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Efficacy of noninvasive mechanical ventilation in prevention of intubation and reintubation in the pediatric intensive care unit

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ABSTRACT

Purpose: To determine the efficiency of noninvasive mechanical ventilation (NIV) both in protection from intubation and in preventing reintubation of postextubation in patients in the pediatric intensive care unit (PICU).
Methods: A prospective observational study was conducted in a multidisciplinary 10-bed tertiary PICU of a university hospital. All patients were admitted to our unit from June 2012 to May 2014 and deemed to be candidates to receive continuous positive airway pressure or bilevel positive airway pressure.
Measurements and Results: We performed 160 NIV episodes in 137 patients. Their median age was 9 months (range, 1-240 months), and their median weight was 7.5 kg (range, 2.5-65 kg). Fifty-seven percent of patients were male. Noninvasive mechanical ventilation was successful in 70% (112 episodes) of patients. There was an underlying illness in 83.8% (134 episodes) of the patients. Bilevel positive airway pressure support was given to 57.5% (92 episodes) of the patients, whereas the remaining 42.5% (68 episodes) received continuous positive airway pressure support. Among the causes of respiratory failure in our patients, the most frequent were postextubation, pneumonia, bronchiolitis, atelectasia, and cardiogenic pulmonary edema. Sedation was applied in 43.1% of the episodes. Complications were detected in 29 episodes (18.1 %). The NIV failure group showed higher Pediatric Risk of Mortality III-24 score, shorter NIV duration, more frequent underlying disease, lower number fed, longer length of PICU stay, and hospital stay, and mortality was higher.
Conclusions: Noninvasive mechanical ventilation effectively and reliably reduced endotracheal intubation in the treatment of respiratory failure due to different clinical situations. Our results suggest that NIV can play an important role in PICUs in helping to avoid intubation and prevent reintubation. Although there were serious underlying diseases in most of our patients, such as immunosuppression, 70% avoided intubation with use of NIV.
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1. Introduction

Acute respiratory failure (ARF) is one of the most frequent causes of admission to the pediatric intensive care unit (PICU). Conventional management of ARF in adult and pediatric intensive care patients consists of endotracheal intubation and mechanical ventilation, with their associated risks and adverse effects, such as the need for heavy sedation, infections, ventilator-associated pneumonia, ventilator-induced lung injury, and laryngeal-tracheal damage [1,2].

Noninvasive mechanical ventilation (NIV) is an alternative form of respiratory treatment that includes various techniques for improving alveolar ventilation, oxygenation, and unloading of respiratory muscles without the need for an endotracheal airway. Noninvasive mechanical ventilation is used to treat acute and chronic respiratory failure in infants and children [3]. Noninvasive mechanical ventilation is primarily used to avoid the need for endotracheal intubation in patients with early-stage ARF and postextubation respiratory failure. Unsuccessful extubation has been noted to be associated with an increase in both morbidity and mortality in adult and pediatric patients [4–7]. It can also be used as an alternative to invasive ventilation at a more advanced stage of ARF or to facilitate the process of weaning from mechanical ventilation [8,9].

The aim of this study was to determine the efficiency of NIV both in prevention of intubation and in preventing reintubation of postextubation as a first-line treatment in the PICU. We report here our experience with the use of NIV in patients who were admitted to our PICU for 2 consecutive years.

Abbreviations: ARF, acute respiratory failure; ARDS, acute respiratory distress syndrome; BiPAP, bilevel positive airway pressure; CPAP, continuous positive airway pressure; CMV, conventional mechanical ventilation; ECMO, extracorporeal membrane oxygenation; EPAP, expiratory positive airway pressure; HFNC, high-flow nasal cannula; HFOV, high-frequency oscillator ventilation; HR, heart rate; IMV, invasive mechanical ventilation; IPAP, inspiratory positive airway pressure; NIV, noninvasive mechanical ventilation; PELOD, pediatric logistic organ dysfunction; PICU, pediatric intensive care unit; PRISM, pediatric risk of mortality; RR, respiratory rate.

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2. Methods

2.1. Setting and patients

This prospective observational study was conducted in a multidisciplinary 10-bed tertiary PICU of a university hospital. Our PICU is a unit that follow up medical and postoperative surgical patients. Approximately 300 to 350 patients are annually admitted to our unit. In our unit, pediatric intensive care sub-branch training is given. In our unit, there is 1 nurse for every 3 patients. All patients were admitted to our unit from June 2012 to May 2014 and were deemed to be candidates to receive continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP). The ethics committee of the hospital approved the study and waived the need for informed consent.

All patients who were referred to the PICU for ventilatory support of ARF and those extubated from invasive mechanical ventilation were eligible for inclusion in the study. Patients who applied to pediatric intensive care for respiratory insufficiency that takes NIV support in order to protect from the intubation are taken into studies as prevention group, and patients who take NIV support when respiratory insufficiency happens after extubation are taken into studies as postextubation group. The decision to institute NIV was made by a PICU physician. Inclusion criterion for age was from 1 month to 20 years. Noninvasive mechanical ventilation was considered as a treatment when the patient presented with (1) acute hypercapnia ($Pco_2 > 50$ mmHg) or hypoxemia ($Po_2 <$ 60 mmHg or oxygen requirement to maintain saturation >92%) or both and (2) clear signs of increased work of breathing, such as high respiratory rate (RR), use of accessory respiratory muscles, and intercostal retractions.

Contraindications to NIV support were cardiopulmonary arrest, hemodynamic instability despite fluid load and vasoactive treatment, Glasgow Coma Scale score lower than 10, facial deformity, facial trauma or surgery, undrained pneumothorax, endotracheal intubation to manage secretions or airway protection, and upper gastrointestinal tract active bleeding.

Acute respiratory failure was defined as failure to sustain a threshold level of alveolar exchange to meet the metabolic demands of cellular respiration and was classified as type 1 or 2 using pathophysiological and clinical criteria modified from Teague [10]. Acute respiratory failure with ventilation-perfusion impairment and hypoxemia and parenchymal condensations on x-ray was considered as type 1. Acute respiratory failure with hypoventilation, hypercapnia without hypoxemia, and parenchymal condensations absent on x-ray (excluding atelectasis) was considered as type 2.

2.2. Protocol for NIV

The overall population was divided into 2 groups depending on whether NIV was used as a first-line treatment or postextubation to prevent reintubation, and was then further divided according to whether CPAP or BiPAP was delivered. Patients were ventilated in NIV mode using the ICU ventilator. Bilevel positive airway pressure was delivered with VENTILogic plus (WEINMANN, Hamburg, Germany). Continuous positive airway pressure was delivered with Infant Flow SIPAP (CareFusion, Yorba Linda, Calif) in infants, and VENTILogic plus supplied CPAP in older children. Bilevel positive airway pressure was delivered using a nasal mask and oronasal mask. Continuous positive airway pressure was delivered using a nasal prong, nasal mask, and oronasal mask. The interface was chosen according to the child's age and size, for comfortability and to avoid air leaks.

Expiratory positive airway pressure (EPAP) in the initial CPAP ventilator setting was 4 to 5 cmH_2O; inspiratory positive airway pressure (IPAP) in the initial BiPAP ventilator setting was started at 8 to 10 cmH_2O and in EPAP at 5-6 cmH_2O.

2.3. Monitoring

All patients were continuously monitored by means of electrocardiography, pulse oximeter, and RR. After measurement of blood gases, all patients received noninvasive ventilatory support for 2 to 4 hours.

2.4. Sedation

Ketamin intravenous boluses (1 mg/kg) followed by continuous infusion (5-20 μg/kg/min), or midazolam intravenous boluses (0.1 mg/kg) followed by continuous perfusion (0.05-0.2 mg/kg/h) or chloralhydrate per os (25-50 mg/kg) were used if the child was stressed with consequent patient-ventilator asynchrony.

2.5. Feeding

A nasogastric tube was placed in all patients to avoid gastric distension or vomiting. It was afterward used to provide feeding when possible.

2.6. Noninvasive mechanical ventilation outcome

Noninvasive mechanical ventilation was deemed successful when conventional mechanical ventilation (CMV) was not necessary. If CMV was needed, the episode was considered as a failure.

2.7. Data collection

Patients with multiple admissions were considered individually since each episode requiring NIV presented new variables potentially affecting the outcome. For each episode, the following variables were collected: age, sex, weight, ARF type, ARF cause, underlying disease, Pediatric Risk of Mortality (PRISM) III-24 score, Pediatric Logistic Organ Dysfunction (PELOD) score, NIV mode (CPAP or BiPAP), type of interface, NIV duration, NIV outcome, use of sedatives, feeding, NIV complications, PICU and hospital stay, mortality, and causes of death. The collected clinical data were RR, blood pressure, heart rate (HR), and So_2 before NIV was started. The same data for CPAP and BiPAP were collected before NIV was started and 2 to 4 hours after NIV support. The collected complementary explorations were blood gas analysis and x-ray.

2.8. Statistical analysis

For testing whether the data were normally distributed, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used. Differences between groups for categorical variables were analyzed by χ^2 test or Fisher exact test, where appropriate. Continuous variables (such as age, weight, PRISM III-24 score, and PELOD score) were compared using Mann-Whitney *U* test among categories of the grouping variable. Descriptive statistics were presented as percentages or median (minimum-maximum). Independent risk factors of the prevention group and postextubation group were studied, as well as between the success group and the failure group. We used multiple logistic regression analysis and adjusted odds ratios; their confidence intervals were calculated. *P* values less than .05 were considered statistically significant.

3. Results

3.1. Patients

During the study period, the total number of NIV episodes included was 160, in 137 patients. Noninvasive mechanical ventilation support was given 5 times to 1 patient, 4 times to 2 patients, 3 times to 3 patients, and twice to 17 patients. The median age was 9 months (range, 1-240 months), and the median weight was 7.5 kg (range, 2.5-65 kg).

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