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Case report

Use of high flow nasal cannula on a pediatric burn patient with inhalation injury and post-extubation stridor

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1. Introduction

Inhalation injuries remain a substantial cause of immediate and delayed morbidity and mortality in burn patients [1]. In addition, prolonged endotracheal intubation is associated with a number of complications including ventilator associated pneumonia, airway injury, and the risk of reintubation. Reintubation is a particular problem in children because of their small airway size, their inability to cooperate with periextubation maneuvers, and their relatively high sedation requirements.

Stridor due to upper airway obstruction occurs in 2.4–63.6% of patients in pediatric intensive care units [2–5]. Nearly 10% of pediatric patients with post-extubation stridor require reintubation, making stridor one of the most common indications for reintubation in this population [5]. The propensity for post-extubation stridor is reportedly dependant on patient age, duration of intubation, size of the endotracheal tube, and absence of air leak at the time of extubation. In a recent prospective cohort study of pediatric trauma patients, mechanism of injury and the absence of air leak at the time of extubation were felt to be the strongest predictors of post-extubation stridor and risk of reintubation [2]. In addition, the smaller airway size of pediatric patients predisposes them to more frequent obstructive airway injuries after intubation, including airway edema and temporary vocal cord paralysis. In a recent study that evaluated the airway of pediatric patients immediately post-extubation, only 10.2% had a normal endoscopy, 24.2% had at least a moderate airway lesion and 10.7% had at least one severe airway lesion. Independent risk factors for a worse endoscopic evaluation included reintubation and endotracheal tube changes [5].

Given these serious consequences, a number of pharmacologic interventions designed to decrease post-extubation stridor and reintubation have been evaluated, including systemic or aerosolized steroids, aerosolized racemic epinephrine, and Heliox. While these therapies hold promise, there is limited data to support their use. A different strategy is the use of noninvasive positive pressure devices such as CPAP, which has had some limited success in preterm infants, older children and adults. Unfortunately, pediatric patients are usually unable to cooperate with the mask equipment necessary to apply noninvasive positive pressure, and masks that fit this population are generally unavailable.

A new technology that administers high flow oxygen with molecular water vapor delivered via high flow nasal cannula has recently been introduced. This specialized nasal cannula device is designed to comfortably deliver humidified oxygen at flow rates that are theoretically high enough to mimic CPAP. A few reports describing the use of this technology in a variety of patient populations have been published. To our knowledge, this is the first reported use of high flow nasal cannula in a pediatric patient with inhalation injury, post-extubation stridor, and potential extubation failure. This case report study was approved by the University of North Carolina School of Medicine Institutional Review Board.

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2. Case summary

The patient is a 12-month-old female with 8% total body surface area partial thickness flame burn involving the upper torso, forehead and cheeks with an associated inhalation injury following a house fire. The child, who had been intubated in the field, was admitted with a 3.5 cuffless endotracheal tube and placed on high frequency percussive ventilation (VDR®) to assist with secretion clearance and maintenance of gas exchange. After 14 days, the patient was switched to conventional synchronized intermittent mandatory ventilation (SIMV) in anticipation of extubation. After 3 days of SIMV, the patient had an airleak and was deemed ready for extubation. Following extubation, the child was placed on aerosolized 40% oxygen via facemask with a baseline heart rate of 140 beats per minute (BPM) and a respiratory rate of 40 breaths per minute. Within several hours of extubation, the child developed coarse breath sounds and expiratory wheezing felt to be due exclusively to upper airway stridor. Her facemask oxygen was increased to 50%, she was given several doses of aerosolized racemic epinephrine and one dose of albuterol with no improvement. As the child's heart rate and respiratory rate increased to a maximum of 175 BPM and 63 breaths per minute, respectively, it was clear she was developing acute respiratory distress. Prior to urgent intubation, and under physician guidance, the child was given a trial of high flow nasal cannula set at 50% oxygen and 15 L/min gas flow. After beginning use of high flow nasal cannula, the patient immediately became more comfortable, with improved breath sounds and corresponding decreases in heart rate and respiratory rate to 144 BPM and 33 breaths per minute, respectively. A timeline of this clinical course is illustrated in Fig. 1. Over the course of the next several days, the patient's high flow nasal cannula was weaned down to 30% oxygen and 10 L/min. The patient continued to improve, was weaned to room air within five days, and was discharged without incident.

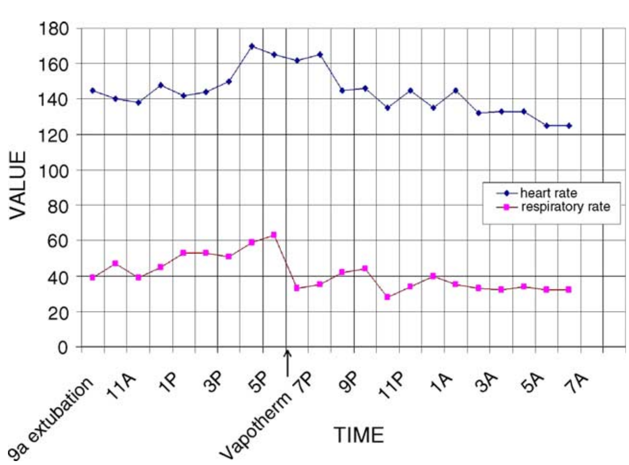

Fig. 1. Physiologic response to Vapotherm™.

3. Discussion

Several strategies have been developed in an attempt to address stridor as a cause for extubation failure, some preventative and some immediately therapeutic. The foremost strategy is the air leak test to avoid extubating a child who most likely will fail. The air leak test has become standard practice in intubated pediatric patients to determine if airway edema is present. This test measures the pressure required to produce an audible sound around the tip of the endotracheal tube. Most centers use a pressure of greater than 30 cm H_2O as a predictor of extubation failure [6].

The use of steroids to prevent laryngeal edema, stridor, and reintubation remains controversial, with only small studies on the subject. Anene randomized 66 patients to intravenous saline or dexamethasone and found decreased reintubation rates, decreased croup scores, and decreased need for aerosolized epinephrine. In an additional prospective randomized double-blind controlled trial with 23 patients, patients received either dexamethasone or sodium chloride placebo [7]. This group was unable to determine if the dexamethasone actually reduced extubation failure rates. They found a better correlation with neurologic impairment than with dexamethasone pretreatment or airway lesion. Two meta-analyses have recommended prophylactic use of dexamethasone to reduce the prevalence of stridor post extubation [8,9], and the Cochrane meta-analysis recommends its use only in patients at high risk to fail extubation, which are difficult to identify prior to endotracheal tube removal.

Therapies to attempt the prevention of imminent reintubation include racemic epinephrine and Heliox, as well as noninvasive positive pressure ventilation devices. The use of racemic epinephrine is ubiquitous in intensive care units, but no studies exist which have compared it to placebo [10]. Helium oxygen therapy has been used as an adjunct therapy for post-extubation stridor in children with burns [11], but larger studies are needed to confirm the efficacy of this therapy [12]. Existing studies of heliox are confounded by the large percentage of asthmatics as subjects.

In adult populations and in older children, noninvasive ventilation has been used successfully to treat post-extubation respiratory distress [13–15]. The role of noninvasive ventilation in children is less clearly defined. Several barriers exist to the application of noninvasive ventilation in children. One difficulty is that employing noninvasive therapies in children may mask the need for diuresis or reintubation for other causes, as has been reported in adult patients [16]. Additionally, manufacturers of the noninvasive devices lack appropriate mask interfaces for the older infant and toddler groups. Further, the cognitive development of these patients makes it nearly impossible to ensure proper adaptation to the CPAP machine due primarily to discomfort from the masks. One notable area of successful use of noninvasive ventilation in pediatrics is the application of CPAP via nasal prongs in preterm infants as a treatment for apnea or mild respiratory distress [17], as well as a means to prevent reintubation [18]. Nasal CPAP is designed with nasal prongs that fit tightly in the nares to prevent air leakage at the nose. This is required for the CPAP system to deliver and measure the requested pressures with flow rates on average of 6–10 L/min. An in vitro study was performed to assess pressure delivery by neonatal nasal CPAP systems, most of which were in the form of nasal prongs. This study demonstrated pressures generated as 0–21 cm H_20 for flow rates of 6 L/min [19]. The same group performed a later study of pharyngeal pressures as compared to preset CPAP levels both with the mouth in a passive position (generally open) and with it actively closed [20]. Nasal CPAP is effective in neonates partially due to the relative ease of fitting the nasal prongs and the lack of need for active patient compliance. These same benefits may be applicable to the Vapotherm™ system and may allow its successful use in children for whom traditional CPAP is not an option.

As reported by the manufacturer, the Vapotherm™ high flow cannula device delivers high flows of air and oxygen along with water vapor. The high flow of gas is tolerable for the patient because the device warms (33–43 °C) and humidifies (relative humidity over 99%) the air for delivery via the nasal cannula. A validation study was recently published confirming the accuracy of heating and humidification [21,22]. The warming, humidification, and vaporization of gases occurs in a vapor exchange cartridge (Fig. 2) and comes in a size specific for the infant population and one specific for larger children and adults. Theoretically, the warmed, humidified air could act by decreasing airway edema and the high flow could provide positive distending pressure [23] for both the larynx and the alveoli. There have been a few published case reports in abstract form describing the use of this device in various settings [24,25]. In clinical circumstances, it has been theorized to mimic noninvasive CPAP [22]. When compared to neonatal CPAP devices, Vapotherm™ therapy is delivered by a similarly shaped but less tightly fitting nasal cannula and applied with higher flows than nasal CPAP. Currently there is not an accurate way to measure the pressure levels generated by the device, as the nasal cannula system is an open system. However, it is theoretically possible that the pressure delivered could be measured in vitro and compared to other nasal CPAP devices, as it is known that they are able to apply measurable end-expiratory pressure.

Humidified air has played a role in the treatment of upper airway obstruction in the form of croup since the 19th century. Its usefulness in relieving stridor has been debated; however, no definitive trial has disproved its worth in moderate to severe croup. One randomized study showed an improvement in croup scores in mild–moderate croup with humidified air [26], yet another trial demonstrated no improvement with mist therapy in a similar patient population [27]. Despite the lack of conclusive evidence, many practitioners still use mist therapy ubiquitously in croup patients on the theory that it can decrease mucosal edema, loosen secretions, and make the patients more comfortable [28].

Fig. 2. Cross-section of Vapotherm™ cartridge.

From a cost standpoint, Vapotherm™ provides a cost-effective alternative to remaining on a ventilator or receiving conventional noninvasive positive pressure ventilation. The Vapotherm™ 2000i unit costs approximately $2400. The vapor exchange cartridges are $140 and can be used for 90 days without changing between patients. The patient charge is $17 per day of use, which includes the cost of Vapotherm™ specific nasal cannula tubing as needed. This daily charge is identical to conventional nasal cannula oxygen therapy at our hospital. The price for a neonatal nasal CPAP machine is $7500, with a $75 a day charge. In contrast, the average ventilator costs $32,000, with a patient charge of $320 per day.

While this case report clearly does not demonstrate the efficacy of high flow nasal cannula in the treatment of post-extubation stridor, we believe that Vapotherm™ therapy incorporates several theoretical principles that could contribute to the prevention of intubation and/or reintubation. Vapotherm™ uses humidified air, which has played a role in upper airway obstruction seen in croup. It adds oxygen therapy, which may alleviate air hunger, and it has the potential to add a component of noninvasive positive pressure, which has been used in some situations to decrease work of breathing and to prevent reintubation. Also, it may avert the use of steroids, which are avoided in the burn population if possible as they can inhibit wound healing and have been postulated to increase infectious complications. Our initial experience with Vapotherm™ high flow nasal cannula demonstrates that it is safe, potentially cost effective, and may have a role in the treatment of post-extubation stridor. Rigorous studies with appropriate controls are required to define the role of this novel technology in the management of post-extubation stridor in pediatric patients with inhalation injury.

Conflict of interest

The authors have no financial or personal conflicts of interest.

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