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Case Report

Transport of an adult with severe respiratory failure on high-flow nasal prongs during a prolonged aeromedical evacuation: A case study

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A B S T R A C T

This case describes the use of high-flow oxygen delivered via nasal prongs in the management of an adult patient with severe undifferentiated respiratory failure for the purposes of prolonged air medical transfer.

High-flow oxygen delivered via nasal prongs (HFNP) is a well-established treatment for respiratory failure for some clinical conditions. In adults with acute hypoxemic respiratory failure from medical causes, HFNP may improve oxygenation and decrease the need for intubation compared with low-flow oxygen systems, although the data are conflicting.[1-3]

In the prehospital and retrieval setting, treatment with HFNP may be preferred to noninvasive ventilation (NIV) or invasive positive-pressure ventilation because it is relatively comfortable for patients and does not require sedation or paralysis, which could precipitate cardiovascular collapse in critically ill patients. However, the air medical transport of a patient on HFNP over long distances presents logistical challenges. HFNP can be administered at flow rates of up to 60 L/min and a fraction of inspired oxygen (FIO_2) of up to 100%. At these maximal settings, a standard C size cylinder of medical oxygen will be depleted in just over 8 minutes. Furthermore, if a patient deteriorates during transport and requires further intervention, NIV or intubation can be difficult to institute during transport.

This case report describes the successful air medical evacuation of a patient with severe respiratory failure from a remote central Australian outback community on HFNP.

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Setting

In the central Australian region, air medical evacuations are conducted by the Central Australian Retrieval Service and the Royal Flying Doctor Service. Retrieval missions are generally conducted with a pilot and a flight nurse and may include a critical care doctor if required.

Most air medical evacuations are for patients in remote communities, which have populations of less than 1,000 people. Communities have a health care clinic managed by remote area nurses who perform initial emergency assessment and liaise with the medical retrieval center. There is no capacity to admit patients or provide higher-level critical care in these facilities. The receiving hospital is Alice Springs Hospital, which is located up to 800 km away from the furthest clinics. If more specialized services are required, patients are transferred to a quaternary center, which is located more than 1,500 km away.

Patient Information

A 55-year-old woman presented to the clinic with breathlessness and purulent sputum production. The patient had a medical history of rheumatic heart disease with mixed aortic and mitral valve pathology, ischemic heart disease, chronic kidney disease, cerebrovascular disease, atrial fibrillation, and hypertension and was also under investigation for restrictive respiratory disease. This case occurred before the coronavirus disease 2019 (COVID-19) pandemic.

Her vital signs included oxygen saturation (SpO_2) of 70% on room air and a respiratory rate of 40 breaths/min. She was referred for retrieval with a working diagnosis of severe pneumonia and acute

Table 1
Arterial Blood Gas Results

pH = 7.2 (normal range: 7.35-7.45)
po_2 = 62 mm Hg (normal range: 82-98 mm Hg)
pco_2 = 68 mm Hg (normal range: 35-45 mm Hg)

congestive cardiac failure. She was initially treated with oxygen, intravenous broad-spectrum antibiotics, bronchodilators, and nitrates.

A fixed wing aircraft with a medical escort was tasked from Alice Springs with a flight time to destination of 90 minutes and a distance of 463 km. On arrival, the patient was in extreme respiratory distress. Her vital signs included SpO_2 of 65% on low-flow oxygen via nasal prongs at 15 L/min, irregular atrial tachycardia, and a confused and agitated mental state but normal blood pressure and temperature.

The retrieval team initiated HFNP at 50 L/min and 100% Fio2 to preoxygenate the patient before rapid sequence induction. This was delivered via the Hamilton T1 ventilator (Hanmilton Medical, Bonaduz, Switzerland) with a humidifier attachment and Optiflow nasal cannula (Fisher and Paykel Healthcare, Aukland, New Zealand). The patient tolerated HFNP and had good improvement in peripheral oxygenation, work of breathing, and mental status. The patient's arterial blood results are provided in Table 1. Of note, the patient had profound hypoxia as well as respiratory acidosis. Fio2 was titrated down to 70% to achieve SpO_2 of 94%. The retrieval team elected to transport the patient on HFNP oxygen.

The transport was performed via a Pilatus PC-12 single-engine turboprop aircraft. The oxygen tank capacity is 3,250 L, with an additional 2 cells available to provide a total of 3,200 L.

The return flight lasted just over 1 hour The cabin altitude was maintained at a maximum of 5,700 ft. There was no need for sedation or institution of escalated ventilatory support at any stage during transport, and there was no change in the patient's condition. On admission to the intensive care unit, the patient was successfully transitioned to bilevel positive airway pressure NIV.

The initial investigations (including an echocardiogram) were suggestive of acute pulmonary edema secondary to decompensated congestive cardiac failure associated with severe rheumatic heart disease. The patient also had a plain chest radiograph suggestive of lobar pneumonia correlating with a positive sputum culture. Treatment at this stage consisted of NIV, diuresis, and antimicrobial therapy.

The patient progressed well, weaning from NIV and discharging to ward-level care within 1 week of admission. She was later transferred to a tertiary care center for valvular intervention assessment and optimization. She has since been discharged back home without valvular surgery.

Discussion

In this case report, we describe the successful air medical transport of a patient with severe undifferentiated respiratory failure from a remote central Australian clinic on HFNP. A pre–COVID-19 retrospective chart review of patient transfers using HFNP in the United States identified 72 adults who were transported on Fio2 settings ranging from 30% to 100% and a transport distance that ranged from 1 to 176 miles (up to 283 km). In this cohort, no patients required intubation during transport. The transport platform is not specified in this article.[4]

HFNP provides ventilatory support without some of the complications associated with NIV or intubation. First, sedative medications such as propofol or ketamine are associated with hemodynamic compromise through mechanisms such as vasodilation or increased myocardial demand. Furthermore, positive-pressure ventilation can reduce venous return, thus exacerbating poor cardiac output and shock state. In this case, the patient was known to have mixed aortic and mitral valvular disease as well as ischemic heart disease, which increased her susceptibility to cardiovascular collapse associated with sedation and positive-pressure ventilation.

HFNP also allows for humidification, which improves patient tolerance and comfort (through the minimization of mucosal drying and airway inflammation), which may improve adherence to treatment.[5] Despite the advantages of HFNP in avoiding the need for sedation and positive-pressure ventilation, there are some limitations to its use in the prehospital setting. First, it is unclear whether the use of HFNP avoids or even delays the need for intubation in adults with acute hypoxemic respiratory failure.[5,6] Furthermore, most of the evidence supporting its use comes from studies of patients with established diagnoses (such as chronic obstructive pulmonary disease or cardiac pulmonary edema), which is not the case for patients with undifferentiated respiratory illness in the prehospital setting. Another constraint is that HFNP use in patients with severe hypoxia requires large volumes of oxygen, which can be prohibitive for prolonged air medical transport. The required volume can be calculated by the product of inspired oxygen and the flow rate in liters. Experts generally recommend that double the calculated required volume of oxygen be carried in case of diversion.[7,8] For a patient requiring Fio2 of 70% at 50 L/min, for a transport time of 90 minutes, the transport team must carry 6,300 L oxygen. The maximum standard oxygen-carrying capacity for the aircraft used in this retrieval is 6,450 L. Furthermore, the inspired oxygen pressure of air is lower at altitude than at sea level, which may further exacerbate hypoxia where air is being entrained into the breathing system.

Finally, in the case of deterioration on HFNP, it can be difficult to escalate oxygenation during transport. Up to 40% of patients with acute hypoxic respiratory failure initially treated with HFNP will require intubation.[6] Initiating NIV via a face mask or performing intubation on an air medical transport platform is challenging because of restricted space, poor lighting, communication difficulty, and limited staffing, more so than a remote clinic or other prehospital environment. This risk is heightened during longer missions.

There is currently little evidence to predict the success or failure of HFNP in adults with acute hypoxic respiratory failure. The ROX index, defined as the ratio of SpO_2/Fio2 over respiratory rate, has been reported to have a positive predictive value for success of HFNP in patients with hypoxemic respiratory failure resulting from pneumonia/acute respiratory distress syndrome of more than 80%. Scores below the cutoffs should prompt consideration of earlier intubation.[6,9] A significant barrier to this approach outside of the hospital is the prolonged monitoring period required. (Patients with an indeterminate score require monitoring for 2 hours or longer.) This is impractical in the retrieval setting where speedy disposition is paramount, and underestimating the possibility of deterioration or treatment failure can be catastrophic.

The HACOR Score is an alternative scoring system that can be used to predict failure of HFNP and progression to intubation, with similar predictive capacity to the ROX index. Applying the HACOR score retrospectively to our patient, we find that they had a HACOR score predictive of the need for invasive postive pressure ventilation however they did not ultimately require intubation.[10,11]

The use of HFNP in air medical transport has further been curtailed during the COVID-19 pandemic because of concerns about aerosol generation and nosocomial infection transmission.

Conclusion

In this case report, we describe the successful air medical transport of a patient with severe undifferentiated respiratory failure on HFNP. This was a unique case given the prolonged transport time and the high volume of O_2 required for the duration of the retrieval. The patient's comorbidities, critical illness, and remote geographic location resulted in clinical and logistical complexity.

The benefits and risks of prolonged air medical transport on HFNP must be carefully weighed in every case. Factors contributing to decision making include the anticipated oxygen consumption, risk of deterioration, and volume of oxygen available balanced against the risks of NIV and rapid sequence induction. This case study shows that HFNP can be safely used during a prolonged air medical transfer and may be preferable to other methods of oxygen delivery.

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