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Characteristics of patients requiring non-invasive ventilation in pediatric intensive care unit

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ABSTRACT

Background: Non-invasive ventilation (NIV) has become an essential tool in the treatment of both acute and chronic respiratory failure in children. This study aimed to determine the efficacy of NIV usage in pediatric patients who were admitted to the Pediatric Intensive Care Unit (PICU) with respiratory failure.

Patients and Methods: This study is a retrospective, cross-sectional review. The data were collected from the medical record of PICU patients at our hospital from 2017 to 2018. Successful NIV was defined as patients who survived without intubation. Failure was defined as worsened patients and needed intubation for the rescue.

Results: The total subjects of this study was 78 patients. The most common indication for NIV was ARDS (78.1%), and CPAP was the most common frequently used (78.68%). The data shows that the NIV was commonly used after extubation (52.56%) than for the first-time rescue (47.44%). The success rate of NIV after extubation were 65.85% and 34.15% failed and shifted to mechanical ventilation. The duration of NIV usage was less than three days (73.77%).

Conclusion: NIV is a useful tool for the treatment of respiratory failure in pediatrics. The use of post-extubation NIV may be a valuable tool to prevent reintubation.

Keywords: NIV, non-invasive ventilation, PICU, CPAP, extubation

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INTRODUCTION

Non-invasive ventilation (NIV) refers to the use of non-invasive techniques to deliver artificial respiration to the lungs without the need for endotracheal intubation. As NIV has proven beneficial in comparison to invasive mechanical ventilation, it has become the optimal modality for initial respiratory support among children with respiratory distress. The first use of non-invasive techniques in the adult population was in the late 1980s.[1]

NIV is primarily used to avoid the need for endotracheal intubation in patients with early-stage acute respiratory failure and post-extubation respiratory failure. By definition, it is a non-invasive technique, which can be applied on demand, causing less morbidity, and discomfort. It also allows preserving essential functions such as swallowing, feeding, speaking, and coughing. Heating and humidification of the inspired air are greatly respected. The primary goal of using NIV is to improve oxygenation by improving functional residual capacity and lung inflation in patients with an adequate respiratory drive.[2]

Techniques for NIV include continuous positive airway pressure (CPAP), bilevel positive airway pressure (BPAP), and more recently, a high-flow nasal cannula (HFNC). NIV improves the effective minute ventilation enhancing CO_2 elimination by augmenting inspiration in patients with respiratory failure or impending respiratory failure without the use of an artificial airway.[3]

The majority of NIV in pediatric patients is utilized for the treatment of imminent respiratory failure associated with acute or chronic respiratory insufficiency secondary to pulmonary disease, neuromuscular disease, airway obstruction, infectious processes, or post-extubation management or to avoid intubation or reintubation. NIV is not appropriate for patients with respiratory arrest, hemodynamic instability, multiple organ failure, recent upper airway or upper gastrointestinal surgery or bleeding, excessive sputum production or a diminished cough reflex or swallowing impairment. As mentioned above, uncooperative or agitated patients are also not eligible for using NIV.[4]

The advantages of NIV are widely reported in the scientific literature. It is much safer than invasive mechanical ventilation. Compared to invasive ventilation, NIV lowers the risk of laryngeal swelling, post-extubation vocal cord dysfunction, barotrauma, and ventilator-associated pneumonia. One can communicate with the patient and does not require deep sedation.[5] Complications of NIV include skin breakdown, gastric distention, interface discomfort, and nasal injury.[6] On the other hand, the successful of NIV is determined by the selection of interfaces, good trained medical teams, and observation.

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This study aimed to determine the efficacy of NIV in pediatric patients who admitted to PICU with respiratory failure since the study of using NIV in Indonesia has not been widely studied.

PATIENTS AND METHODS

This research was a descriptive, retrospective, cross-sectional study. The data were obtained from the medical record of patients who were applied NIV at the Pediatric Intensive Care Unit (PICU) of our hospital from January 2017 to December 2018. The inclusion criteria were all patients aged one month to 18 years old. Subjects were excluded if the medical record data was not complete. The research protocol was approved by the institutional review board.

This research data included a primary characteristic of the subject such as age, gender, nutritional status, diagnosis, the Pediatric Logistic Organ Dysfunction (PELOD) score, NIV mode, interface, duration of usage, and mortality incidence. Based on the formula used to see minimal sample size, we found the minimum sample size for this study was 78 samples.[7] The data was analyzed and presented descriptively using Microsoft Excel 2017 software tool.

RESULTS

The most common age group used the NIV was below two years old. The male-to-female ratio was 1.1:1. The characteristics of the study subjects are presented in Table 1. In our hospital, we have introduced the HFNC since a few years ago. It is a relatively new, non-invasive ventilation therapy that seems to be well-tolerated in children.

In this study, the most common conditions that needed NIV was post-extubation patients. There were, however, some patients required re-intubation after using the NIV. The most common mode of NIV was continuous positive airway pressure (CPAP). The oxygen fraction (FiO_2) of 40% was often used for weaning in our hospital, but lower FiO_2 values were also adjusted.

Table 1 Characteristics of the study subjects

Variable	n = 78
Age, n (%)	
0-2 years	66 (84.62)
3-5 years	7 (8.97)
6-11 years	5 (6.41)
12-18 years	0 (0)
Sex, n (%)	
Male	42 (53.85)
Female	36 (46.15)
Nutritional status, n (%)	
Well-nourished	34 (43.59)
Malnourished	34 (43,59)
Severe malnutrition	6 (7.69)
Overweight	3 (3.85)
Obesity	1 (1.28)
The presence of ARDS, n (%)	
Present	61 (78.21)
Absent	17 (21.79)
PELOD Score-2 1 day, n (%)	
< 7	75 (96.15)
≥ 7	3 (3.85)
NIV modes, n (%)	
CPAP	56 (71.79)
BiPAP	16 (20.51)
HFNC	6 (7.69)
The background of NIV application, n (%)	
Rescue	37 (47.44)
Successful NIV	24 (64.86)
NIV failure	13 (35.13)
After extubation	41 (52.56)
Successful NIV	27 (65.85)
Reintubation after NIV usage	14 (34.14)
Interface, n (%)	
Nasal mask	72 (92.31)
Facial mask	6 (7.69)
Full-facial mask	0 (0)
Nasal injury, (for nasal mask) n (%)	
No	69 (95.83)
Yes	3 (4.16)
The duration of NIV, n (%)	
≥ 72 hours	15 (19.23)
< 72 hours	63 (80.77)
Mortality	
No	57 (73.08)
Yes	21 (26.92)

DISCUSSION

In this study, we found that the most patients using NIV were well-nourished and malnourished. Schleder *et al.*[8] had concluded that nutritional status was not related to the time of permanence under invasive mechanical ventilation.

In this study, it showed that the majority of respondents were developing ARDS. The use of NIV for the treatment of ARDS remains controversial. A previous study has demonstrated that approximately half of their patients were spared

Table 2 Characteristics of subjects treated due to ARDS

Variable	n = 61
NIV, n (%)	
CPAP	48 (78.68)
BiPAP	13 (21.31)
HFNC	0 (0)
The Goal of using NIV, n (%)	
Rescue	37 (47.44)
Successful NIV	24 (64.86)
NIV failure	13 (35.13)
After extubation	35 (57.37)
Successful NIV	25 (71.42)
Re-Intubation after using NIV	10 (28.57)
The Duration of NIV, n (%)	
≥ 72 hours	16 (26.22)
< 72 hours	45 (73.77)
Mortality	
No	40 (65.57)
Yes	21 (34.42)

Table 3 The clinical diagnosis of pediatric patients who used NIV

Variable	n = 78
Respiratory diagnoses, n (%)	
Pneumonia	48 (78.68)
Bronchiolitis	8 (13.11)
Asthma	3 (4.91)
Aspiration pneumonia	2 (3.27)
Non-Respiratory diagnoses, n (%)	
Neurology	6 (35.29)
Postoperative	5 (29.41)
Gastrohepatoenterology	2 (11.76)
Hematology	2 (11.76)
Immunology	2 (11.76)

from endotracheal intubation through the application of NIV. The result was similar to the meta-analysis reported by Agarwal *et al.*, that the severity of the disease was significantly higher in patients who received invasive ventilation only compared to NIV only, although there were no significant differences in the PICU's length of stay. Patel *et al.* evaluated ARDS patients submitted to NIV and drew attention to the importance of the NIV interface. They discussed their interesting findings focusing also on the ventilator settings and the current barriers to lung protective ventilation in ARDS patients during NIV.[9]

Table 3 showed that pneumonia (78.68%) was the most typical disease that required NIV. Asthma and aspiration pneumonia were the least. Our study was comparable to the previous study reported by Abadesso *et al.*, in which the main diagnoses were bronchiolitis and pneumonia.[10]

In this study, the most frequent causes used NIV was neurology disease. According to previous journals and literature, the causes of respiratory failure in the children supported by NIV were chronic diseases-infection, neuromuscular diseases, renal transplantations-immunosuppression, leukemias, and respiratory infections.[11] In the previous study, they found a few types of the underlying malignancy (leukemia, lymphoma, solid tumor) that did not associate with NIV success or failure.[12] Piastra *et al.* had found that organ cancers were determinant evident for NIV failure in critically care children.[13]

In this study, the PELOD-2 score was calculated on the first day the patients used NIV. The most frequent values of PELOD-2 score in this study was <7. Bernet *et al.*[14] similarly did not find differences in PELOD between patients managed successfully and unsuccessfully on NIV, whereas Essouri *et al.* using PELOD and Paediatric Risk of Mortality (PRISM) scores have shown a correlation between these prognostic severity scores and prediction of NIV success.[15]

Septic shock affected NIV, distinctly (P = 0.027) and the failure group showed increased rate. Steroid use was stated for the success and failure group (seven success and twelve failures in children who applied NIV). Statistically, a significant difference was found in both group (P = 0.017), but not inotropic and granulocyte colony-stimulating factor a use, but not inotropic and granulocyte colony-stimulating factor use.

Bi-level positive airway pressure (BiPAP) devices provide two levels of positive airway pressure during the respiratory cycle. A higher level of pressure is provided during inspiration, and a lower level of pressure is provided during expiration. In this study, CPAP mode was the most used. This is similar to data on heterogeneous modes of NIV modalities in the PICU described in separate studies conducted by Yaman *et al.*, that reported NIV support with BiPAP mode was given to 57.5% (92 episodes) of the patients, while the remaining 42.5% (68 episodes) received CPAP support, and there was none with high-flow nasal cannula.[16] Manley *et al.* compared treatment failure in infants within three days of extubation comparing the use of HFNC with CPAP. In that study, 34.2% of the nasal cannula infants experienced treatment failure, whereas 25.8% of the CPAP group demonstrated failure. Of the failures, 50% were successfully treated with CPAP without re-intubation. Based on their predetermined criteria, this led to a conclusion that the use and efficacy of HFNC was not inferior and was therefore similar to that of CPAP as a form of respiratory support for very preterm infants following extubation.[16]

In this study, although there are several subjects that demonstrated failure from the NIV, the number of successes from using the NIV is also significant. This is certainly in accordance the to another report that studied the early use of NIV on the PICU may serve as a first line interventional tool to prevent intubation.[17]

Limitations associated with the successful application and use of CPAP and NIV can be attributed to the patient interfaces, the delivery devices, and the available technology. Interfaces include a nasal cannula, nasal pillows, nasal masks, oronasal masks, total face masks, and extended nasal cannula or nasal tubes positioned in the nasal pharyngeal airway. The primary patient interfaces used in small infants are nasal cannula and nasal masks. Both nasal cannula and nasal masks are associated with system leaks, which may necessitate the use of a chin strap to maximize positive pressure delivery.[18] On the characteristic of interface in this study, the most frequently used was 'nasal mask'.

In the event of nasal injury, only a few who had a nasal injury after using NIV. Some studies show that the prolonged time of use of nasal prongs increases the risk of nasal injury. However, in that study, terse times were noted before the occurrence of nasal injury in 60% of the patients analyzed. The patients developed injuries within an average of 18 hours of use, enabling us to infer that care and constant vigilance significantly affect the onset of injuries and that evaluations of the improvement of the quality of care for infants should include nasal injury triggered by the use of nasal cannula for NIV as an indicator. Another factor possibly associated with the onset of nasal injuries is linked to the manufacturing brand of the device, which, in turn, is related to the quality of the material and the nasal cannula design (for example, the distance between the nasal catheter insertion and the catheter's length). There were no statistically significant differences between the children with nasal injuries and those without, although chemical and physical structures of the materials used in the nasal cannula have not been analyzed.[19]

In this study, there was the commonest used NIV for more than three days. On the previous study, NIV support median duration was 48 hours (range: 2-448), and in the successful group (no reintubation), the average NIV duration was 48 hours while this was 20 hours in the unsuccessful group (with re-intubation).[20] Besides that, in this study, there was 26.92% death after used NIV.

The limitation of this study is related to its limited number of subjects. Also, there are no description of the NIV setting, patients' vital signs, and ventilator-free day outcomes. A further study is needed to describe the utilization of NIV in children, determinate the efficacy of NIV, and describe its safety profile in PICU patients.

CONCLUSION

NIV is a useful tool for the treatment of respiratory failure in pediatrics. The use of post-extubation NIV may be a valuable tool to prevent reintubation.

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