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Non-invasive Ventilation in Pediatric Patients with Acute Respiratory Failure

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Introduction

Academic and clinical interest in noninvasive ventilation (NIV) for the treatment of acute respiratory failure (ARF) is high (Figure 1). The NIV isn't often used. The evidence overwhelmingly favors its usage in those who are experiencing COPD (chronic obstructive pulmonary disease) exacerbations and people who have acute cardiogenic pulmonary edema. Acute and chronic respiratory illnesses were the cause of 8% of child fatalities, 20% of weekly GP visits, and 15% of hospital admissions in the UK in 2001 [1]. Increased proof of efficacy, advancements in ventilator technology, and pediatric user interface design, as well as public and physician awareness, are all potential contributing factors. Numerous of these kids were raised at home [2, 3]. When used in conjunction with ventilatory support, pediatric intensive care unit (PICU) admissions can be decreased [4] and hospital release following ventilatory decompensation can be facilitated [5]. Even though many instances are benign and self-limited, some individuals need more advanced respiratory care. In many situations of ARF, invasive mechanical ventilation (IMV) is a crucial strategy; yet endotracheal intubation (ETI) has obvious dangers [6].

Noninvasive positive pressure ventilation (NPPV) can be a highly beneficial substitute for IMV in patients who need ventilatory assistance without ETI. It has been demonstrated to use fewer resources and avoid numerous ETI-related problems, including upper airway damage, laryngeal edema, post-extubation glottic dysfunction, and nosocomial infections. It is typically considered safer than IMV. Children receiving long-term ventilator support and their families may now treat respiratory failure with NIV thanks to technological advancements in the field, which have been demonstrated to enhance survival [8-11] and halt functional deterioration. However, case series are often short and concentrate mostly on outcomes in Duchenne muscular atrophy (DMD) and spinal muscular atrophy (SMA), without the corresponding loss in health-related quality of life [12]. Case series, however, are often brief and concentrate mostly on the results of DMD and SMA. IMV with a tracheostomy is a suitable substitute for

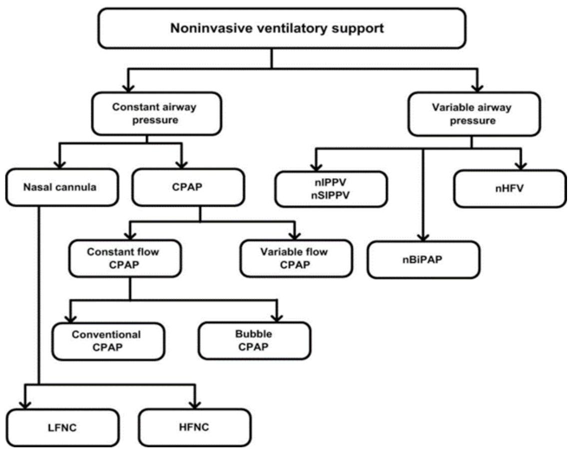

Figure 1: Types of non-invasive ventilator support given to neonates. CPAP, continuous positive airway pressure; HFNC, high-flow nasal cannula; nBiPAP, nasal bilevel positive airway pressure; nIPPV, nasal intermittent positive airway pressure; nSIPPV, synchronized nasal intermittent positive airway pressure; nHFV, nasal high-frequency ventilation [7].

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h [13]. NIV has been applied to additional disease categories, including chronic lung illnesses, neurological and neurodevelopmental syndromes, and upper airway problems linked to hypoventilation, possibly because of its effectiveness in treating NMD patients. The outcomes were also not definitive.

In most cases, NPPV refers to continuous positive airway pressure (CPAP) or two-level airway support, which includes expiratory positive airway pressure (EPAP) and inspiratory positive airway pressure (IPAP), also known as biphasic positive airway pressure (BIPAP) and bilevel positive airway pressure (BiPAP), and is administered through nose tips, masks, or helmets. Although there is a wealth of research supporting the use of NPPV in the treatment of ARF for a variety of conditions, including acute cardiogenic pulmonary edema [15] and aggravation of COPD [14], there is less evidence to support reports of its use in children with this acute illness. Knowing when to begin NIV as well as when this therapy fails is crucial. It is still debatable whether NIV can be successfully delivered to patients with ARF outside of the ICU. Although there are several interfaces, the oronasal mask is the most effective first interface for reducing leakage and enhancing patient comfort. However, group ventilators made expressly for NIV have greater leak compensation. Some intensive care ventilators include NIV modes that correct for leaks well. "Neither CPAP nor the strap-on positive pressure breathing mask are novel therapeutic approaches. Instead, it is outmoded because it is risky and cruel. A patient who requires CPAP also requires an endotracheal tube. it was however, as indicated by the rise in research published, there is more interest in adopting NPPV as a therapy for kids with respiratory issues. Additional restrictions on age range: infants to 18 years old. 332 articles on the topic were found, with 8% of them appearing in the previous five years. The effectiveness of NPPV in children with ARF older than one-month-old is the main emphasis of this condensed review, which does not include patients with neurological or chronic pulmonary conditions. All doctors who treat patients with severe respiratory failure ought to have access to NIV.

Methods

CPAP and NIV protocol

Patients who have developed respiratory failure and chronically increased daytime arterial carbon dioxide pressure (CO_2) (>6.5 kPa) are started on NIV. NIV is initiated in this instance without oximetry or nighttime transcutaneous CO_2 ($TcCO_2$) monitoring. This study looked at using NIV at night to reduce daytime CO_2 levels. Patients were told to use NIV at specified times of the day if daytime CO_2 could not be controlled even with ideal nightly settings. When required, the causes of anomalies such as adenotonsillar hyperplasia were investigated and addressed. Patients who have increased nocturnal $TcCO_2$ (>6.5 kPa) for more than 50% of the night should get nocturnal NIV. The IPAP was raised to the patient's highest tolerable level or until the tidal volume objectively improved. In individuals with anomalies of the upper airways, EPAP was raised from the standard setting of 4 cm H_2O. In patients with high respiratory rates, the amount of time spent inhaling and the number of breaths per minute were calculated according to age and corrected for spontaneous rate. The interface of choice when respiratory assistance was started in a non-acute context was a nasal mask or nasal pillow device. Patients whose nasal interface did not provide them with adequate control had the nasal interface changed to an oronasal mask. Depending on the severity of the symptoms, the patient's desire, and the distance to the hospital, patients either began receiving inpatient or outpatient care [16]. Following discharge, patients had several sleep tests with respiratory assistance for three months. If the sleep study's outcomes weren't ideal, the patient can return for another sleep study at the consulting doctor's discretion after the settings were modified.

Pediatric Acute Respiratory Failure

Without immediate and effective management, acute respiratory failure can result in considerable morbidity and death and might be regarded as a physiological aberration. Children frequently attend the emergency room for acute obstructive airway issues. From a minor, self-limiting illness to life-threatening types of quickly progressing airway blockage, the severity of various illnesses varies. Noninvasive positive pressure ventilation (NPPV) is better than conventional therapy in avoiding intubation and lowering mortality in individuals with acute respiratory insufficiency. The management of upper airway blockage, atelectasis, and exacerbations of neuromuscular illness, as well as the facilitation of weaning from invasive mechanical ventilation, are other applications of NPPV in pediatric critical care. NPPV is a prospective substitute for standard medicines in the management of acute respiratory distress in children, notwithstanding these difficulties. According to the respiratory component, individuals with respiratory failure may generally be separated into two groups: hypoxic respiratory failure and hypercapnic respiratory failure [17].

The Type I of Hypoxic Respiratory Failure

Nearly all acute lung diseases that impair normal lung and airway function, such as status asthmaticus, bronchiolitis, pneumonia, and pulmonary edema, are linked to hypoxic respiratory failure (type I). Impaired gas exchange because of the abrupt failure of one or more respiratory system components is the hallmark of acute hypoxemic or *de novo* respiratory failure (hypoxemic ARF). The provision of supplementary oxygen at a level adequate to elevate the arterial oxygen saturation (SaO_2) over 9% is the main treatment for type respiratory failure in children. ARF in hypoxemic individuals, who typically have a partial pressure of oxygen (PaO_2) of 25 breaths per minute, is expected to be worse than in patients who are not as hypoxemic and have a PaO_2/FiO_2 ratio of >200 mmHg [18]. On the basis of clinical and straightforward biological data, such as the PaO_2/FiO_2 ratio and respiratory rate, a functional definition of hypoxemic ARF should be developed. To aid doctors at the bedside, it is crucial for researchers to identify individuals in trials who have comparable traits.

The Type II of Hypercapnic Respiratory Failure

NIV, a novel therapeutic approach to improve alveolar ventilation, can be carried out sub-atmospherically or with positive pressure administered through an external interface. NPPV prevents intubation and lowers mortality in individuals with ARF better than usual therapy. When pre-existing conditions like pneumonia or status asthmaticus, which first manifests as hypoxemia without hypoventilation, are made worse by respiratory muscle exhaustion, type II failure can start slowly and sneak up on you. NPPV is also used to help patients wean off IMV and treat upper airway blockage, atelectasis, and exacerbations of neuromuscular illness in the pediatric critical care unit. The response characteristics of commercially available bilevel ventilators and the unavailability of adequately sized interfaces make it difficult to successfully deploy NPPV in newborns with respiratory distress. Children with type II respiratory failure should begin receiving therapies that lessen the strain on their respiratory muscles and improve alveolar ventilation in addition to more oxygen. NPPV is being used more often to treat children with respiratory distress because it is seen to be a secure and efficient substitute for intrusive mechanical ventilation.

NPPV for Acute Respiratory Failure: When to Use It?

Twelve children with acute mild hypercapnic respiratory failure underwent prospective physiological research to determine if NPPV might relax the respiratory muscles and enhance gas exchange. The underlying cause of ARF is treatable, and medical therapy increases lung function while addressing it. In contrast, ventilatory support seeks to "benefit" patients by relaxing the respiratory muscles, boosting ventilation, and lowering dyspnea and respiratory rate while enhancing gas exchange. NPPV has been demonstrated to benefit children with ARF in two recent physiological trials [19, 20].

Chronic Lower Airway Obstruction (ALO)

An often-occurring cause of ARF is lower airway illness. The majority of these conditions are caused by asthma, however, infections such as viral bronchiolitis are frequent and mostly impact the tiny airways. In children with lower airway blockage, ETI and positive pressure breathing may worsen bronchoconstriction, increasing the danger of airway leaks, and adversely influence blood flow and cardiac output. Therefore, until respiratory collapse is imminent despite all available treatment interventions, ETI should be avoided. NPPV can enhance symptoms and ventilation without causing noticeably negative side effects, which can lessen the requirement for IMV, according to clinical trials in kids with acute lower airway stenosis [21-26]. Patients' airway resistance and expiratory time continuously rise during acute bronchospastic episodes. Dynamic hyperinflation, which results in an increase in positive pressure in the alveoli at the conclusion of exhalation (auto-PEEP), is caused by a protracted expiratory time constant combined with the premature closure of inflamed airways during expiration. Automatic PEEP raises the inspiratory strain and weakens the respiratory muscles since the alveolar pressure must be decreased below atmospheric levels to start the next breath. NPPV improved gas exchange and respiratory effort and was well tolerated without significant side effects. NPPV usage has been linked to improvements in respiratory rate and $PaCO_2$ in children with severe bronchiolitis [27-29] a decrease in the effort of breathing [30], and the avoidance of ETI in 67–100% of patients.

Upper Airway Blockage that is Acute

Dynamic upper airway blockage in children can be a serious, sometimes fatal condition that results in severe alveolar hypoventilation. According to 2006 research by a French PICU group, 67% of pediatric intensivists employed NPPV regularly or consistently to treat children with dynamic upper airway blockage [31]. In children with dynamic upper airway blockage, NPPV is linked to a considerable reduction in respiratory effort and a persistent improvement in gas exchange [32, 33].

Bronchoscopy

In critically hypoxemic patients with other comorbidities that raise the risk of bronchoscopy-related complications, flexible bronchoscopy is frequently necessary. Additionally, it can assist and evaluate bronchial status in patients with expiratory central airway collapse and avoid hypoventilation in patients with obstructive sleep apnea and OHS who need bronchoscopy. With diffuse pulmonary infiltrates, NIV-assisted bronchoscopy and lung biopsy may be helpful for making a diagnosis in hypoxemic individuals. NIV should only be used during bronchoscopy at facilities with substantial experience in NIV purposes, including pulmonary diagnosis. Despite several papers documenting its utility, treatment for emphysema, central airway obstruction, benign strictures, lung infections, and intraepithelial lesions like carcinoma *in situ*. As part of difficult airway management, intubation or airway control, and lung lavage, this treatment is carried out by anesthesiologists, cardiothoracic and trauma surgeons, otolaryngologists, and intensivists. However, research on bronchoscopy is limited in comparison to the simulation-related literature that is accessible in other procedural domains.

Immunosuppressed Patients

ARF is most frequently brought on in immunocompromised people by infections, pulmonary localization of the original illness, or even cardiogenic pulmonary edema following chemotherapy. Ventilation is frequently necessary for patients with ARF. In such individuals, endotracheal intubation is linked to a substantial death rate. In two RCTs and a few observational studies, the benefit of NIV in immunocompromised individuals with ARF has been assessed. NIV patients had greater oxygenation, fewer rates of intubation, and a decreased death rate. Hilbert et al. [34] randomized hypoxemic immunosuppressed patients with severe respiratory failure and pneumonia to receive supportive oxygen or NIV alone [35], and they found that the NIV group required less endotracheal intubation and experienced fewer hospital deaths. The longer time between admission and the initial administration of NIV, the requirement for vasopressor or renal replacement treatment, and the presence of ARDS were all related to NIV failure in this group of patients [36]. The kind of lung illness appears to have an impact on how well NPPV works in immunocompromised children; ETI avoidance rates range from 0% in ARDS to 100% in pneumonia.

Conclusions

There is strong evidence to back the use of NIV in some patients. The use of NIV is regarded as the best practice for individuals with acute cardiogenic pulmonary edema or COPD exacerbations. All doctors treating patients with ARF should have NIV in their toolbox since it is well tolerated, has very few major side effects, and is linked to better gas exchange, less labor required to breathe, and a decreased requirement for ETI. NPPV has made use of both portable and intensive-care ventilators. As a result, several crucial concerns like patient identification, the ideal time to do NPPV, and suitable settings are still lacking. Furthermore, it is necessary to decide where NPPV and high-flow oxygen treatment should be used in children with ARF due to various situations [37].

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