

Essential Practices

A clinical decision-making resource for the respiratory care professional



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Trends in Noninvasive Respiratory Support: Continuum of Care

Noninvasive ventilation provides ventilatory support without the use of invasive respiratory devices. It can often eliminate the need for intubation and preserve normal respiratory tract functions. Noninvasive positive pressure ventilation (NPPV) delivers a set pressure for each breath, as opposed to negative pressure ventilation, which exposes the chest wall to subatmospheric pressure during inspiration. NPPV is usually delivered by a nasal or face mask, thus eliminating the need for intubation or tracheostomy. NPPV can be given by a pressure-controlled ventilator, a volume ventilator, a bilevel positive airway pressure (BIPAP or bilevel ventilator) device, or a continuous positive airway pressure (CPAP) device. The main clinical rule with noninvasive ventilation is to use the most cost-effective and simplest method to achieve the desired therapeutic goals. The recent introduction of high flow oxygen therapy, NPPV, and CPAP, have provided a continuum of care that offers the respiratory therapist simpler, less costly options before proceeding to the more costly, invasive procedures. In this edition of Clinical Foundations, we describe these noninvasive strategies beginning with high flow oxygen (simplest and least costly) and proceeding to NPPV and CPAP.

High Flow Oxygen Delivery

By Jonathan Waugh PhD, RRT, RPFT

High flow therapy (HFT) delivers warm, humidified gas to the patient through a nasal cannula. Body temperature and pressure saturated gas can be beneficial, regardless of whether the patient is receiving supplemental oxygen, although the mechanism is not yet fully clear. Breathing cool, dry gases can produce deleterious effects in the respiratory tract and when delivered through an artificial airway, can magnify the negative impact of ventilation. HFT can be used in the emergency room and other settings and is suitable for patients high oxygen requirements. Discussed in this article are several devices used to deliver HFT. Also discussed are the many current and potential applications of HFT.

Noninvasive Ventilation

By Tim Op't Holt EdD, RRT, AE-C, FAARC and **William Pruitt**, MBA, RRT, CPFT, AE-C

Noninvasive positive pressure ventilation (NPPV) is a viable alternative to ventilating in many patients and continuous positive air pressure (CPAP) has several uses, including mobilizing secretions, reducing or preventing atelectasis, reducing air trapping in chronic obstructive pulmonary disease (COPD), and others. NPPV has been used as a bridge to successful extubation and in the treatment of new onset respiratory failure following extubation. Duration of ventilation has been shown to decrease in patients who were extubated and ventilated with NPPV, and were failing spontaneous breathing trials. Shortening the duration of ventilation also decreases the need for tracheostomy, the need for tube feeding, the incidence of nosocomial pneumonias, and death. Compared to invasive ventilation, NPPV has also been shown to decrease mortality, the incidence of nosocomial pneumonia, hospital length of stay and total duration of ventilation. Other topics of discussion in this article include the uses of wet or dry CPAP, fixed or variable gas delivery, and tips for dealing with claustrophobia and noncompliance.

High Flow Oxygen Delivery

By Jonathan B. Waugh RRT, RPFT, PhD

High flow therapy is the delivery of high inspired gas flows (ideally greater than the patient's peak inspiratory demand) which may or may not have an increased oxygen concentration. For a gas flow to fully supply a patient's resting minute ventilation, the gas should be warm and humidified (ideally at body temperature and pressure saturated [BTPS]). The importance of warming and humidifying inspired gas has been known for several decades.¹⁻⁶ Breathing cool, dry gases can produce deleterious effects such as mucosal damage, reduced ciliary motility, decreased mucus production, bronchospasm, and nasal discomfort and bleeding.⁷ Delivering cool, dry gases via an artificial airway can magnify the negative impact of ventilation (e.g. retained secretions, mucus plugging, atelectasis, increased work of breathing, hypoxemia, and hypothermia).⁸ Conversely, some studies have shown a protective or even therapeutic effect from inhaling warm, humidified gas (WHG).⁹ Heated humidification can prevent intraoperative hypothermia or hasten rewarming¹⁰ and has been shown to reduce or eliminate episodes of nocturnal asthma¹¹ and exercise-induced asthma.¹² These benefits can be observed without using supplemental oxygen.

Therapeutic administration of WHG to spontaneously breathing patients is not a new concept, but only in the past decade have nasal cannula been used. In 1987, the Oxygen Enrichment Company introduced the dishwasher-sized Tran-

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spirator MT-1000 which could produce up to 20 L/min at BTPS, intended to enhance cystic fibrosis secretion clearance. Two years later, a new model designed to treat race horses for exercise-induced pulmonary hemorrhage was found to be an effective both before and after treatment. Transpirator Technologies Inc. marketed a horse model which is currently used by many stakes winners and tracks in the USA and Canada. Although the company developed a model for human use, it was never brought to market. In 1997, Vapotherm (Stevensville, Maryland) licensed rights to develop a shoe box-sized device (Model 2000i) for human use using new membrane technology, similar to the membrane filter used in hemodialysis. This device can achieve

flow rates up to 40 L/min at BTPS and be used with infants to adults.¹³ Salter Labs (Arvin, California) introduced a nasal cannula and non-heated bubble humidifier in 2004 that could deliver flow rates up to 15 L/min with a little more than 70% relative humidity (RH).¹³ This flow range is higher than the traditional nasal cannula but not sufficient to meet a patient's full minute ventilation requirement (the resulting significant dilution with room air helps explain why ambient temperature is used). In 2005, Smiths Medical ASD (Weston, Mass.) introduced the AquinOx®, a heated aerosol (15-35 L/min at 95-100% RH) that uses a filter proximal to the patient designed to capture particulate water and allow only molecular humidity to pass through to pediatric or adult patients.

The most recent high flow nasal cannula (HFNC) devices come from Hudson RCI/Teleflex Medical (Durham, NC), Fisher & Paykel Healthcare (Laguna Hills, Calif.), and Southmedic (Barrie, Ontario). The Hudson RCI Comfort Flo™ Humidification System features a single limb, smooth bore, double heated wire circuit and a specialized humidification column capable of BTPS humidification at flows ranging from 1-40 L/min. Four sizes of cannula, from premature infant to adult, are packaged separately. The system is disposable, thus minimizing the risk of cross-contamination and bacterial growth. The system is intended for use with Aquapak® prefilled water products and is compatible with all of the ConchaTherm® heated wire capable heaters. (Hudson RCI product literature).

F&P Healthcare combines a heated humidifier (MR850), breathing circuit (RT329), and infant nasal cannula that will deliver about 2 L/min BTPS before triggering a 40 cm H₂O system pressure relief valve. Five new F&P low resistance cannulas designed for neonatal and pediatric use are now available with reported maximum flow rates ranging from 6-8 L/min BTPS. An adult high flow package capable of 50 L/min is scheduled

for release in Fall 2006.⁶¹ Southmedic is taking a new direction in HFT with the Oxymask™. The mostly open mask shell is designed to direct a plume of gas (24-90% O₂, depending on a selected flow of 1-40 L/min) at ambient temperature to the nose and mouth, blanketing them in a way that acts as a reservoir.

How Does High Flow Therapy Benefit the Patient?

Respiratory textbooks for the past twenty years have typically noted that the flow rate for a nasal cannula should not exceed 6-8 L/min. Some mention that higher flows at ambient temperature from a bubble humidifier can cause nasal discomfort, due to the expectation that the nasopharyngeal reservoir would be completely saturated. Therefore, the delivered oxygen concentration was thought to plateau at flow rates greater than 6-8 L/min. Oddly enough, earlier studies of oxygen appliances demonstrated that oxygen concentrations continued to increase at flow rates above 8 L/min. Kory et al¹⁴ and Poulton et al¹⁵ documented flow rates up to 10 L/min and reported that the fraction of delivered oxygen (FDO₂) continued to increase up to the highest flow tested. In 1976, Gibson et al observed that oxygen concentrations in the trachea continued to increase at flows as high as 15 L/min.¹⁶ More recently, Wetstein reported that an FDO₂ as high as 0.75 could be achieved at a flow rate of 15 L/min, depending on breathing pattern.¹⁷ Malinowski et al reported fractional oxygen concentrations up to 0.84 at a flow rate of 25 L/min.¹⁸ Using an anatomically correct head extension airway model, Tiep found that tracheal oxygen concentrations increased over the tested range of 10-30 L/min.¹⁹ These experiments indicate that oxygen delivery for a nasal cannula does not plateau at 6-8 L/min.

Published studies and case reports of patients treated with HFT by nasal cannula (HFT-NC) demonstrate that there can be a beneficial effect from BTPS high flows, independent of supplemental ox-

The clinical rule of using the most simple and cost-effective therapy to satisfactorily treat the patient has led many

oxygen (or in the form of decreasing the FDO₂ requirement). Several mechanisms of action have been discussed as possible explanations. Some authors have suggested that high flows of BTPS gas can impart significant but not excessive moisture to water-deficient airways, producing a stabilizing and perhaps protective effect. This may also enhance ciliary movement and mucous clearance. (It is well-known that airways contain pressure and temperature receptors and it is conceivable that these may be stimulated by high BTPS gas flow). A few studies indicate that high nasal cannula flow creates a small degree of positive airway pressure which would explain at least in part why oxygen requirements decrease and signs of decreased breathing effort is often seen.²⁰ Others argue that HFT by nasal cannula can flush the anatomic deadspace of the upper airways similar to



ComfortFlo (Hudson RCI, Teleflex Medical)

the effect of tracheal gas insufflation and thereby provide ventilatory assistance. In summary, we have documented evidence that high flows via nasal cannula can produce improvement but the mechanism of action has yet to be elucidated.

To obtain the potential benefits of high gas flows by nasal cannula, the gas must be properly conditioned to make it tolerable to the patient. Optimum humidity is achieved when the inspired gas is at body core temperature and at 100% RH.⁵ Mucosal dysfunction can often be seen with gas that is thermally inappropriate with humidity outside the optimal level.⁶ Every breath not at BTPS presents a water volume and energy (thermal) challenge to the airway mucosa which is typically handled well by the upper airways. When the challenge exceeds the homeostatic mechanism, then airway dysfunction begins and may progress to alterations in the ventilation-perfusion ratio and a decrease in compliance. Drying of the airways can produce an osmotic challenge to mucosal cell function²¹ and cause nasal congestion by altering mucosal blood flux²², but attempting to compensate with aerosolized or instilled water may be hazardous due to the potential of these methods to deliver excess water to the airways. Molecular humidity is the safest form of humidification for HFT (especially for young patients) because the water content is limited to what can be carried in the vapor phase.

What Are the Current and Potential Applications of HFT?

Many clinicians experienced in the use of HFT by nasal cannula use it in place of a nonrebreather mask (NRM). Walsh reported that CHF patients in the emergency room had higher oxygen saturations with a 20 L/min nasal cannula compared with NRM.²³ Spontaneously breathing patients with high oxygen requirements (e.g. interstitial pulmonary fibrosis, congestive heart failure, pulmonary edema, chronic obstructive pulmonary disease [COPD]) would be suitable

candidates for HFT. The clinical rule of using the most simple and cost-effective therapy to satisfactorily treat the patient has led many to use HFT as a way to avoid mechanical ventilation. In clinical reports by Taft (n=61) and Hill (n=29), patients had pre-HFT mean oxygen saturations of 88% and respiratory rates of 25 bpm or greater and all were able to avoid mechanical ventilation.^{24,25} Rojas et al (n=377) reported a 51% decrease in the use of mechanical ventilation, with a 97.3% decrease in nasal continuous positive airway pressure (CPAP).²⁶ Some HFT nasal cannula devices have the ability to deliver heliox and nitric oxide.²⁷⁻²⁹ Clinicians are using HFT-NC to enhance exercise tolerance for asthmatic and COPD patients.³⁰⁻³⁴ Successful traumatic and post-operative rewarming has been done with HFT-NC.^{35,36} Sreenan et al found HFT-NC as effective as nasal CPAP for treating apnea of prematurity and Martinez-Gomez reported increased success with infant extubations.^{37, 38} Lung transplant candidates needing to exercise prior to surgery have used HFT-NC tolerate pre-conditioning.³⁹

Case Study

Consider the following infant case study (adapted from a contribution by Douglas Petsinger, BS, RRT, Children's Healthcare of Atlanta, Atlanta, Georgia). The patient was a 3.0 kg, 36-week old infant with the diagnosis of coronary artery fistula and patent ductus arteriosus. The patient arrived in normal sinus rhythm, mild respiratory distress, and moderately

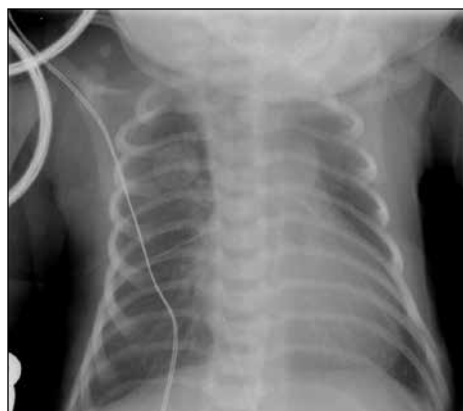


Figure 1. Chest film of patient in supine position prior to starting HFT-NC therapy.



Figure 2. Chest film of patient in supine position soon after starting HFT-NC therapy.

tachypneic with $f = 60-90$ bpm. Pre-ductal SpO_2 was 100% on 1 L/min oxygen via traditional nasal cannula. The initial umbilical line blood gas measurement (pH 7.27, $PaCO_2 = 47$, $PaO_2 = 35$, base deficit = -6 , $HCO_3 = 18$, and $SaO_2 = 63\%$) revealed mixed acidosis. The chest radiograph revealed eight ribs expanded and was otherwise unremarkable (see Figure 1).

Pre- and post-ductal SpO_2 measurements revealed a gradient of 13%. Nasal cannula flow was increased to 2 L/min without any change in the gradient. A 5% albumin infusion (10cc/kg) was given over 15 minutes without a significant change in status. The patient was placed on HFT-NC (Vapotherm 2000i) for respiratory distress and oxygenation difficulties. Coarctation of the aorta was ruled out by echocardiogram. Initial HFT-NC settings were 100% O_2 and a flow of 6 L/min (based upon CPAP settings and the concurrent hemodynamics). The pre- and post-ductal gradient resolved over a 15-minute period and the initial blood

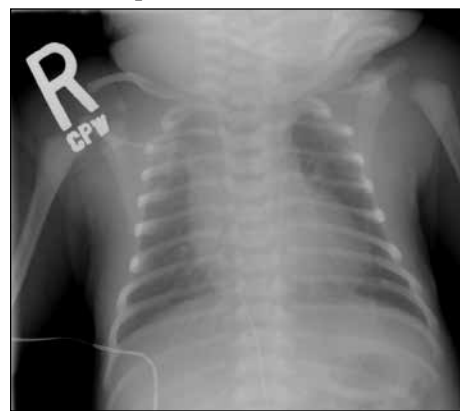


Figure 3. Chest film of patient in prone position the following morning after starting HFT-NC therapy.

gas measurement on HFT-NC revealed a pH of 7.34, a $PaCO_2$ of 44, a PaO_2 of 67, a base deficit of -2 with a HCO_3 of 22, and a SaO_2 of 92%. The patient also received a transfusion of packed red blood cells (45 cc) over a two-hour period. The pre- and post-ductal SpO_2 remained at 98%, enabling weaning of FIO_2 to 0.40 over a 2-hour period (see Figures 2 & 3).

The blood gas measurement on HFT-NC settings of 6 L/min and 40% O_2 had a pH of 7.32, $PaCO_2$ of 48, PaO_2 of 96, base deficit of -2 with a HCO_3 of 25, and a SaO_2 of 97%. Antibiotics were started on the patient when the referring hospital divulged an untreated maternal beta hemolytic *Streptococcus* infection 24 hours after transport. The ease of application of the HFT-NC system, the reduced risk of skin/nasal trauma-breakdown, and the ability to alter pulmonary function were strong points for using this modality for this case of respiratory distress due to parenchymal lung disease as evidenced by poor CO_2 clearance and maternal history.

Summary

At present, we have documented evidence that high flows via nasal cannula can produce patient improvement but the mechanism of action has yet to be elucidated. Further research is needed to determine if there is a particular flow for each of the infant, child, and adult flow ranges that would be a best starting point. The utility of HFT-NC should be investigated for more patient populations such as cystic fibrosis.

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Part I: Noninvasive Ventilation

By Tim Op't Holt, EdD, RRT, AE-C, FAARC

Noninvasive positive pressure ventilation (NPPV) has been seen as a viable alternative to ventilating any patient who does not show any contraindication to its use. The focus of this review will be the use of NPPV immediately after extubation as a means of shortening intubation time, its continued success in ventilating patients with exacerbation of COPD, and the marginal success in ventilating patients with hypoxemic respiratory failure.

NPPV has been used as a bridge to successful extubation (i.e. extubation before it would have normally been performed) and in the treatment of new onset respiratory failure following extubation.

Ferrer et al. observed that the duration of ventilation, among other variables, was decreased in patients who were extubated and ventilated with NPPV, and yet were failing spontaneous breathing trials.⁴⁰ These authors also demonstrated a decrease in the incidence of nosocomial pneumonia, increased survival, a decreased incidence of serious complications, decreased need for tracheostomy, and no need for sedation. These outcomes were attributed to a more normal breathing pattern (not rapid and shallow), and the ability of NPPV to improve hypoxemia and hypercapnia. Shortening the duration of ventilation also decreased the need for tracheostomy, the need for tube-feeding, the incidence of nosocomial pneumonias, and death. It seems that from this study, one could conclude that once a patient is stabilized on invasive ventilation and if they had no exclusion criteria for NPPV, that intubation is

likely to be successful. This seems to be particularly true for patients recovering from an exacerbation of COPD.

Burns et al came to similar conclusions after reviewing five trials among 171 patients with predominantly COPD.⁴¹ Compared to invasive ventilation, NPPV decreased mortality, the incidence of nosocomial pneumonia, hospital length of stay and total duration of ventilation (all $P < 0.05$). The duration of ventilation related to weaning was unchanged with the use of NPPV. Like Ferrer, these authors attribute the decrease in mortality to a reduction of nosocomial infection, this being the result of shorter endotracheal intubation time or less need for tracheostomy. Despite these outcomes, the authors were cautious to recommend NPPV for weaning, based on the small number of patients in some studies and heterogeneity in pooling the results of these studies. They note that while the outcomes are promising, “the net benefits, risks, and consequences associated with adopting the NPPV weaning strategy have not been fully elucidated.” They recommended that if NPPV weaning is to be adopted, it should be in patients with COPD in a controlled intensive care environment.

Another issue that has been studied is the effectiveness of NPPV postextubation after new-onset respiratory failure. The documented need for reintubation after new-onset respiratory failure is 13-19%. In this event, should patients be reintubated or placed on NPPV? While reintubation protects the airway, it is associated with a significantly higher mortality rate because of intubation-related risks and

ventilator-related complications (i.e. nosocomial pneumonia). Esteban et al found that noninvasive ventilation did not decrease mortality in patients who had to be reintubated and speculated on reasons why NPPV was ineffective in preventing the need for reintubation.⁴² These included the health care team's experience with NPPV, the timing of implementation, and the demographics of the study population (only 10% were COPD). The delay in reintubation may have been the reason for this increase in death and may have only prolonged the inevitable clinical deterioration, characterized by cardiac ischemia, increased respiratory muscle fatigue, aspiration pneumonitis, and complications of emergency reintubation. One might conclude from these studies that NPPV may be effective in preventing postextubation respiratory failure, but it must be implemented shortly after extubation. Delaying reintubation until 48 hours after initial extubation causes significant morbidity and mortality.

This conclusion is supported by a study by Nava and colleagues in which preventive application of NPPV (within 48 hours) after a successful spontaneous breathing trial and extubation reduced the need for reintubation.⁴³ The etiology of extubation failure and the time to reintubation are both strong predictors of outcome. The need for reintubation in this 48-hour period is based on clinical signs of failure such as tachypnea, new-onset accessory muscle use, and abdominal paradox.

In a similar study, Ferrer and colleagues attributed several factors to explain the success of NPPV in avoiding postextubation respiratory failure. These include the high percentage of chronically hypercapnic COPD patients in the study (51%), early application on NPPV, use of a ventilator specifically for NPPV, and staff experience with NPPV.⁴⁴ Hypercapnia during weaning attempts should alert the staff to start measures such as NPPV immediately following extubation.

NPPV is commonly used in patients

with an exacerbation of COPD. The evidence for this will not be reviewed here, because a trial of NPPV is now the standard of care for patients with COPD exacerbation. Other questions remain about the use of NPPV in stable COPD, in a mild exacerbation, the effects of a variety of patient interfaces, and the appropriate time to extubate the COPD patient prior to initiation of NPPV.

A two-year Italian multicenter trial of NPPV investigated the potential benefits of adding NPPV to long term oxygen therapy (LTOT) in patients with stable COPD and chronic hypoxemia.⁴⁵ Results demonstrated an improvement in daytime PaCO₂, dyspnea, and health related quality of life in the NPPV + LTOT group, compared to LTOT alone. The authors concluded that while there were improvements in ventilation, dyspnea, and health-related quality of life, further study was needed to determine if LTOT + NPPV was effective in reducing the frequency and severity of exacerbation.

In COPD exacerbation, NPPV has been shown to reduce the need for intubation, and to decrease total duration of ventilation, hospital length of stay, mortality, work of breathing, and pneumonia. Most of the research has been directed to patients with severe exacerbation (pH < 7.3, PaCO₂ > 50 mm Hg). Others have sought to determine if NPPV is as effective in patients with a mild exacerbation (pH > 7.3).⁴⁶ In the NPPV group, the Borg dyspnea index was decreased (P=0.004). However, NPPV was not well tolerated in this group of patients. Over 50% of patients did not wear the mask as directed. While there was a decrease in dyspnea, other benefits were not demonstrated. Therefore, the authors could not recommend NPPV for this cohort.

One of the most common reasons for failure of NPPV is patient intolerance of the mask. While oronasal masks permit mouth breathing and reduce mouth air leaks, they interfere with speech, eating, and expectoration and may cause claustrophobia. Nasal masks, while comfort-



Hybrid Dual-Airway Interface (Hudson RCI/Teleflex Medical)

able, permit more mouth leakage and are less reliable at maintaining tidal volumes. Kwok et al determined that patients with acute respiratory failure treated with NPPV are more intolerant of nasal, rather than oronasal masks, primarily due to mouth air leaks.⁴⁷ Rather than condemn the nasal mask, the authors concluded that the masks performed similarly in other respects. It may be common practice to begin NPPV with an oronasal mask. Once the patient is comfortable and stable, a trial of the nasal mask may be warranted if the patient can control any mouth air leak. A new dual-airway interface that consists of an oral cushion that covers the mouth and two nasal pillows that fit into the patients' nostrils will be available in 2007. At this time there are no published studies.

More recently, a full head helmet has been developed and tested for use during NPPV. This clear plastic helmet adheres at the neck and has straps under the axillae. The helmet is connected to the ventilator via a standard 2-tube circuit.⁴⁸ The helmet was better tolerated and allowed longer NPPV times with minimal air leaks, so it may be a viable alternative to the oronasal mask. Increased PaCO₂ in the helmet group was thought to be due to CO₂ rebreathing and less reduction in inspiratory effort (i.e. the patient works harder with the helmet on when the treatment is failing). The authors recommended the use of the helmet for COPD patients who do not tolerate the

face mask. A new product has been recently released that utilizes a nasal pillow or prong and resembles an oversized oxygen cannula (Nasal Aire II Critical Care, Hudson RCI/Teleflex Medical). There are no published studies on this new product as of yet.

In a controlled prospective multicenter study of 90 patients with an infectious exacerbation of unspecified severity (unknown pH and PaCO₂), Wang and associates examined the issue of when to extubate the patient with exacerbation of COPD in order to implement NPPV and take advantage of its known outcomes.⁶² They hypothesized that if a pulmonary infection control (PIC) window could be identified, early extubation followed by NPPV could be successful. The PIC window was identified as the time when the following criteria were met: significantly decreased radiographic infiltrates, reduced quantity of sputum, decreased body temperature, normal leukocyte count, and a mandatory ventilator rate of 10-12 breaths/minute with PSV of 10-12 cm H₂O. When the PIC occurred, patients were randomized to remain intubated with a standard weaning protocol, or be extubated to NPPV. The strategy was successful. The NPPV group had a shorter duration of ventilation by about 5 days, a lower incidence of nosocomial pneumonia, fewer ICU days, and a lower hospital mortality. It appears that if a PIC can be identified and the patient successfully extubated, the other complications of invasive mechanical ventilation may be avoided.

Although NPPV is well established in hypercapnic respiratory failure, its use in hypoxemic respiratory failure is not as clearly established. In congestive heart failure (CHF), most patients are treated with diuretics, oxygen and nitrates, with some patients also requiring CPAP. The question of the usefulness of NPPV in CHF patients remained in the late 1990s, and several studies revealed a decrease in intubation rate when NPPV was used as cited in the study by Levitt.⁴⁹ Results

demonstrated no difference in respiratory rate, SpO₂, dyspnea score, or hospital stay.

Ferrer randomized patients to receive 50% oxygen by entrainment mask or NPPV.⁵⁰ Intubation rate for the group was significantly less (P<0.01) when NPPV was used, a difference which persisted in the pneumonia subgroup, but not for patients with acute respiratory distress syndrome (ARDS), trauma, or CHF. This observation led the author to question the advice of subsequent studies of NPPV in patients with ARDS due to the severity of hypoxemia and impairment of pulmonary mechanics. In addition to the decreased intubation rate, patients in the NPPV group had a shorter hospital stay among intensive care unit (ICU) survivors and a lower ICU mortality.

In a review of 31 randomized clinical trials of NPPV in acute hypoxemic respiratory failure, results varied depending on etiology of hypoxemia.⁵¹ Half of the trials showed a lower rate of intubation with NPPV. Of seven trials reporting length of ICU stay, two suggested benefit from NPPV. The pooled results favored NPPV. They concluded that patients with acute hypoxemic respiratory failure are less likely to require endotracheal intubation when NPPV is added to standard treatment. There may be a potential to improve patient outcome, however, small sample sizes and heterogeneity of study samples prevented a more definite conclusion. They noted that the literature does not support routine NPPV for patients presenting with acute hypoxemic respiratory failure, but strong consideration should be given to its use in patient groups with a known high mortality rate, if they are normally required to undergo invasive mechanical ventilation (immunosuppressed patients or post-thoracotomy patients).

In summary, the successful application of NPPV in patients with hypoxemic failure is less certain than in those with COPD.

Part II: Continuous Positive Airway Pressure

Bill Pruitt, MBA, RRT, CPFT, AE-C

Continuous positive airway pressure (CPAP) has been found to be effective in treating sleep disorders such as obstructive sleep apnea and hypopnea, and has been extensively utilized in these sleep disturbances. However, CPAP has also been used to help patients mobilize secretions, reduce or prevent atelectasis, reduce air trapping in COPD, reduce severe asthma attacks and cardiogenic pulmonary edema, and treat hypoxemia. Long-term use, particularly in patients with sleep disorders, has revealed that patient noncompliance is a problem. Compliance can be affected by many issues, including self-image and appearance, feelings of claustrophobia, discomfort with the interface (pressure from the nasal mask, nasal pillows, oronasal mask), discomfort due to the headgear and straps around the head, irritation due to leaks around the interface, conjunctivitis, nasal congestion, nose bleeds, mouth breathing, oronasal drying, and skin irritation.⁵² Several of the problems vary with patient body position and with the level of required treatment pressure, either of which can cause leaks or alter pressure points on the face or head. According to the literature, trials with various masks and headgear are the most common approach to finding the right system.

In a study conducted in France, researchers looked at CPAP compliance over a 9-year period.⁵³ Of the 137 consecutive patients enrolled in the study, (after accounting for 30 patients who died and 5 lost to follow-up), 30 (29%) patients stopped using CPAP, most of them during the first five years. In research related

to the causes for poor compliance, most of the effort has focused on issues related to humidification, use of more sophisticated machines that alter delivery of the positive pressure, and patient education. In this article, we look at recent findings on these three topics and discuss several issues related to CPAP interfaces

Wet or Dry CPAP?

CPAP devices use air flow to create a positive pressure in the oropharynx and laryngopharynx. The flow may be constant or varying based on the design of the machine, and most CPAP systems have an intentional outlet to vent the excess flow. Thus, there is a tendency to dry the oronasal mucosa which causes discomfort and noncompliance. In a randomized, controlled, parallel, double-blinded study of 70 patients with newly diagnosed obstructive sleep apnea syndrome, Duong et al compared the use of heat humidification (n=34) versus placebo (n=36) during the first night of nasal CPAP (nCPAP) titration.⁵⁴ Following night-time nCPAP titration, the patients completed a questionnaire to assess their quality of sleep, toleration of the nCPAP, likelihood to use nCPAP in the future, and level of nasal side-effects (i.e. stuffiness, discharge, etc.) Nasal airway resistance was measured with a published, standardized procedure in accordance with the International Committee on Objective Assessment of the Nasal Airways.⁵⁵ The authors concluded that compared to placebo, heated humidification in the initiation of nCPAP did not provide significant benefit in reducing nasal airway resistance, symptoms, toleration of the therapy, nor did it affect the likeli-

hood of future use.

In another study covering a longer period of time, researchers in a Veterans Affairs hospital examined the effect of heated humidification on patient compliance and quality of life.⁵⁶ A total of 98 patients with obstructive sleep apnea (OSA) were started on nCPAP and randomly assigned to heated humidification (n=49) or standard care (n=49). Data was gathered regarding nCPAP compliance, quality of life, subjective sleepiness, nasal symptoms and side effects after 1, 3, and 12 months of therapy. The authors found no significant difference in compliance, sleepiness, or quality of life. Initially at 1 month there was a significant difference between groups in the incidence of dry mouth and nose. However, at 3 and 12 months, there was no significant difference in these side effects. In a 2003 cross-over study comparing 3 weeks of humidified nCPAP with non-humidified nCPAP, there was no difference between treatment arms in terms of subjective treatment satisfaction or alertness. The authors concluded that although the results support the use of heated humidification as a strategy to reduce side-effects related to CPAP, there is insufficient evidence to support its routine use.⁵⁷

For those cases that may need or want humidification, companies are offering CPAP units to newly diagnosed patients that include a built-in humidifier as an integral part of the device (for example, see the Resmed S8 or Respironics REM star M series CPAP units.) For those who already have a CPAP unit and need to add humidification, a stand-alone can be added to the system (for example, see the Hudson/RCI/Teleflex Medical, Conchatherm® 2000 or the Fisher & Paykel HC150 humidification units.)

Fixed or variable?

Constant or fixed CPAP units deliver a constant flow of air whereas auto-adjusting CPAP units titrate the flow throughout the night to optimize the pressure. Various devices are available

Patients with the poorest adherence to CPAP therapy

and each uses its own, unique algorithm to set the flow. Because they allow one to vary the flow, the assumption is that automatic adjustments (APAP) would be more comfortable and should increase compliance. A 2004 Cochrane review of interventions for improving compliance with CPAP in patients with OSA examined 14 studies comparing APAP to fixed CPAP.⁵⁸ The authors evaluated parameters such as patient compliance (hours per night of CPAP usage) percentage of days when CPAP is used, patient preference, patient withdrawal from treatment, daytime sleepiness, arousals, treatment pressures, apnea/hypopnea index, quality of life, and adverse effects/tolerability. After analyzing the results, they concluded that the evidence did not justify the use of APAP in unselected patients. There was only marginal benefit for patients needing treatment pressures above 10 cm H₂O, or patients who had been identified as not complying with fixed CPAP.

Knowledge/Understanding: Keys to success?

As noted, noncompliance has been a problem with CPAP. Aside from the problems related to the device and interface, the patient's acceptance of CPAP treatment also contributes to the compliance issue. Chasens et al evaluated claustrophobia as a cause for noncompliance and found that patients with the poorest adherence to CPAP therapy had significantly higher claustrophobia scores.⁵⁹ Of the 153 patients who participated in the study, 30% reported that claustrophobia

was a problem. However, they also found that there was a tendency for claustrophobia scores to decrease over time, suggesting that frequent use and familiarity with the sensation of wearing a CPAP interface can improve compliance in patients who initially experienced claustrophobia. Patients undergoing magnetic resonance imaging (MRI) also experience claustrophobia and various methods have been used to reduce it, including cognitive behavioral therapy, combination therapy utilizing distraction and guided threat reappraisal, and desensitization. They recommend these strategies as potentially useful interventions to improve CPAP compliance in claustrophobic patients.

There is some evidence to support patient education for reducing sleep problems associated with CPAP and in improving compliance. In a Swiss study by Golay et al (n=35; 22 male, 13 female), a one-day educational program was given to patients diagnosed with OSA who had been using CPAP for at least 6 months prior to enrollment.⁶⁰ Spouses were included in the program. The topics covered in the program included, "What does CPAP do?", "How to use CPAP", "The benefits of CPAP", "Daily life with CPAP and its disadvantages", "What I can do to address my particular situation?" A round table discussion with the patient and spouse on "Intimacy and CPAP" was also included. The night following the program, the patients were examined to establish baseline sleep data. They were examined again at 3 months and the sleep scores were compared with baseline. Preliminary results reflected a significant decrease in the Epworth Sleepiness Scale (11 +1 before, 8 + 0.8 after; p<0.05) and 24% of the patients increased their usage of CPAP by more than one hour.

Interfaces – the bridge between CPAP machine and patient

There are many manufacturers of CPAP devices and almost all have their own interface or several interfaces. (See Table 1) The interfaces most often used

for long-term CPAP include the nasal mask, nasal pillows, or the oronasal mask. A new design in interface technology has combined an oral mask with nasal pillows to deliver the air flow/pressure to both upper airway openings. Full-face mask or whole head applications (sometimes called a CPAP helmet) have been explored in more acute settings with varying degrees of success. Each interface is held in place by headgear and straps around the head. Some devices call for two or three straps, others use one. The straps are adjustable by using hook and loop connections. (In the helmet application, the device is sealed around the neck with a soft cushion and held in place with adjustable straps around the underarms.)

Problems contributing to noncompliance

Nasal and oronasal mask designs can cause a pressure point on the bridge of the nose. Interfaces may have a brace that rests against the forehead, also causing a pressure point. Some of the nasal pillow systems and the oral mask/nasal pillow combination design avoid the problems related to pressure points on the nose or forehead, but may cause pressure points on the nares. Headgear may cause some minor discomfort as the head lies on the pillow but this can usually be relieved by repositioning the head. Some patients dislike using CPAP due to problems with swallowing while receiving positive pressure. As they swallow, the positive pressure is trapped in the Eustachian tubes and pressurizes the eardrum. This creates the same sensation as that experienced during an airline flight in a pressurized cabin but the pressure cannot be relieved unless the interface is removed and the pressure is released. If the patient opens his mouth while wearing a nasal mask or nasal pillows, the flow of gas from the CPAP device constantly rushes out of the mouth. A chin strap may be used to stop this from happening. Finally, it is most difficult to speak while receiving CPAP therapy, again due to the rush of air that

Table 1. CPAP masks and interface devices

Mfg/Dist.	Mask/Interface
AEIOMed	Headrest
DeVilbiss	Serenity
Hans Rudolph	VIP 7500, VIP 76
Fisher & Paykel	Aclaim, HC405, HC406, HC431, HC481, oRACLE
Puritan Bennett	Adam, Breeze, Dreamseal
Swift	Resmed Activa, Mirage / Ultra-Mirage
ResMed Corp	Vista
Respironics	UltraMirage
	Comfortclassic, Comfortcurve, Comfortfull, Comfortgel, Comfortselect, Profile Lite, Simplicity, Total Face
Somnotech	Nasal Mask
Hudson RCI/Teleflex	Hybrid, Nasal-Pap Freestyle, Nasal-Aire II, Nasal Aire II Petite, Respica
Tiarra	Snapp
Viasys Healthcare	Lyra

Derived from the American Sleep Apnea Association Apnea Support Forum <http://www.apneasupport.org/about2841.html> (accessed 9/2/06) and Product Index (2006) RT Journal for Resp Care Practitioners 19(4):12.

comes out of the mouth due to the flow delivery.

Patients are evaluated in a sleep disorders center (SDC) to see if there is a sleep disorder present and if the problem may be treated by CPAP. The SDC will often use one type of interface of the appropriate size to fit the patient's face and perform a "CPAP study" to establish the right settings (CPAP or bi-level pressure, supplemental oxygen, etc.) Should the patient have problems with the interface, another may be tried – however, most SDCs do not have a wide range of different interfaces designs since there are



Nasal-Aire II (Hudson RCI, Teleflex Medical)

so many choices and the cost becomes prohibitive to keep a large number of designs on hand. Beyond these obstacles, some manufacturers recommend using only their mask with their CPAP device exclusively. Finally, as new designs/devices are introduced to the medical market, most SDCs cannot easily retire the older equipment and change to newer releases.

Once the parameters for treatment are established, the patient receives a prescription for CPAP and is referred to a home health or durable medical equipment (DME) company to receive their CPAP system. If the prescription specifies a particular interface, the company will supply it. If not specified, the company will often use the same approach as seen in the SDC; the right size device will be tried in the home setting and if there are compliance problems, the company may have one or two other optional interfaces to try. The same limitations apply in the home as seen with the SDC regarding the variety of interfaces available (too many choices, prohibitive cost, manufacturer-specified interfaces, release of new designs/devices). Moreover, some patients may not inform the DME company of any problems after the initial visit and setup, and may just stop using the device. If neither the SDC nor the DME schedules a follow-up visit with these patients, they may never use their device. This is an unfortunate situation that may be avoided provided the proper interface is used and more emphasis is placed on follow-up with CPAP patients. Still, the selection of the patient interface and headgear is often arbitrary – depending on the SDC and DME. However, the appropriate selection is usually quite subjective and individualized depending on the patient's cooperation, comfort, and patience.

CPAP has been shown to be effective in treating a variety of problems and has been a great help to many thousands of patients. However, a significant number of patients become noncompliant and miss the benefits of this intervention.

Problems that contribute to noncompliance are sometimes difficult to correct due to the pressures, flow, interfaces, and head straps needed to properly administer CPAP. Trials with various configurations of masks, nasal pillows, and headgear are sometimes necessary to find the right combination, provided the clinician can entice the patient continue using the CPAP system while the various configurations are being tried, and depending on being able to choose from various devices. As we have seen from these studies, neither humidification nor APAP have made a substantial impact on compliance. Providing education and understanding, and dealing with the discomfort of claustrophobia may be the most effective tools for increasing compliance once the best fitting, best feeling interface has been selected.

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Questions

- Which of the following statements are true, based on the literature cited about NPPV during weaning in COPD?
 - NPPV should be implemented following stabilization of the COPD patient on CMV, provided there are no contraindications for NPPV.
 - NPPV is likely to decrease the incidence of nosocomial infection.
 - NPPV may be delayed for 48 hours after new-onset ventilatory failure to allow time for conventional therapy.
 - NPPV is more effective in severe exacerbation than in mild exacerbation.
 - I, II, III only
 - II, III, IV only
 - I, III, IV only
 - I, II, IV only
- What was concluded about the addition of NPPV to long term oxygen therapy (LTOT)?
 - NPPV in addition to LTOT decreases the severity of exacerbation.
 - NPPV in addition to LTOT decreases the frequency of exacerbation.
 - NPPV in addition to LTOT improved gas exchange.
 - NPPV in addition to LTOT improved gas exchange and Health-Related Quality of Life.
- One of the most common reasons for failure of NPPV is:
 - mask intolerance
 - failure to decrease the PaCO₂
 - failure to increase the PaO₂
 - continued dyspnea
- The pulmonary infection control window is characterized by all of the following EXCEPT a decrease in:
 - sputum production
 - dyspnea
 - body temperature
 - infiltrates on the chest radiograph
- In a review of 31 randomized clinical trials of NPPV in acute hypoxemic respiratory failure, Keenan found that:
 - Standard treatment + NPPV decreased the need for intubation
 - Study design suffered from small sample size and heterogeneity
 - NPPV should be routine for this cohort
 - The head helmet is the most effective interface
- Which of the following is NOT included in the indications for CPAP?
 - Reduce atelectasis
 - Treat hypopnea
 - Treat non-cardiogenic pulmonary edema
 - Reduce air trapping in COPD
- In the research by Duong et al, what parameter was measured by using a published standardized procedure?
 - Quality of sleep
 - Nasal airway resistance
 - Tolerance of nCPAP
 - PAP heated humidifier output for water vapor
- In the Veterans Affairs hospital study, Madar found a significant difference at one month of use between the CPAP group receiving an intervention and the CPAP control group in which of the following?
 - Compliance
 - Quality of life
 - Subjective measure of sleepiness
 - Incidence of dry mouth and nose
- In the Cochrane review examining improvement of compliance with CPAP, which of the following patient groups showed a marginal benefit for using auto-adjusting CPAP?
 - Patients who required supplemental oxygen greater than 3 L/m
 - Patients who needed treatment pressures above 10 cm H₂O
 - Patients with an apnea/hypopnea index greater than 12 per hour
 - Patients with a Body Mass Index greater than 35.
- Which of the following are limitations for DME companies in trying to establish the correct interface for a CPAP patient?
 - Too many possible devices on the market
 - The cost of the existing interfaces prohibits having a variety of choices
 - Retiring older devices to bring on new interface designs is challenging
 - All of the above
- The maximum adult flow settings for currently available high flow nasal cannula devices range from _____ L/min.
 - 6 to 8
 - 10 to 35
 - 15 to 40
 - 20 to 60
- Which of the following statements are true about high flow nasal cannula devices?
 - All devices marketed as "high flow nasal cannula" deliver BTPS gas.
 - All devices marketed as "high flow nasal cannula" can be used with infants.
 - All devices marketed as "high flow nasal cannula" use a variation of an aerosol nebulizer to humidify gas delivered to the patient.
 - All devices marketed as "high flow nasal cannula" generally produce a higher FDO₂ as the flow rate increases.
- Published research on the effects of warm, humidified gas indicates which of the following?
 - High flows of oxygen and BTPS gas produce positive effects independent of each other
 - BTPS gas at a FIO₂ of 0.21 can produce beneficial effects in some patients
 - High flow via nasal cannula typically generates a small amount of positive airway pressure
 - Insufficient humidification leading to drying of the airways can cause nasal congestion
 - I, II
 - I, III
 - I, II, III
 - I, II, III, IV

This program has been approved for 2.0 contact hours of continuing education (CRCE) by the American Association for Respiratory Care (AARC). AARC is accredited as an approver of continuing education in respiratory care.

To earn credit, do the following:

- Read the educational offering (both articles).
- Complete the post-test for the educational offering online at: <http://www.saxetesting.com/crce/>
The questions are the same as above
- Complete the learner evaluation.
- To earn 2.0 contact hours of continuing education, you must achieve a score of 75% or more. If you do not pass the test, you may take it again one more time. You will not be charged to take the test a second time.
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Participant's Evaluation

The goal of this program is to educate healthcare professionals on the management of the difficult airway in prehospital and hospital settings.

1. What is the highest degree you have earned? Circle one.

- Diploma
- Associate
- Bachelors
- Masters
- Doctorate

2. Indicate to what degree were you able to meet the objectives of this program:

Objectives

Upon completion of the course, the reader was able to:

1. List the various types of high flow nasal cannula devices currently available.

Strongly Agree Strongly Disagree
1 2 3 4 5 6

2. Describe the benefits of high flows of BTPS delivered via nasal cannula.

Strongly Agree Strongly Disagree
1 2 3 4 5 6

3. Identify potential applications of high flow nasal cannula therapy.

Strongly Agree Strongly Disagree
1 2 3 4 5 6

4. Describe the variables that been improved in patients with COPD as a result of the use of early NPPV during the weaning process.

Strongly Agree Strongly Disagree
1 2 3 4 5 6

5. Describe the ASA difficult airway algorithm.

Strongly Agree Strongly Disagree
1 2 3 4 5 6

6. List the indications for continuous positive airway pressure.

Strongly Agree Strongly Disagree
1 2 3 4 5 6

Please indicate your agreement with the following statement. "The content of this course was presented without bias of any product or drug."

Strongly Agree Strongly Disagree
1 2 3 4 5 6

Answers

- | | | | | | | | | | |
|---|----------------------------|----------------------------|----------------------------|----------------------------|----|----------------------------|----------------------------|----------------------------|----------------------------|
| 1 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 8 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 2 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 9 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 3 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 10 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 4 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 11 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 5 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 12 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 6 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | 13 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D |
| 7 | <input type="checkbox"/> A | <input type="checkbox"/> B | <input type="checkbox"/> C | <input type="checkbox"/> D | | | | | |

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