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High Flow Nasal Cannula

Meagan N. Dubosky, MS, RRT-ACCS, NPS, AE-C

Heated and humidified high-flow nasal cannula (HFNC) usage has gained popularity in the management of patients with moderate to severe hypoxemia. Capable of providing gas flow rates up to 60 LPM, HFNC therapy can potentially exceed the patient’s inspiratory flow demands resulting in a fixed delivery of the desired fraction of inspired oxygen (FiO₂), ranging from 0.21 to 1.0. Its reported effectiveness and improved patient comfort warrants clinicians to understand how to apply and manage this oxygen therapy device. This article will explain the HFNC’s evolution, potential mechanisms of action, use in various patient conditions, and suggest a recommended application and management.

Panel Discussion: High Flow Nasal Cannula: Opinions from the Experts

Moderator: David Vines, PhD, RRT, FAARC
Panelists: Jonathan Waugh, PhD, RRT, FAARC
           Robert Joyner, PhD, RRT, FAARC
           Ronny Otero, MD, FAAEM, FACEP

In this panel discussion, four experts convene to discuss topics such as the role and potential benefits or hazards with the use of HFNC in the management of acute hypoxemic respiratory failure, the role and potential benefits or hazards with the use of HFNC in acute exacerbation of COPD patients, the role of HFNC in the management of patients with chronic conditions in subacute or home care, improving patient comfort and tolerance with HFNC, weaning from HFNC, and whether or not the size of the bore of the HFNC makes a difference. A full list of references is included.
First utilized in neonatal and pediatric respiratory care, HFNC is a first-line therapy in managing patients with respiratory distress syndrome, apnea of prematurity, hypoxic respiratory failure and hypoxemia post extubation. With nasal prongs now tailored to fit adults, the potential advantages for those with dyspnea and hypoxemia have increased.1,2,3

Mechanisms of Action

Dead Space Washout

The washout of expired CO₂ from anatomical dead space is thought to be one of the primary mechanisms contributing to the success of HFNC therapy.1,2

Increased work of breathing, secretion clearance, patient tolerance as well as avoidance of intubation.

Flow Demands

As stated earlier the high flow provided by this device meets or exceeds the inspiratory flow demands of a patient allowing a more precise FiO₂ delivery.2 Patients in respiratory distress often have inspiratory flow rates that exceed traditional low flow device outputs. Intubation of room air occurs with all oxygen delivery devices, but is minimized with the HFNC, especially with closed-mouth breathing.5

Clinical Applications

The main indication for use of HFNC is to support spontaneously breathing patients with high oxygen and/or flow requirements with moderate to severe hypoxemia and increased work of breath. Potential benefits consist of improved oxygenation, work of breathing, secretion clearance, patient tolerance as well as avoidance of intubation.1,2,3,4

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Introduction

Heated and humidified high-flow nasal cannula (HFNC) usage has gained popularity in the management of patients with moderate to severe hypoxemia. Capable of providing gas flow rates up to 60 LPM, HFNC therapy can potentially exceed the patient’s inspiratory flow demands resulting in a fixed delivered of the desired fraction of inspired oxygen (FiO₂) ranging from 0.21 to 1.0.1-3 Its reported effectiveness and improved patient comfort warrants clinicians to understand how to apply and manage this oxygen therapy device.4 This article will explain the HFNC’s evolution, potential mechanisms of action, use in various patient conditions, and suggest a recommended application and management.

The Evolution of HFNC

Oxygen therapy has long been used in the treatment of hypoxemia and has evolved in the past two decades.1 Low flow systems, capable of delivering 1-15 LPM, include the nasal cannula, simple mask and partial/nosebreathing mask. These devices deliver a variable FiO₂ due to the delivered oxygen mixing with room air being inspired by the patient. The amount of delivered FiO₂ is associated with lower FiO₂ settings. Generally speaking, a FiO₂ of 0.40 or higher is associated with an air entrainment ratio that may not meet a majority of patients’ inspiratory flow demands. A HFNC system combines an air/oxygen blender with an active humidity system, allowing for independent control of temperature, FiO₂ and gas flow rates ranging from 2-8 LPM in infants and 16-60 LPM in adults.1,5,5,11 When a gas flow rate is 60 LPM or higher the device is considered to deliver a fixed FiO₂ and this flow exceeds most patients’ inspiratory flow rates.1,5,5,11

High flow systems, such as air entrainment masks, provide a more precise FiO₂ than low flow systems but have lower tolerance due to mask discomfort and inadequate heat and humidification.5,10 This fixed FiO₂ is associated with lower FiO₂ settings. Generally speaking, a FiO₂ of 0.40 or higher is associated with an air entrainment ratio that may not meet a majority of patients’ inspiratory flow demands. A HFNC system combines an air/oxygen blender with an active humidity system, allowing for independent control of temperature, FiO₂ and gas flow rates ranging from 2-8 LPM in infants and 16-60 LPM in adults.1,5,5,11 When a gas flow rate is 60 LPM or higher the device is considered to deliver a fixed FiO₂ and this flow exceeds most patients’ inspiratory flow rates.1,5,5,11

The washout of expired CO₂ from anatomical dead space is thought to be one of the primary mechanisms contributing to the success of HFNC therapy.1,2

Metabolic Expenditures

Resting energy expenditure, an estimate of base metabolic rate, is increased in critically ill patients and those with abnormal pulmonary mechanics.1,2 Decreasing the energy used by the respiratory muscles to breathe and the upper airway to condition inhaled gases may benefit those who are ill and in respiratory distress. Variable resistance is created by the nasopharynx with more resistance created during the inspiratory phase than the expiratory phase. Patients with an increased respiratory rate spend more time working to overcome this inspiratory resistance. Traditionally CPAP was used to split these airways open and normalize functional residual capacity (FRC), consequently, reducing the work load. It is likely that HFNC meets the flow demands of the patient and when the patient’s mouth is closed, in turn decreasing energy used in resistive work of breathing.2,5,12 Energy is also required to raise the temperature of room air and to vaporize water content creating gas conditions that are body temperature (37°C) and fully saturated at 100% relative humidity. The nasal passage heats and humidifies air under normal conditions, but is stressed when cold, dry medical gas is administered. This issue too is resolved with the use of heated and humidified HFNC.1,2

Gas Conditioning & Comfort

Another potential benefit of the heated and humidified gases being delivered is improved secretion clearance and patient comfort. Unconditioned medical gas administration moves the isotherm saturation boundary (ISB) further into the inspired gas. This shift can damage ciliary function and dehydrate mucosal tissue creating retention of secretions. A bench study evaluating the effects of gas humidification on human airway epithelial cells found an increase in inflammation markers following 8 hours of low humidity.2,5 Aside from cellular damage, breathing cold, dry medical gas can lead to discomfort and pain. Numerous studies have provided subjective data stating that patients better tolerated HFNC when compared to other devices, including NIV.2,5,5,11,13,14 Often times comfort leads to compliance and in patients refusing to wear conventional oxygen masks or NIV interfaces, the HFNC has been shown to be more comfortable. This is likely due to the less intrusive, soft nasal cannula delivering heated and humidified airflow.2,5 Perceived comfort may also be directed related to the patient’s ability to eat, drink and speak freely while on HFNC.

Potential benefits consist of improved oxygenation, work of breathing, secretion clearance, patient tolerance as well as avoidance of intubation.

Acute Hypoxemic Respiratory Failure (AHRF)

Respiratory failure occurs when the lungs can no longer achieve gas exchange in a manner that is suitable to support life if left untreated. Hypoxemic respiratory failure (Type I) is a failure to oxygenate and ventilatory failure (Type II) presents with a rise in carbon dioxide and an inability to clear it. Noninvasive ventilation (NIV) is a cornerstone treatment for those in Type II respiratory failure but data has lacked regarding NIV use in Type I or AHRF. Frat et al recently published back to back studies exploring HFNC in this population. The first clinical study (n=310) compared HFNC, standard oxygen and NIV in patients with AHRF, defined as a partial pressure of arterial oxygen to the fraction of inspired oxygen (P/ F) of ≤ 300 mm Hg without hypercapnia.26 At day 28 was the primary outcome with all-cause mortality in the intensive care unit (ICU), 90-day mortality and ventilator free days at day 28 recorded as secondary outcomes. They found no significant difference in the primary outcome of 28 day extubation rates amongst the 3 devices, although the rate was higher in the NIV and standard oxygen groups. A difference was found favoring the HFNC in 90-day mortality. In a subgroup analysis, they did report a benefit in intubation rates in patients with P/F ratio of less than 200. The study team speculated that the lower mortality rate may have resulted from the overall effects of less intubation. It was reported that at 1-hour post study enrollment, subjective measures of discomfort and dyspnea were highly improved in the HFNC arm.1,2 A more recent retrospective study with historical controls observed a significant reduction in invasive and noninvasive interventions in severe AHRF patients with the use of HFNC.27 Frat et al also explored the use of
HFNC alternating with NIV in AHRF, defined as a P/F ≤ 300 mm Hg with standard oxygen mask with an increased respiratory rate (> 30 breaths/ min) or respiratory distress. Twenty-eight subjects were included and clinical efficacy was evaluated. They concluded that HFNC was better tolerated and resulted in improved oxygenation and tachypnea (mean PaO₂ from 83 to 108 mm Hg). Although oxygenation with NIV (mean PaO₂ from 83 to 125 mm Hg) did improve more dramatically, the improved tolerance with HFNC might serve as an alternative.23,25

Post Cardiothoracic Surgery
NIV is commonly used to prevent reintubation in hypoxemic patients following cardiothoracic surgery. Moderate evidence (grade 2) supports the practice of NIV following cardiac or thoracic surgery to correct hypoxemia and stave off reintubation, although approximately 20% fail and still require reintubation. Stephan and colleagues devised a multicenter, randomized, noninferiority trial (n=830) hypothesizing that HFNC was not inferior to NIV for prevention or resolution of AHRF following surgery. Measured outcomes were frequency of treatment failure (primary) and changes in respiratory variables and complications (secondary). Enrollment occurred at the time of a failed spontaneous breathing trial or when extubation failed. The outcomes supported HFNC use in these patients as there was no difference in treatment failure or ICU mortality. Skin breakdown in patients receiving BiPAP treatment was significantly greater than those treated with HFNC (p < .001).27

Intubation and Post Extubation
Intubation and extubation involve moments where the airway is occluded and oxygen delivery is interrupted. Tracheal intubation is a common procedure in the ICU and is often associated with hypoxic complications. Pre-oxygenation is routine practice but often neglected when a patient becomes so unstable that airway protection is at risk. Romain et al compared preoxygenation with a nonrebreather (NRB) to HFNC during direct laryngoscopy in the ICU (n=101). The use of HFNC when pre-oxygenating significantly decreased severe hypoxemia when compared with NRB during intubation. The ability to leave the device in place throughout the entire procedure potentially increased the oxygen delivery delaying desaturation.28

Post extubation use of HFNC has increased in recent years. When compared to a NRB mask in a retrospective analysis (n=67) it was found that P/F improved in the HFNC group as well as more ventilator-free days (p < 0.05). Potential benefits supporting HFNC success in this population were the maintenance of mucosal function preserved by heat and humidity. Patient tolerance may have been achieved with the ability to speak and eat while on the HFNC device.29

Do-Not-Intubate
Noninvasive ventilation is commonly used in patients at the end of life with a do-not-intubate (DNI) directive. The respiratory insufficiencies in this population have traditionally been supported with a face mask and NIV, however, there was often difficulty with mask fit and tolerance. The Mayo Clinic assessed the effectiveness of HFNC in hypoxemic DNI patients (n=50) with mild hypercapnia (PaCO₂ < 65). Nine (18%) of the 50 subjects escalated to NIV, which was the primary endpoint. The other 82% were maintained on HFNC for a median duration of 20 hours. HFNC was found to provide acceptable oxygenation and may be considered as an alternative to NIV in DNI patients.30

Heart Failure
Heart failure (HF) is a common cause of AHRF and is associated with poor outcomes. Patients with HF often have issues oxygenating with conventional oxygen therapy leading to use of NIV and potential intubation. Not only do these rescue therapies with positive pressure improve oxygenation, they also increase intrathoracic pressure reducing the work of breathing and decreasing preload, each of these being highly beneficial in HF.

Rynn and colleagues hypothesized that the level of pressure created with HFNC delivery would decrease preload in HF without changing cardiac output. They enrolled stable NYHA class III heart failure patients (n=10) with an ejection fraction of < 45%. Air (FiO₂ 0.21) was delivered to these patients via HFNC while the inferior vena cava (IVC) was measured via transthoracic echocardiography (TEE). Inspiratory collapse of the IVC was used as a surrogate for preload and was measured while HFNC was delivered at different flow rates. Inspiratory collapse was significant with baseline (no flow) at 37% collapse, HFNC (20 LPM) was 29% and HFNC (40 LPM) was 21%. The increase in HFNC flow appeared to correlate with an increase in intrathoracic pressure and decrease in inspiratory collapse of the IVC. Also found was that respiratory rates significantly reduced and no other clinical changes were noted. It was concluded that NYHA class III heart failure patients might benefit from HFNC treatment.31

COPD
Many of the mechanisms of action previously reviewed regarding HFNC could potentially benefit COPD patients. The “go-to” treatment in this disorder is NIV, but treatment intolerance and mask discomfort are well documented. Potential benefits of HFNC include the increase in pressure and decrease in respiratory rate with high flow rates helping to support inspiratory efforts. The elevated positive expiratory pressures may splint open the airways allowing a lower FRC similar to the effect associated with pursed lipped breathing. This support could lower the work of breathing while the higher flow rates wash out of CO₂ from dead space.32 Of note is the fact that FiO₂ can be manipulated with HFNC therapy making the device an option to deliver low FiO₂ and high flows to COPD patients.

Delivery Techniques
Clinical data for the application of HFNC in the adult population is increasing, but there is still a lack of formal recommendations for usage.

Physiologic response to flow and FiO₂ are evident in animal and human studies and these are the two parameters that are adjusted. Flow rates in published studies have started at 30 LPM up to 50 LPM.33,34,35 One could start at a flow of 30 LPM and that is titrated in response to the patient’s respiratory rate and work of breathing. This initial flow rate is usually increased to 50 LPM if tolerated by the patient and observed respiratory distress lessens. Unless they have COPD, the FiO₂ is started at 1.0 and adjusted to maintain a target saturation of 92-98%. Patients with COPD start at FiO₂ of 50% or less and then adjusted FiO₂ to a target saturation of 90-92%. Further study is needed for full validation.

Nasal prong sizing is an important aspect and manufacturer guidelines and sizing tools should be followed. Typically, the nasal cannula prong diameter should be approximately half the size of the patient’s nostril for adequate delivery.

Patients receiving HFNC should be assessed often for comfort and physiologic response in the form of heart rate, respiratory rate, breath sounds and SpO₂. Flow and FiO₂ should be monitored on the device as well as patency of the circuit and cannula with both being change when visibly soiled.

Conclusion
Use of HFNC in the adult patient population continues to evolve. With respiratory distress and hypoxemia being a common issue in the clinical setting, the HFNC is a welcome addition to the arsenal of noninvasive strategies. Patient tolerance is pivotal in the increased usage and this is likely due to the small size of the interface and the heated and humidified gas. Clinicians also find the interface easy to maneuver during procedures such as intubation and extubation, patients with HF often have issues oxygenating with conventional oxygen therapy leading to use of NIV and potential intubation.
providing a continual source of oxygen and dead space washout. Comprehensive strategies for use will need to be further developed as the data from clinical trials increases.

References


9. Haep M, Hetzel J, Riessen R. Nasal high-flow oxygen therapy and non-invasive ventilation (NIV) for patients treated with HFNC. What is also amazing is that the majority of the studies in the last few years have focused on the management of acute hypoxemic respiratory failure. 

Otero: I believe that the role of Heated Humidified High-Flow Nasal Cannula (HFNC) is improper patient selection. Practitioners should probably avoid using HFNC in patients with moderate to severe hypercarbia, acute hypoxemic respiratory failure with other organ failure and definitely should be avoided in patients with nasal anatomical abnormalities which would preclude use of nasal prongs and also the presence of a pneumothorax. 

What is the role and potential benefits or hazards with the use of HFNC in the management of acute hypoxemic respiratory failure?

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Waughs: While some consider HFNC to be anything greater than the upper end of the typical flow rate delivered by "traditional" nasal cannula (depending on the patient size), most clinicians would describe it as delivering a rapid inspiratory flow that exceeds the maximum oxygen flow rate that can be supplied by mask and NIV but a significant difference in favor of HFNC for 90-day mortality. In clinical reports by how tracheal gas injection flushes the tracheal dead space. Purring CO2 from the airway and replacing it with oxygen-enriched gases provides a greater abolishment of oxygen starvation at whatever FIO2 setting is used. HFNC is susceptible to the same hazards that all therapeutics have—failure to recognize that the patient requires different therapy in a timely fashion. 

Spontaneously breathing patients with high oxygen requirements are usually candidates for HFNC. Many clinicians substitute HFNC when a nonbreather mask (NBM) would otherwise be used. One of the earliest and certainly HFNC clinical reports described that CHF patients in the emergency room had higher oxygen saturations with a HFNC at 20 LPM compared to NBM. 

Acute hypoxemic respiratory failure is often treated with HFNC for patients with acute respiratory failure that does not respond to conventional oxygen therapy. A recent study shows a rapid improvement in a patient’s perceived dyspnea in the emergency department (ED) when HFNC is applied. Support for this approach can be found in the recent FLORALI trial which compared standard oxygen therapy vs HFNC for noninvasive ventilation. In this study there was no difference in intubation rates between these two therapies but a statistically significant increase in ventilator free days and 90-day mortality for patients treated with HFNC. What is also amazing is that the majority of the studies in the last few years have focused on the management of acute hypoxemic respiratory failure. 

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patients had pre-HFT mean oxygen saturations of 88% and respiratory rates of 25 breaths per minute and all were able to avoid mechani-
cal ventilation.14 Rojas et al (n=377) reported a 31% decrease in the use of noninvasive ventilation, with a 97.3% decrease in nasal continuous positive airway pressure (CPAP).15 Seenan et al, found HFNC as effective as nasal CPAP for treating apnea of premat-
uity and Martinez-Gomez reported increased success with infant extuba-
tions. HFNC is more comfortable for patients because it covers the nose or nasal mucosa to have its effect. It does not require pressure on the skin or nasal mucosa to have its effect. Greater comfort translates to greater compliance with therapy.

Joyner: The high flow nasal cannula (HFNC) is a wide-bore nasal can-
nula that can provide a patient with heated and humidified oxygen at a concentration up to 100% and flow rates up to 60 LPM.16 Determining if a HFNC is appropriate in the care of patients with acute hypoxemic respi-
atory failure requires the practitioner to have knowledge of the physiology causing the hypoxemia. Research tri-
als to date are conflicting and seem to suggest that humidification is not a needed consideration. The acute hypoxemic respiratory failure may benefit from HFNC, but seem to also suggest not all patients will ben-
efit from it. HFNC is a warm and humid source of oxygen to an SPO2 of ~90%. By the time we have HFNC device and 157 afterward, the average time on ventilator dropped from 21 to 11 days.

Joyner: The sustained use of a HFNC requires a large bulk oxygen source that can be applied at high pressures (i.e., standard 30 psi outlet). In the hospital setting, essentially the oxygen source is unlimited and therefore a necessary component of the HFNC circuit temperature of 34 degrees F helps dering dexmedetomidine. It is a α adrenergic agonist. This means that it upregulates the inhibitory action of the α2 receptor which decreases sym-
pathetic outflow with the effect that patients will be in a calm state but not necessarily under sedation. Caution must be used in hypertensive patients when using dexmedetomidine as it can cause a sudden drop in blood pressure. This risk can be decreased by avoiding a bolus of the medication and starting a continu-
ous drip.

Waugh: HFT can be accomplished in many adults at a flow rate around 25 LPM though some seem to ben-
fit from a flow rate as low as 10-15 LPM.21 Starting flow rates are generally 4-6 LPM and children are 10-12 LPM. Vital signs and degree of labored breathing are assessed before and after starting therapy and moni-
tored for improvement. If you do not see improvement, increase flow by 3-5 LPM and re-evaluate. This is repeated until improvement is seen. Suggestions to improve outcome when CF therapy is working. FIO2 is adjusted to achieve the desired SPO2. Starting high and weaning quickly works well.

Joyner: My suggestion would be to initially provide the patient with a sufficient FIO2 to maintain a SPO2 of at least 90%. I would begin de-
ecreasing a flow of 0.1LPM when the FIO2 to obtain the saturation be-
ing sought. The flow being delivered to the patient should be guided by patient tolerance with meeting the goal. Once the patient is stable, guidelines from professional organi-
izations for specific disease states can be utilized to provide the best state of the science care for the patient. For example the American Heart As-
association now suggests patients who have had a myocardial infarc-
tion should be supported with oxygen to an SPO2 of ap-
proximately 94%.22 In patients with COPD the GOLD guidelines suggest maintaining SPO2, of at least 90%.

What can be done to improve patient comfort and tolerance with HFNC? Otero: Initial - in general, patients tolerate HFNC fairly well and usually better than noninvasive ventilation, perhaps due to the humidification. In the rare case where a patient is anxious (and not critically hypoxemic) anxiolytics can be prescribed. In my area, cli-
icians have become comfortable or-
dering dexmedetomidine. It is a α2 adrenergic agonist. This means that it upregulates the inhibitory action of the α2 receptor which decreases sym-
pathetic outflow with the effect that patients will be in a calm state but not necessarily under sedation. Caution must be used in hypertensive patients when using dexmedetomidine as it can cause a sudden drop in blood pressure. This risk can be decreased by avoiding a bolus of the medication and starting a continu-
ous drip.

Joyner: Assuring the straps securing
the cannula are not overly tightened or crossing over a sensitive area (e.g., ears or areas of skin breakdown) is important. Precise control of the highest flow tolerated but not exceeding that rate is important to assure delivery of an accurate FIO₂. Periodic evaluation of cannula placement and strap tension should be considered, as patients’ needs can vary quickly with fluid re-suscitation or the use of diuretics.

**Describe how you would recommend weaning from HFNC?**

**Otero:** Similarly to when we initiate High flow NC we wish to titrate our FIO₂ down to approximately 40%. We will reduce flow to 20-30 LPM. After this we transition to nasal cannula.

**Waugh:** The HF nasal cannula bore size is important for at least two reasons. As previously discussed, it is desirable to avoid a snug fit of the cannula prongs in the patient’s nares. A study by Friz- ne and colleagues showed that the desired O₂ and CO₂ was obtained at lower flow rates when the nares were less obstructed by HFNC prongs. This allows greater flushing of the upper airway dead space with less end-expiratory distending pressure. Some devices use only one prong to maximize the opportunity for flushing of the upper airway pre-oxygenation. It is important to generate sufficient flow to flush airway dead space and narrowing the internal diameter increases the flow at the tip of the cannula prongs. This jet flow must be at near BTPS conditions so that the flow remains comfortable. Narrowing the internal bore of the cannula increases resistance which in turn raises pressure in the circuit so the system must be designed to deliver sufficient flow as resistance increases. Small infants tend to be the greatest challenge for maintaining a combination of sufficient jet flow and adequate leak for flushing the airways.

**Joynier:** Within an acceptable tolerance range we do not believe the bore size is an important matter. However if the flow is very high and the bore size is small the gas coming out of the cannula will be at high pressure and likely uncomfortable for the patient. At the opposite end of the spectrum a bore size large enough to approximate the diameter of the patient’s nare may intermittently create a seal and prove difficult to irrigate as well. Anecdotally it seems that a bore size approximately one-half to three-quarters the size of the patient’s nare diameter is best.

**References**


Bremsland L, Lyrflay H, Hoke N. High Flow jour- nals as, well as authored and co-authored sev- eral national and international medical meetings and in his areas of research interest.

Robert J. Joynier, PhD, RRT-ACCS, FAARC is Associate Dean, Henson School of Science & Technology Professor of Health Sciences, and Director, Respiratory Therapy Program Salis- bury University, Maryland. In 1998, he graduated from the Department of Physiology at Dartmouth Medical School with a PhD in Physiol- ogy: his area of focus was cardiorespiratory physiol- ogy, investigating the feasibility of intravenous volatile liquids as selective pulmonary vasodila- tors. He is the recipient of numerous awards and scholarships and he has published extensively in his field.

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Ronny M. Otero, MD, FAEM is Associate Profes- sor, University of Michigan Hospital and Health Systems Department of Emergency Medicine University of Michigan School of Medicine, Ann Arbor, Michigan. Although his primary interest is in critical care, his publications include the early intervention in critical care cases, 2. Blood and Serum Biomarkers for Sepsis and Organ Dys- function: communication of organ dysfunction: cardiac arrest management 5. Noninvasive ven- tilation strategies, and 6. Procedural sedation. Otero is active in several professional organ- ization: American Academy of Emergency Physi- cians, American College of Emergency Physicians and Society for Academic Emergency Medicine. He is the recipient of many awards for his research, clinical and teaching activities. Dr. Otero has published extensively and presented at several national and international medical meetings in his areas of research interest.

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1. Heated and humidified high-flow nasal cannula (HFNC) can deliver a fraction of inspired oxygen (FiO₂) ranging from 0.21 to 1.0?
A. True
B. False

2. Which of the following are reasons that low flow devices deliver a variable FiO₂?
A. Oxygen from the low flow device mixes with room air.
B. Patient’s breathing patterns vary breath to breath.
C. Patient’s inspiratory flow rates exceed the flow delivered by the low flow device.
D. All of the above.

3. What is the range of gas flow rates that may be delivered with common adult HFNC systems?
A. 2-8 LPM
B. 8-15 LPM
C. 16-40 LPM
D. 16-60 LPM

4. The washout of expired CO₂ from anatomical dead space is thought to be one of the primary mechanisms contributing to the success of HFNC therapy.
A. True
B. False

5. Unconditioned medical gas administration moves the isothermic saturation boundary (ISB) to where?
A. Higher in the nasal passage
B. The vocal cords
C. Further into the lower respiratory tract
D. The diaphragm

6. Data from multiple animal studies and clinical trials has shown a reduction in PaCO₂, tidal volume, minute ventilation, and dead space with use of HFNC.
A. True
B. False

7. Non-invasive ventilation (NIV) has documented treatment intolerance due to the following reason(s)?
A. Mask discomfort
B. Patient inability to speak, eat or drink
C. Gases delivered are not optimally conditioned
D. All of the above

8. Respiratory failure occurring with an inability to clear carbon dioxide is known as this type of failure?
A. Type I
B. Type II

9. What settings can be adjusted independently when using a HFNC system?
A. Flow, Saturation, Temperature
B. Flow, FiO₂, Saturation
C. Flow, FiO₂, P/F ratio, Saturation
D. FiO₂, P/F ratio, Saturation

10. Nasal prong sizing typically requires the prong diameter to cover approximately how much of the patient’s nostril for adequate delivery?
A. 1/4 the size of the nostril
B. 1/2 the size of the nostril
C. 3/4 the size of the nostril
D. The prongs should fit the nostrils snugly

Participate’s Evaluation
1. What is the highest degree you have earned?
Circle one. 1. Diploma. 2. Associate. 3. Bachelor. 4. Masters. 5. Doctorate

2. Indicate to what degree the program met the objectives:

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3. Describe the recommended application and management of HFNC.

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4. Please indicate your agreement with the following statement: “The content of this course was presented without bias toward any product or drug.”

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Strongly Disagree</th>
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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. Saxe Communications is accredited as a provider of continuing education by the American Nurses Credentialing Center’s Commission on Accreditation. This education activity is approved for 2.0 contact hours. Provider approved by California Board of Nursing, Provider #14477. Provider approved by the Florida Board of Nursing, Provider # CE 50-17032 for 2.0 contact hours.

To earn credit, do the following:
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2. Complete the entire post-test.
3. Mark your answers clearly with an “X” in the box next to the correct answer. You can make copies.
4. Complete the participant evaluation.
5. Go to www.saxetesting.com to take the test online.
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Answers
1. A B C D
2. A B C D
3. A B C D
4. A B C D
5. A B C D
6. A B C D
7. A B C D
8. A B C D
9. A B C D
10. A B C D

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