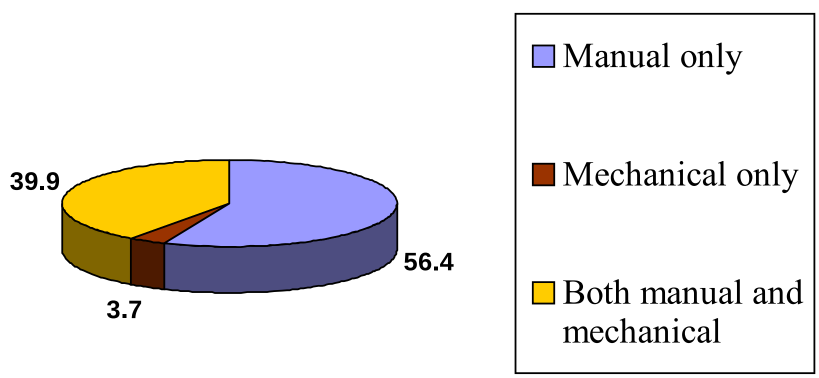
Endotracheal intubation can be performed through oral or nasal route.

Route used	No.of cases	Percentage
Orotracheal	184	97.9%
Nasotracheal	4	2.1%
Total	188	100%

Majority of the children (97.9%) were intubated orally.

CHART – 5 : TYPES OF INVASIVE VENTILATION USED

A total of nine ventilators were available in the PICU at ICH&HC during the study period. The children were subjected to either manual or mechanical ventilation based on the availability of ventilators at the time of admission to PICU.



Manual ventilation in isolation was employed in 106 children (56.4%), 7 children (3.7%) were exclusively mechanically ventilated and 75 children (39.9%) were ventilated using a combination of manual and mechanical ventilation.A total of 96% of children did not get an access to a ventilator at the time of admission to the PICU.

TABLE – 9 : DURATION OF VENTILATION IN MANUALLY VENTILATED CHILDREN

The following table gives the duration of manual ventilation employed.

Duration of ventilation	No.of cases	Percentage
Less than 48 hours	71	66.9%
48 hours to less than 7 days	34	32.2%
7 days and more	1	0.9%

It was observed that, among the children who were ventilated manually, 71 children (66.9%) were ventilated for a period less than 48 hours. **The mean duration of manual ventilation was 1.55 days ± 1.64 days.**

TABLE – 10 : DURATION OF VENTILATION IN MECHANICALLY VENTILATED CHILDREN

The following table gives the duration of mechanical ventilation.

Duration of ventilation	No.of cases	Percentage
Less than 48 hours	1	14.3%
48 hours to less than 7 days	4	57.1%
7 days and more	2	28.6%

It was observed that, among the children who were ventilated mechanically, 6 children(85.7%) were ventilated for 48 hours or more. **The mean duration of ventilation was 5.3 days ± 5.5 days, and ranged from 1 day to 16 days.**

TABLE – 11 : DURATION OF VENTILATION IN COMBINED MANUAL AND MECHANICAL VENTILATION

The children who were ventilated manually were put on mechanical ventilation as and when the ventilator became available. The following table describes the duration of ventilation in these children.

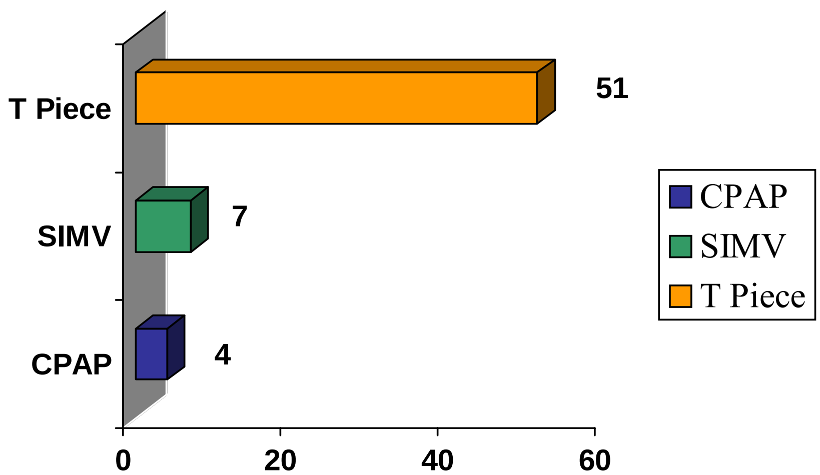
Duration of ventilation	No.of cases	Percentage
Less than 48 hours	14	18.7%
48 hours to less than 7 days	36	48.0%
7 days and more	25	33.3%

Sixty one children (81.3%) were ventilated for a period of 48 hours or more.

The mean duration of manual ventilation prior to being mechanically ventilated was 1.3 days ±1.2 days and the **duration of mechanical ventilation ranged from 12 hours to 42 days with a mean duration of 4.5 days ± 6 days.**

CHART – 6 : WEANING METHODS USED

The various methods used for weaning the patient from ventilation were as follows:



T piece was the major method of weaning (57.3%) followed by SIMV (7.9%) and CPAP (4.5%). It is to be noted, however that, 27 children (30.3 %) extubated spontaneously.

TABLE – 12 : CHANGE OF ENDOTRACHEAL TUBE

Routine change of endotracheal tube is not practised in the PICU. However, 32 children needed reintubation for various reasons, the commonest cause being tube displacement followed by extubation failure.

Endotracheal tube	**No.of cases**	**Percentage**
Changed	32	17%
Not changed	156	83%
Total	188	100%

TABLE – 13 : REASON FOR RE- INTUBATION

Reson for reintubation	**No.of caes**	**Percentage**
Displacement	15	46.8%
Obstruction	6	18.8%
Extubation failure	11	34.4%

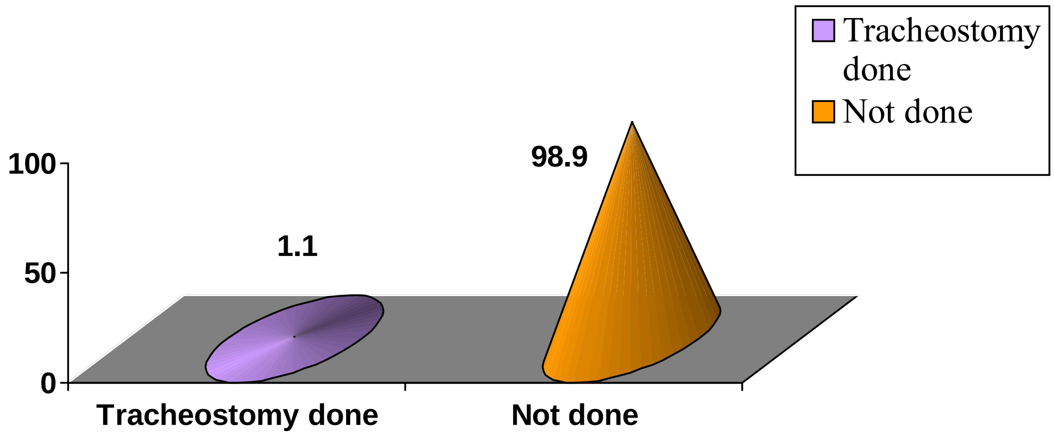
TABLE – 14 : COMPLICATIONS

Artificial ventilation though life saving, has its own complications.

The commonest complication in the ventilated children was Nosocomial pneumonia in 16% (n=13) followed by air leak in 8.9% (n=17) children. The various complications encountered in the ventilated children in PICU were as follows**:**

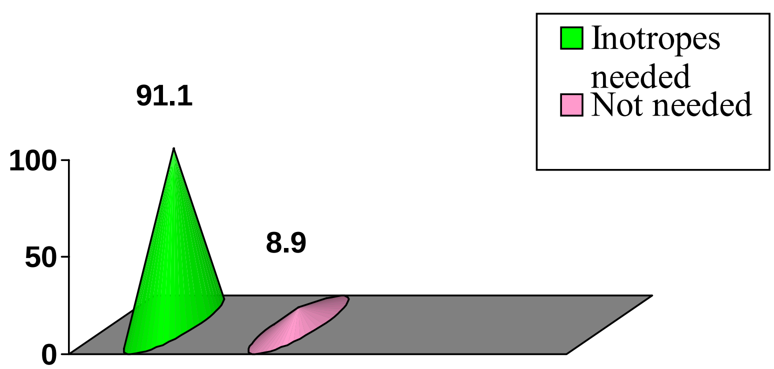
Complication	No.of cases	Percentage
Nosocomial pneumonia	13	16.0%
Air leak	17	8.9%
Pressure sores	11	5.8%
Post extubation stridor	02	1.1%
Collapse	02	1.1%
Obstructive emphysema	06	3.2%
Equipment failure	04	4.7%

CHART – 7 : NEED FOR TRACHEOSTOMY



Only 2 children (1.1%) out of the 190 children underwent tracheostomy, which was performed in these children for the need for prolonged ventilation.

CHART – 8 : NEED FOR INOTROPES



A total of 173 children (91.1%) needed inotropes support.Inotropes were started either in the Pediatric Emergency Department or in the corresponding pediatric ward or the PICU for stabilising the child. The inotropes used were Dopamine, Dobutamine, Epinephrine and Norepinephrine.

TABLE – 15 : CHILDREN WITH RAISED INTRACRANIAL PRESSURE

Raised Intracranial Pressure	No.of cases	Percentage
Present	33	17.4%
Absent	157	82.6%
Total	190	100%

A total of 33 children (17.4%) had features of raised intracranial pressure, out of 190 children.

TABLE – 16 : OUTCOME OF VENTILATED CHILDREN

Out of the 190 children, a total of 91 children (48.4%) were discharged and 97 died.(51.6%)

Outcome	No.of cases	Percentage
Discharge	91	48.4%
Death	97	51.6%
Total	188	100%

TABLE – 17 : TYPES OF VENTILATION AND OUTCOME

Ventilation	Discharge	Death	Total
Manual < 48 hours	35 (49.3%)	36 (50.7%)	71
Manual 48 hours or more	10 (28.6%)	25 (71.4%)	35
Mechanical < 48 hours	0 (0%)	1 (100%)	1
Mechanical 48 hours or more	6 (100%)	0 (0%)	6
Both < 48 hours	3 (21.4%)	11 (78.6%)	14
Both 48 hours or more	35 (59.3%)	24 (40.7%)	59
Non-invasive	2 (100%)	0 (0%)	2
Total	91	97	188

Among the children who were ventilated for more than 48 hours, there was increased mortality in the manual ventilation group which was statistically significant with p = 0.01.The outcome of 2 children could not be assessed as they were discharged against medical advice.

TABLE – 18 : AIRLEAK AND OUTCOME

A total of 16 children (94.1%) out of 17 who developed air leak died.

Outcome	Air leak n %	No Air leak n %	Total
Discharge	1 (5.9%)	88 (52.1%)	89
Death	16 (94.1%)	81 (47.9%)	97
Total	17	169	186

Airleak was significantly associated with mortality with p = 0.000.

TABLE – 19 : ICP AND OUTCOME

Outcome	ICP n %	No ICP n %	Total
Discharge	9 (28.2%)	82 (52.6%)	91
Death	23 (71.8%)	74 (47.4%)	97
Total	32	156	188

Among the children who were ventilated, 32 had features of raised intracranial pressure out of which 23 (71.8%) died, which was statistically significant with p = 0.01.

TABLE – 20 : NOSOCOMIAL PNEUMONIA IN VENTILATED CHILDREN AND REINTUBATION

Re-intubation was a significant risk factor for nosocomial pneumonia in ventilated children with a p value of 0.000.

Nosocomial pneumonia	Re Intubated	No Reintubation	Total
Present	9	4	13
Absent	23	152	175
Total	32	156	188

TABLE – 21 : AIR LEAK AND TYPE OF VENTILATION

Air Leak	Manual	Mechanical	Combined	Total
Present	10	1	6	17
Absent	95	7	69	181
Total	105	8	75	188

There was no significant association between occurrence of airleak and the type of ventilation with p = 0.838.

DISCUSSION

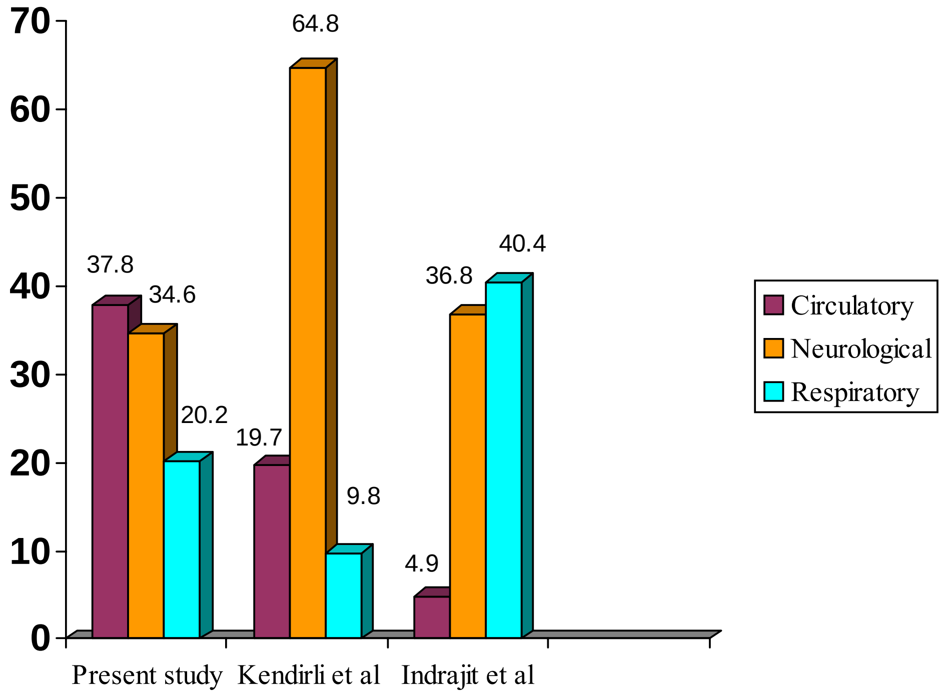
This descriptive observational study was conducted to study the demographic, clinical profile of children who were ventilated at the PICU, and their complications and outcome.

TABLE-22 : COMPARISON OF AGE AND SEX DISTRIBUTION WITH OTHER STUDIES

Study	Study design	Sample size	Median age in months	Age range	Male:Female
Present study	Prospective	190	33	35 days to 12 years	1.09:1.0
Da Silva et al (39)	Prospective	49	32	—	1.6:1.0
Kendirli et al (40)	Retrospective	91	08	1 to 180 months	1.02:1.0
Indrajit et al (41)	Retrospective	141	10	3 days to 18 years	2.44:1.0

The median age in the present study (33 months) was comparable to the study by Da Silva et al in Brazil (32 months). The sex ratio in present study was 1.09:1.0 which was similar to the study by Kendirli et al in Turkey 1.02:1.0.

CHART - 9: COMPARISON OF INDICATION FOR VENTILATION WITH OTHER STUDIES



The commonest indication for intubation and artificial ventilation was circulatory dysfunction including shock, unlike other studies,where neurological indications predominated in the study by Kendirli et al and respiratory causes were the commonest causes for artificial ventilation in the study by Indrajit et al. Intubation was performed orotracheally in 97.9% of children and nasotracheally in 2.1% in present study compared to no nasotracheal intubation performed in the study by Da Silva et al. Rapid Sequence intubation(RSI) was performed in 54.8% of the study population compared to routine RSI protocol used in the study by Da Silva et al.

Though mechanical ventilation is the standard of care, our hospital being a Government hospital and a tertiary referral centre, many critically ill children with need for ventilation are being referred to here, which could not be met by the available resources in PICU and hence, many children needed manual ventilation. Out of the 106 children who were manually ventilated, 45 (42.5%) survived. Another 75 children required manual ventilation for varying duration in addition to mechanical ventilation, and the survival was 52.1% in that subgroup. None of the studies in available literature have data on manual ventilation.

The mean duration of artificial ventilation in the study was 3.56 ± 5.2 days. The duration of mechanical ventilation in the study was

4.6±5.9 days. A total of 181 children (96.3%) were ventilated manually during their PICU stay, and among them, 75 children were ventilated mechanically after variable duration of manual ventilation. In comparison, the ventilation days were 18.8±14.1 days in the study by Kendirli et al and the median ventilation days were 6.5 days in the study by Da Silva et al.

Nosocomial pneumonia was encountered in 13 out of 81 ventilated children (16%) in the present study, lower than that observed by Kendirli et al (17.5%), but higher than that reported by Elward et al (47) where the incidence was 5.1%. Many individual studies done report an incidence between 27% to 35% (48,49).

Nosocomial pneumonia was significantly associated with re-intubation, which was also reported by the study by Elward et al.

Torres et al(50) had analysed separately, the role of re-intubation in nosocomial pneumonia. They found that re-intubation was a significant risk factor after adjusting for age, sex and prior bronchoscopy. The studies by Rajasekhar et al (51), Ibrahim et al (52) and Kollef et al (52) had come up with similar results.

Air leak was observed in 17 out of 190 children (8.9%) compared to an incidence of 13.1% reported by Kendirli et al and 6.9% reported by Benjamin et al (43).

Tracheostomy was performed in 2 out of 188 (1.07%) patients in the study as compared to 3 out of 86 children who underwent tracheostomy in the study by Da Silva et al.

Mortality in the ventilated children in the study was 51.6 % which was comparable to the study done in Turkey conducted by Kendirli et al where the mortality was 58.3%. However it is still high compared to the observations made by Da Silva et al and Indrajit et al where the mortality were 19.8% and 24% respectively.This could be ascribed to unavoidable use of manual ventilation in our study, where the pressures were not regulated resulting in excessive lung injury apart from improper ventilation.

SUMMARY AND CONCLUSIONS

- Infants contributed 46.3% of children who were ventilated in the Pediatric Intensive Care Unit.
- The sex ratio was almost equal with slight male preponderance. Male:Female = 1.09:1.0
- The commonest cause for intubation was circulatory failure and the commonest clinical diagnosis was septic shock.
- Of the children who were ventilated in the PICU, 76.6% were intubated at the Emergency Department.
- Rapid Sequence Intubation was performed in 54.8% of children, and orotracheal route was the commonest route of intubation.
- Many children (56.4%) were manually ventilated and it was associated with an increased risk of mortality especially when done for 48 hours or more.
- Nosocomial pneumonia was the commonest complication encountered in ventilated children and was more common in those who were reintubated.
- Mortality and complications in ventilated children in the PICU can be reduced with increased availability of mechanical ventilators.

RECOMMENDATION

- Though not ideal, manual bag and mask ventilation can be life saving in resource limited settings, which may have to be advocated in the absence of mechanical ventilators.

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ANNEXURE

DATA ENTRY FORM

Name Age Sex I.P.No.

D.O.A.

D.O.A. at PICU

Clinical Diagnosis

INTUBATION DETAILS:

Intubation done: outside/ER/ward/PICU

Vitals prior to intubation:

HR

RR

BP

SaO2

Indication for intubation:

Circulatory / Respiratory /Neurological/ Others

Drugs used for intubation:

Sedative/Relaxant/ Analgesic

Endotracheal Tube:

Appropriate/Small/Big

Cuffed /uncuffed

Nasotracheal / orotracheal

MECHANICAL VENTILATION DETAILS:

Invasive:

Duration : Days Hours

Non-invasive:

Duration: Days Hours

Ventilator:

Duration:

Maximum pressures reached:

Weaning methods: Duration

SIMV

CPAP

T Piece

MANUAL VENTILATION DETAILS:

Duration of manual ventilation:

Days Hours

Number of times ET changed:

Reason: Displacement

Obstruction

Extubation failure

Complications:

Nosocomial Pneumonia

Pneumothorax/Pneumomediastinum

Pressure sores

Post extubation stridor

Segmental collapse/Lung collapse

Obstructive emphysema

Equipment failure

Others

Need for tracheostomy: Y/N

Outcome: Discharge/Death