

Use of a High-Flow Oxygen Delivery System in a Critically Ill Patient With Dementia

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We used a high-flow nasal cannula with a patient who required a high fraction of inspired oxygen but could not tolerate a nasal or facial mask. We saw a 92-year-old woman with delirium and dementia in the intensive care unit for multi-lobar pneumonia with severe hypoxemia. Attempts to oxygenate the patient failed because she was unable to tolerate various facial and nasal masks. We then tried a high-flow nasal cannula (Vapotherm 2000i), which she tolerated well, and she had marked improvement in gas exchange and quality of life. The patient had severe health-care-associated pneumonia, accompanied by delirium and hypoxemia. It became apparent that the patient's death was imminent, and the goal of therapy was palliative. She had previously clearly expressed a desire not to undergo intubation and mechanical ventilation. In a situation where the patient was agitated and unable to tolerate a mask, the high-flow cannula reduced her agitation and improved her dyspnea, oxygenation, tolerance of oxygen therapy, and comfort at the end of life. Oxygen via high-flow cannula may enhance quality of life by reducing hypoxemia in patients who are unable to tolerate a mask but need a high oxygen concentration. Key words: high-flow oxygen, palliative care, hypoxemia. [Respir Care 2008;53(12):1739–1743]

Introduction

We have previously delivered supplemental oxygen via high-flow nasal cannula to burn patients who had trouble tolerating a tight-fitting facial or nasal mask.¹ We report a medical patient with dementia who did not tolerate nasal or facial masks commonly used for noninvasive ventilation but had marked improvement in oxygenation, work of breathing, comfort, and nutrition with oxygen via high-flow cannula.

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Case Report

The patient was a 92-year-old female who had previously determined that she did not wish to be intubated or resuscitated in the event of a cardiopulmonary arrest. She was admitted with right-lower-lobe pneumonia and received empirical treatment with levofloxacin. She improved clinically after 5 days of in-patient treatment and was discharged to a skilled nursing facility on oral levofloxacin to complete a 14-day course of therapy. However, she missed at least one day of antibiotics in the transition from the hospital to the skilled nursing facility. Within 3 days of transfer she developed progressive confusion and worsened hypoxemia associated with diffuse alveolar infiltrates. She was readmitted to the hospital and was initially restarted on levofloxacin, which was changed to ciprofloxacin, vancomycin, and piperacillin-tazobactam within the first 24 hours of admission.

Her medical history was remarkable for hypertension and dementia (chronic and progressive deterioration in short-term memory, cognitive impairment, and functional deterioration). Prior to developing severe cognitive impairment she had expressed a desire to forego life-sustaining treatment in the event of a cardiopulmonary arrest. This was confirmed by one of her sons, who was her proxy

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Fig. 1. Radiograph on hospital day 1 shows multi-lobar pneumonia.

via durable power of attorney for health care. She was a nonsmoker and her out-patient medications included lisinopril, olmesartan, atenolol, amlodipine, aspirin, donepezil, and namenda. In the emergency department her vital signs were temperature 37.4°C, blood pressure 160/57 mm Hg, heart rate 86 beats/min, respiratory rate 28 breaths/min, and saturation (measured via pulse oximetry [S_{pO_2}]) 81% on room air. At admission, she was mildly confused, disoriented as to place, and had poor short-term memory. She had a regular heart rate and rhythm, and crackles were heard in the left lung. She had no clubbing, cyanosis, or edema. Laboratory results were remarkable for a white-blood-cell count of 13,000 cells/uL. Her blood urea nitrogen was 31 mg/dL, and her creatinine was 1.5 mg/dL. Blood, sputum, and urine cultures were negative. At that point her chest radiograph (Fig. 1) showed marked multi-lobar progression in the initial right-lower-lobe infiltrate.

After admission her clinical status progressively deteriorated. Within hours of admission she developed a respiratory rate as high as 35 breaths/min and a heart rate of 106 beats/min. S_{pO_2} dropped to < 80% while receiving oxygen at 5 L/min via nasal cannula, and S_{pO_2} increased to only 87% with a 50% air-entrainment mask. She became more confused, restless, and agitated and was transferred to the medical intensive care unit on the third hospital day. There she had crackles in the basilar lung fields bilaterally and a regular tachycardia, without murmurs, gallops, or rubs. Her S_{pO_2} was as low as 60% when on room air. Although S_{pO_2} could easily be increased to > 90% with a nonrebreather mask or noninvasive ventilation, she con-

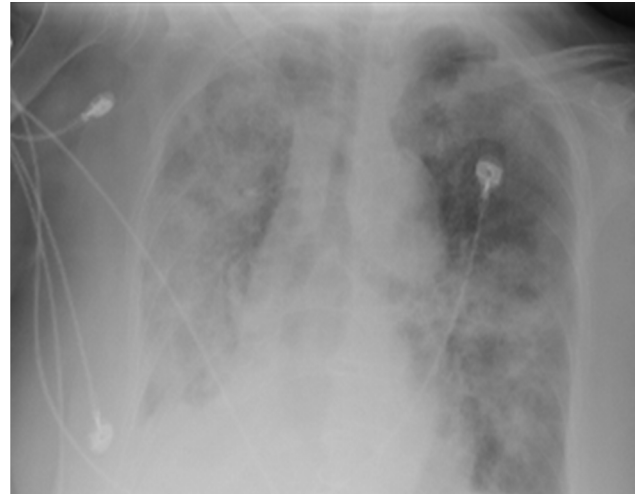


Fig. 2. Radiograph on hospital day 4.

sistently became irritated by masks. We tried several types of masks, but she removed them within minutes if not constantly monitored. She tolerated low-flow nasal cannula, but this did not substantially improve her hypoxemia. During this period she had persistent psychomotor agitation and developed a transient supraventricular tachycardia, with a heart rate as high as 190 beats/min. She also refused to eat.

Six days prior to admission, her arterial blood gas (ABG) values included pH 7.45, P_{aCO_2} 32 mm Hg, P_{aO_2} 54 mm Hg, and arterial oxygen saturation (S_{aO_2}) 87%. Her initial ABG in the emergency department showed pH 7.50, P_{aCO_2} 32 mm Hg, P_{aO_2} 85 mm Hg, and S_{aO_2} 96% on an indeterminate level of supplemental oxygen. On the second hospital day her ABG values were pH 7.48, P_{aCO_2} 28 mm Hg, and P_{aO_2} 58 mm Hg on a nonrebreather mask. By the third hospital day her ABG showed pH 7.58, P_{aCO_2} 24 mm Hg, and P_{aO_2} 39 mm Hg while on a 50% air-entrainment mask. Figure 2 shows the chest radiograph from hospital day 4.

We considered several options to improve oxygenation and reduce dyspnea, including the oxygen delivery systems mentioned above, and narcotics. We did not use narcotics initially because we wanted to avoid respiratory depression while attempting to treat a potentially reversible cause of respiratory failure. A reservoir nasal cannula was another option, but was not readily available at our institution at the time. Since she tolerated nasal cannula well but did not derive sufficient oxygenation improvement with the low-flow conventional nasal cannula, we tried high-flow nasal cannula (2000i, Vapotherm, Stevensville, Maryland). We started at 20 L/min, which the patient tolerated very well. Over the next 6 hours we increased the flow to 25 L/min, and respiratory rate fell to 23 breaths/min, heart rate fell to 80 beats/min, blood pressure fell to 125/51 mm Hg, and S_{pO_2} rose to 98%. After initiating the high-flow cannula, ABG showed pH 7.52, P_{aCO_2} 29 mm Hg,

and P_{aO_2} of 64 mm Hg. The oxygen flow was adjusted to as high as 30 L/min the next day to facilitate patient comfort and to maintain $S_{pO_2} \geq 90\%$. She became much more relaxed and cooperative and began to eat a regular diet. Although she could not clearly express how she felt subjectively, because of her underlying dementia, she appeared more comfortable with the high-flow cannula, as evidenced by tolerance of the nasal cannula interface, reduction in psychomotor agitation, resolution of the tachycardia, and more relaxed breathing.

Ultimately, her pulmonary process progressed and she developed a drug rash to piperacillin and, later, cefepime. She became more obtunded in the 48 hours after transfer to the intensive care unit. Although further increase of the nasal cannula flow might have maintained her oxygenation, her family decided that we should provide comfort measures only, after she failed to respond to antimicrobial therapy and comprehensive supportive care. High-flow oxygen was withdrawn and intravenous morphine was administered to relieve dyspnea. Within 3 hours after high-flow cannula was withdrawn, she developed progressively worsening hypoxemia and died on the sixth hospital day. On the day that high-flow cannula was withdrawn, the ABG showed pH 7.39, P_{aCO_2} 36 mm Hg, and P_{aO_2} 60 mm Hg.

Discussion

This patient's severe health-care-associated pneumonia, along with confusion, uremia, tachypnea, hypoxemia, dementia, and advanced age, suggested a high risk of death.²⁻⁵ Once she was admitted to the intensive care unit with progressive pulmonary infiltrates and refractory hypoxemia despite broad-spectrum antibiotics, it was apparent that her death was imminent without heroic resuscitation measures. Although she did not have a terminal condition per se, the severity of her clinical presentation indicated that her condition was irreversible without antibiotics and mechanical ventilation. However, she had previously determined that she did not wish to undergo endotracheal intubation, and once all other treatment options had been exhausted, the goals of therapy were to promote comfort and relieve suffering. Her refractory hypoxemia and psychomotor agitation were sources of suffering and were adversely affecting her quality of life, so we treated her with oxygen via high-flow cannula, which improved her oxygenation and palliated her suffering.

The use of supplemental oxygen to relieve dyspnea in palliative care is controversial. It is not clear that supplemental oxygen actually reduces dyspnea at the end of life, and it is conceivable that it may unnecessarily prolong suffering. The data concerning supplemental oxygen in palliative care are sparse, and are most often reported in association with cancer or chronic obstructive pulmonary disease.⁶⁻⁹ In a study of oxygen versus air in patients with

advanced illness, Philip et al found that symptoms improved with both air and oxygen, and there were no significant differences between the treatments.⁶ Some clinicians withdraw supplemental oxygen at the end of life and replace it with palliative sedation to reduce dyspnea, which raises the ethical issue of double effect (the treatment relieves symptoms but hastens death), which poses the ethical and moral dilemma of hastening death in a person with absent or marginal respiratory reserve.^{7,10} Nevertheless, conscious patients with severe hypoxemia often clearly benefit from supplemental oxygen.

Certain patients will not tolerate the mask needed to deliver high-flow oxygen in the conventional manner. Air-entrainment masks, nonrebreather masks, and the nasal and facial masks used in noninvasive ventilation may not be tolerated by patients who are agitated, demented, claustrophobic, or who have facial burns, trauma or deformities. Though nasal cannula may be better tolerated by these patients, conventional nasal cannula may not provide sufficient oxygen flow to correct hypoxemia. A high-flow cannula system (which heats and humidifies the inspired oxygen) may be better tolerated than a mask, allowing for ease of administration with less agitation and discomfort. With a conventional nasal cannula system, flow > 6 L/min is not recommended, but a high-flow cannula allows for flow up to 40 L/min, with relative humidity approaching 100%.¹¹ As seen in our patient, a high-flow cannula may improve oxygenation, tolerance of oxygen therapy, and comfort.

High-flow nasal cannulas have been found to be superior to conventional nasal cannula and equivalent to nasal continuous positive airway pressure in pediatric patients. In neonatal intensive care unit patients, high-flow cannula performed better than a standard nasal cannula in maintaining a normal-appearing nasal mucosa, a lower respiratory effort score, and averting re-intubation.¹² In preterm infants with mild respiratory illness, high-flow cannula provided support comparable to nasal continuous positive airway pressure.¹³

High-flow cannula improves gas exchange by delivering a high oxygen concentration (near 100%) comfortably and noninvasively. There may also be independent benefits to the airway because the gas is heated and humidified. Cold, dry gas can induce bronchoconstriction,¹⁴⁻¹⁷ so the salutary effects of high-flow, heated, humidified gas may be at least partially related to a mild bronchodilator effect. The decrease in FEV_1 associated with breathing cold, dry gas during exercise or during a dry-air tachypneic challenge can be prevented by fully humidifying the inspired air at body temperature.^{14,18} Spontaneously breathing heated, humidified gas with a fraction of inspired oxygen of 0.21 during sleep significantly reduced or eliminated nocturnal asthma episodes during sleep testing.¹⁹ In addition, the high flow may produce a small amount of con-

tinuous positive airway pressure¹³ and thereby increase alveolar ventilation, reduce physiologic dead space, and further reduce the work of breathing.

We could have used a reservoir nasal cannula instead of a high-flow cannula with this patient. A reservoir cannula stores oxygen during exhalation, which is then available at near body temperature and humidification for the next inhalation. Reservoir cannulas improve S_{aO_2} with less oxygen than a standard cannula,^{20,21} and they have been used in acute care.²² Our patient had substantial intrapulmonary shunt and required consistent supplemental oxygen at a concentration of near 100%. We do not know whether a reservoir cannula could have provided oxygen at a level equivalent or superior to high-flow cannula.

We observed no important adverse effects with this high-flow cannula in this patient. Particularly in patients with underlying lung disease, a high oxygen concentration may induce hypercapnia by reducing respiratory frequency, altering ventilation-perfusion relationships, and perhaps by increasing gas viscosity and density.^{23,24} Having had no pre-existing lung disease, our patient had hypoxemic respiratory alkalosis from diffuse alveolar infiltrates and hyperventilation. There was no evidence in this patient that high-flow cannula compromised ventilation, even after 48 hours of continuous use. High-flow cannula is particularly useful for patients with severe hypoxemia but without carbon dioxide retention.

In August 2005 there were reports of outbreaks of infection or colonization with *Ralstonia* species in patients who used the Vapotherm 2000i. This was thought to be due to contamination of the 2000i.^{25,26} In December 2005 the manufacturer voluntarily recalled the 2000i. Although the source of the contamination has not been definitively determined, the company developed improved disinfection techniques, and the 2000i was re-introduced in January 2007, with emphasis on single use of the vapor-transfer cartridges and disinfection kits.²⁷ The Food and Drug Administration continues to monitor the 2000i.²⁸ Our hospital has incorporated the enhanced disinfection techniques and has had no reported cases of *Ralstonia* species infection or colonization.

Although our patient ultimately died during hospitalization, the high-flow oxygen delivery system enhanced her quality of life for a brief period, allowing her to interact with her family and to maintain a degree of dignity at the end of life. It allowed for consistent supplemental oxygen delivery, improved oxygenation, reduced work of breathing, reduced dyspnea and agitation, and enhanced nutrition and comfort. High-flow nasal cannula should be considered to enhance comfort in patients who do not want endotracheal intubation and who do not tolerate conventional forms of supplemental oxygen delivery. High-flow cannula may be particularly suited for patients with severe hypoxemic respiratory failure who need respiratory pallia-

tive care, and patients who might benefit from partial ventilatory assistance.

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