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Effectiveness of high-flow nasal oxygen therapy in management of acute hypoxemic and hypercapnic respiratory failure

Ieva Norkienė*,

Raquel d'Espiney,

Juan F. Martin-Lazaro

Intensive Care Unit,
Newham University Hospital,
Barts Health NHS Trust,
London, United Kingdom

Background. High-flow nasal oxygen therapy (HFNOT) therapy has been increasingly used in patients with acute hypoxemic (Type I) respiratory failure (RF). Meanwhile indications and clinical effectiveness of HFNOT in patients with hypercapnic (Type II) RF remain controversial. The aim of our study was to evaluate the outcomes of primary HFTNOT in patients with hypoxemic and hypercapnic RF.

Material and Methods. We conducted a retrospective observational study of patients diagnosed with severe community acquired pneumonia (CAP), who required HFNC oxygen therapy for hypoxemia. Primary end-point was intubation or escalation to NIV rate after HFNOT. The secondary endpoint was the 30-day mortality after an admission regardless of the cause.

Results. Analysis was conducted on all 51 (n = 51) patients. Of these, 32 (63%) were diagnosed with Type I RF and 19 (37%) with Type II RF. The partial pressure of arterial carbon dioxide ($PaCO_2$) in Type I RF patients was 34.05 mmHg at admission and decreased to 33.07 mmHg after 1 hour of HFNOT. In patients with Type II RF $PaCO_2$ decreased from 56.47 to 54.97 mmHg. In Type I RF successful outcome was achieved in 25 patients (78%) compared to 11 patients (58%) with Type II RF. Escalation was required in seven patients with Type I RF and eight patients in Type II group. There were no mortalities in our population group.

Conclusions. Our data suggest that HFNOT can be effectively used in Type I and Type II RF. Clinicians should be cautious identifying patients at risk of escalation. A larger population group study is needed to identify predictors of HFNOT failure.

Keywords: high flow oxygen therapy, respiratory failure, non-invasive ventilation

* Correspondence to: Ieva Norkienė, Santariškių 2, Vilnius 08406, Lithuania. Email: ievanork@gmail.com

INTRODUCTION

High-flow nasal oxygen therapy (HFNOT) delivers warm and humidified oxygen through a nasal cannulas with a high flow rate (up to 60 L/min) and facilitates increase in the fraction of inspired oxygen (FiO_2) to 1.0 (100%) (1). A number of physiological benefits, such as humidification, reduced anatomical dead space, positive end-expiratory pressure effect, and fewer restrictions on food intake or communication makes HFNOT tolerable for a longer therapeutic period (2, 3) and superior in comparison with conventional non-invasive ventilation (NIV). Despite multiple beneficial effects of HFNOT, research data is controversial. Recent meta-analysis failed to prove different intubation and mortality rates compared with standard oxygen therapy or NIV in patients with acute hypoxemic respiratory failure (4). In patients with hypercapnia, NIV is still recognized as the first-line intervention. However, several recent studies suggested that HFNOT is effective in patients with carbon dioxide retention, and demonstrated improvement in ventilatory parameters (5, 6).

The aim of this study was to investigate the feasibility of the use of HFNC oxygen therapy in patients with acute pneumonia-related respiratory failure and to compare primary and secondary outcomes in hypoxemic (Type I) and hypercapnic (Type II) respiratory failure.

MATERIALS AND METHODS

This retrospective observational study included patients admitted to the intensive care of tertiary university hospital, diagnosed with severe community acquired pneumonia (CAP) and started on HFNOT due to progressively worsening respiratory failure. Exclusion criteria were: severe hemodynamic instability and use of vasopressors, a Glasgow Coma Scale score of 12 points or less (on a scale of 3 to 15, with lower scores indicating reduced levels of consciousness), contraindication to NIV, urgent need for endotracheal intubation, and a do-not-intubate order. Patients were defined as having (1) hypoxemic respiratory failure (Type I) or if arterial oxygen tension (PaO_2) was lower than 60 mm Hg with a normal or low arterial carbon dioxide tension ($PaCO_2$) and (2) hypercapnic respiratory failure (Type II) if $PaCO_2$ value was higher than 50 mm Hg.

Patients were started on HFNOT if certain criteria were present: (a) respiratory acidosis ($PaCO_2$ > 45 mm Hg and arterial pH < 7.35), (b) severe dyspnoea with clinical signs suggestive of respiratory muscle fatigue, (c) persistent hypoxemia (PaO_2/FiO_2 200 mm Hg) despite optimal medical treatment. HFNC was delivered by the Fisher & Paykel Optiflow system. Therapy typically was initiated at FiO_2 > 50% and a flow of 35 L/min, titrating flow upward if tolerated to 45–60 L/min. The FiO_2 was subsequently adjusted to maintain an oxygen saturation of 92% or more. Oxygen flows were set by the attending physician based on the patient's condition. We collected arterial blood gas analysis including oxygen saturation, pH, PaO_2/FiO_2 ratio, PaO_2 and $PaCO_2$ one and six hours before and after HFNOT intervention. The primary end-point was intubation rate after HFNOT. The secondary endpoint was the 30-day mortality after an admission regardless of the cause.

Statistical analysis

Excel software was used for initial data collation and Statistical Package of Social Sciences (SPSS v.15) was used for statistical analysis. Demographic data were expressed as mean ± standard deviation, and dichotomous variables were reported as number (percentage).

RESULTS

Fifty one ($n = 51$) patients were included in the final analysis: 32 (63%) were diagnosed with Type I RF and 19 (37%) with moderate hypercapnic respiratory failure and were qualified as Type 2. Changes in clinical and arterial blood gas analysis are presented in the Table. The mean age was 51.6 ± 9.5 and 68.1 ± 7.8 years in Type I and Type II groups, respectively. After one hour of HFNOT there was an improvement of oxygen saturation in Type I RF patients (from 94.8 to 95.03%) and an increase in PaO_2/FiO_2 ration from 181 to 191 mmHg. In type II RF patients, $PaCO_2$ levels improved from 56.4 to 54.9 mmHg and PaO_2/FiO_2 improved from 193.6 to 209.9 mmHg.

Within six hours of HFNT therapy we observed a further increase in PaO_2/FiO_2 ration in

Table. Effectiveness of HFNOT in Type I and Type II respiratory failure

Variables	TYPE I RF		TYPE II RF	
	Pre HFNOT	Post 1 hr HFNOT	Pre NHFT	Post 1 hr NHFT
Vital Signs				
HR (beats/min), mean ± SD	107.1 ± 10.2	105.7 ± 9.9	93.3 ± 10.8	87.6 ± 11.2
RR (breaths/min), mean ± SD	29.3 ± 9.3	29.2 ± 10.4	21.4 ± 11.0	19.4 ± 9.3
Saturation SO_2(%), mean ± SD	94.9 ± 10.4	95.0 ± 5.3	93 ± 10.1	93.4 ± 9.1
Arterial Blood gases				
pH, mean ± SD	7.4 ± 0.1	7.4 ± 0.1	7.3 ± 0.2	7.3 ± 0.1
PCO_2 (mmHg), mean ± SD	34.05 ± 9.3	33.07 ± 6.8	56.47 ± 5.3	54.97 ± 7.8
PO_2 (mmHg), mean ± SD	81.15 ± 5.5	78.38 ± 6.5	72.90 ± 8.5	74.03 ± 9.5
HCO_3 (mmol/L), mean ± SD	22.02 ± 5.4	21.68 ± 6.1	26.03 ± 10.1	26.25 ± 9.1
PaO_2/FiO_2 ratio (mmHg), mean ± SD	181.22 ± 10.3	198.219 ± 11.6	193.62 ± 11.5	209.98 ± 13.7
Escalation to NIV (*n* (%))	4 (8%)		7 (14%)	
Intubation rate (*n* (%))	3 (6%)		1 (2%)	

HR – heart rate; FiO_2 – the fraction of inspired oxygen; HFNOT – high-flow nasal oxygen therapy; NIV – non-invasive ventilation; $PaCO_2$ – arterial carbon dioxide partial pressure; PaO_2 – arterial oxygen partial pressure; SD – standard deviation; RR – respiratory rate.

both groups to 182.3 and 223.9 mmHg, respectively. Escalation to non-invasive ventilation was required in four (8%) patients in Type I RF group and seven (14%) in Type II group. Three and one patient were intubated in each group, respectively. There were no mortalities in either of the groups.

DISCUSSION

We investigated the effectiveness of HFNOT in patients with acute Type I and Type II respiratory failure. Type I, or hypoxemic, failure is commonly seen in pulmonary oedema or pneumonia, where lung tissue itself is damaged. Meanwhile, Type II respiratory failure is multifactorial and caused by alveolar hypo-ventilation or insufficient excretion of the CO_2 that is being produced. Hypoxaemia resulting from ventilation/perfusion abnormalities or impaired diffusion can easily be corrected by supplementing inspired oxygen, whereas in hypercapnic patients, generally more than one factor contributes to the rise in $PaCO_2$ (7). NFNOT might be effective in hypercapnic respiratory failure due to its physiological effect of CO_2 washout from the anatomical dead space, with resulting increase in ventilatory efficiency (8, 9). In addition, positive airway pressures result in improvement of ventilation and perfusion matching and a reduction in respiratory workload. Despite numerous HFNOT advantages for patients who cannot tolerate or fail standard NIV, there are no established guidelines for the use of high flow oxygen in hypercapnic respiratory failure. Our data confirmed that HFNOT might be beneficial not only in hypoxemic but in acute hypercapnic respiratory failure as well. We have observed increase of Pa/FiO_2 ratio alongside with clinically improving symptoms of hypoxemia in Type I respiratory failure. In patients with Type II respiratory failure, improvement of hypercapnia was achieved after 1 hour of HFNOT. Similar effects of HFNOT have been reported in cases with acute respiratory failure with CO_2 retention (10, 11). Our findings were similar to recent study data providing the evidence that HFNOT have similar escalation to intubation rates to NIV (12, 13). Most of the authors agree that in the light of conflicting heterogenous data clear criteria for respiratory support escalation are necessary and mechanical ventilation should not be delayed if appropriate oxygenation goals are not obtained with HFNOT support. More evidence of HFNOT versus other forms of non-invasive positive-pressure ventilation is needed to establish recommendations and guidelines.

CONCLUSIONS

Our data suggests that HFNOT can be effectively used in Type I and Type II RF, either as a rescue therapy, when NIV fails, or even as an alternative to non-invasive ventilation in thoroughly selected and closely monitored patient group. Clinicians should be cautious when identifying patients at risk of escalation for intubation and avoid the risks of delayed escalation. A larger population group study is needed to identify predictors of HFNOT failure.

CONFLICT OF INTEREST

None declared.

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Ieva Norkienė, Raquel d'Espiney,
Juan F. Martin-Lazaro

DIDELĖS TĖKMĖS DEGUONIES TERAPIJOS EFEKTYVUMAS GYDANT ŪMŲ HIPOKSEMINĮ IR HIPERKAPNINĮ KVĖPAVIMO NEPAKANKAMUMĄ

Santrauka

Įvadas. Didelės tėkmės deguonies terapija (DTDT) vis plačiau naudojama ūmaus hipokseminio (I tipo) kvėpavimo nepakankamumo (KN) gydymui. Tačiau DTDT efektyvumas gydant hiperkapninį arba II tipo KN lieka kontraversiškas.

Tyrimo tikslas. Įvertinti pacientų su hipokseminiu ir hiperkapniniu kvėpavimo nepakankamumu po DTDT prognozes.

Objektas ir metodai. Retrospektyvinis observacinis tyrimas, į kurį įtraukti pacientai, kuriems diagnozuota pneumonija ir taikytas gydymas DTDT. Tyrimo metu buvo renkami pirminiai duomenys apie paciento būklės ir kraujo dujų parametrų dinamiką praėjus vienai valandai po DTDT taikymo. Intubacijos bei 30 dienų mirštamumo dažnis vertinti kaip antrinės išeitys.

Rezultatai. Į tyrimą įtrauktas 51 pacientas. 32 (63 %) buvo nustatytas I tipo KN ir 19 (37 %) II tipo KN. Pradinis $PaCO_2$ I KN grupėje buvo 34,05 mmHg ir sumažėjo iki 33,07 mmHg, praėjus 1 val. po DTDT taikymo. II KN grupės pacientų $PaCO_2$ atitinkamai sumažėjo nuo 56,47 iki 54,97 mmHg. DTDT buvo dažniau sėkminga I KN grupėje – 25 pacientams (78 %), o II KN grupėje – 11 pacientų (58 %). Kvėpavimo funkcijos palaikymo reikėjo septyniems pacientams iš I KN ir aštuoniems iš II KN grupių. Mirusių ligonių abiejose grupėse nebuvo.

Išvados. Tyrimo duomenimis, DTDT gali būti efektyviai naudojama I ir II tipų kvėpavimo nepakankamumo atvejais. Būtina laiku įvertinti pacientų, kuriems būtini kiti ventiliacijos būdai, būkles. Veiksnius, susijusius su nesėkminga DTDT, būtina identifikuoti atliekant didesnės apimties tyrimus.

Raktažodžiai: didelės tėkmės deguonies terapija, kvėpavimo nepakankamumas, ne-invazinė ventiliacija