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The quandary of prehospital oxygen administration in chronic obstructive pulmonary disease - a review of the literature

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Abstract

Introduction

Perpetual debate continues regarding the amount of oxygen that should be delivered by paramedics to patients with acute exacerbations of chronic obstructive pulmonary disease (COPD). A number of studies argue that providing excessive levels of oxygen in COPD patients results in hypercapnic respiratory failure. Despite the prevalence of COPD there continues to be a paucity of prehospital literature on this topic.

Objective

To review and analyse the literature regarding prehospital administration of oxygen therapy in patients with COPD.

Design

Literature review using a variety of medical databases including Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, MEDLINE, CINAHL and PubMed. The following MeSH terms were used in the search: *lung diseases, obstructive; emergency medical services; respiratory therapy*.

Results

Using exclusion and inclusion criteria a total of 9 papers were located. There is a lack of high quality evidence to adequately address the issue of oxygen prescription to COPD patients in the prehospital setting. It is recommended that oxygen flow is titrated in COPD patients to maintain SpO₂ between 90-92%.

Conclusions

There is a need for randomised controlled trials in the prehospital setting to address the issue regarding oxygen prescription for COPD patients. Oxygen can be titrated using pulse oximetry to minimize complications of hypoxia and the risk of hypercapnia from excessively high oxygen concentration.

Keywords

chronic obstructive pulmonary disease; COPD; oxygen; prehospital emergency care.

Introduction

Paramedic use of oxygen for COPD patients in the prehospital setting is a contentious issue. Many studies recommend controlling oxygen with fixed inspired oxygen $\text{FiO}_2 \leq 0.28$.¹⁻³ This restriction in oxygen is thought to prevent carbon dioxide retention, which can lead to hypercapnic respiratory failure. A number of theories attempt to explain how oxygen results in carbon dioxide retention. It is likely that oxygen contributes to carbon dioxide retention through a combination of ventilation-perfusion mismatch, respiratory depression, hypoventilation and the Haldane effect.³⁻⁷

Oxygen therapy is thought to create a ventilation-perfusion mismatch by decreasing hypoxic vasoconstriction of pulmonary capillaries in poorly ventilated regions of lung, resulting in an increase in dead space.^{7,8} The role of oxygen in decreasing hypoxic respiratory drive, thereby reducing ventilation remains controversial. Reports disagree about how significant the contribution of oxygen is in decreasing hypoxic respiratory drive.⁵⁻⁸ Robinson *et al* investigated the impact of hypoventilation and ventilation-perfusion ratios in patients with acute exacerbations of COPD. Findings of this study indicate that administration of 100% oxygen to carbon dioxide retainers result in an increase in alveolar dead space and a decrease in ventilation.⁸ This suggests that both ventilation-perfusion mismatch and hypoventilation contribute to hypercapnia in these patients.⁸

Conversely, a number of studies oppose limiting the concentration of oxygen provided to COPD patients in the prehospital setting. It is their belief that hypoxic respiratory drive and the risk of high flow oxygen contributing to hypercapnia is overstated, with hypoxia presenting a much greater danger to COPD patients with acute exacerbations.

The conflicting theories regarding oxygen therapy and the associated risks of carbon dioxide retention, has led to confusion regarding prehospital use of oxygen therapy in COPD. The aim of this paper is to undertake a literature review of prehospital administration of oxygen therapy in COPD patients and develop recommendations for the future use of oxygen.

Methods

The purpose of this review was to critically evaluate the available literature on prehospital administration of oxygen therapy in patients with COPD. A literature review was undertaken using several electronic databases, these included:

- Cochrane Database of Systematic Reviews (to 2nd Quarter 2007)
- Cochrane Central Register of Controlled Trials (to 2nd Quarter 2007)
- MEDLINE (1950-May 2007)
- EMBASE (1974-week 22, 2007)
- CINAHL (1982-May week 4 2007)
- PubMed (to May 2007)

The following MeSH terms were used in the search:

emergency medical services; lung diseases, obstructive; respiratory therapy.

Using truncation, the search strategy used the following keywords:

lung diseases, obstructive or bronchitis or pulmonary emphysema or COPD or COAD or CAL
and

emergency medical services or emergency health services or patient transport or ambulances or pre-hospital or pre hospital or prehospital or emergency treatment and respiratory therapy or oxygen inhalation therapy or oxygen or Hudson mask or nasal cannula or Venturi mask

Other articles were reviewed for references from the retrieved papers to identify relevant articles that may have been missed during the initial search process.

Literature Review Results

Articles were included in this review if the title and abstract indicated that the content addressed the use oxygen therapy in patients with acute exacerbations of COPD in the prehospital setting. Articles involving paediatrics, patients with acute asthma, or letters to the editor were excluded from this review. A total of 9 papers were located and are presented in table 1.

Table 1: Located literature

Author and date of publication	Study type & Level of evidence	Study size (n)	Age mean (SD)	Patient group	Key Findings	Limitations
Austin & Wood-Baker, 2006	Systematic Review Level I	-	-	Adults with acute exacerbation of COPD (AECOPD) in the prehospital setting	No completed randomised controlled trials (RCTs) of O ₂ administration at different concentrations or O ₂ versus placebo	Lack of RCTs
De Lorenzo, 1994	Single Case Study	1	68	Adult with AECOPD in the prehospital setting	Haldane effect is major cause of increased PaCO ₂ . Signs and symptoms of hypoxaemia should determine oxygen provision in prehospital setting	Low level of evidence and limited applicability to population
Denniston <i>et al</i> , 2002	Prospective audit Level IV	97	69.7 (9)	Adult patients with AECOPD in the prehospital and A&E setting	Higher mortality rate with higher concentration O ₂ (FiO ₂ ≥0.28). No significant group difference in PaCO ₂ or PaO ₂ with high or low FiO ₂ . Mortality greatest in group with severe respiratory acidosis	Audit – association of FiO ₂ with mortality but many confounding factors such as disease severity
Durrington <i>et al</i> , 2005	Retrospective comparative audit Level III-3	Pre-low FiO ₂ : 108 Post-low FiO ₂ : 103	Pre-low FiO ₂ : 73 (range 44-98) Post-low FiO ₂ : 72 (range 47-91)	Adult patients admitted to hospital with AECOPD. Pre and post implementation of low FiO ₂ ≤0.28 guidelines in prehospital setting	Significant rise in proportion of patients receiving low FiO ₂ in the ambulance post guidelines. No significant change in complication rates (mortality or incidence of acidosis and hypercapnia)	Retrospective comparative audit – potential for confounders and bias such as severity of disease
Gooptu <i>et al</i> , 2006	Retrospective Audit Level IV	18	64.4 (13.3)	Adult hypercapnic patients with	63% admissions managed by ambulance according to card-holder	Study only evaluated the compliance of

				O ₂ alert cards in ambulance and A&E setting	protocol, 94% compliance in A&E	O ₂ alert cards
Murphy, Driscoll <i>et al</i> , 2001	Literature review	-	-	Oxygen therapy in COPD patients	Hypoxia can result in cardiorespiratory arrest and irreversible damage to organs. PaO ₂ should be kept above 50mmHg. CO ₂ retention can cause depression in neurological and cardiorespiratory function. Hypercapnia becomes dangerous in the range of 80-120mmHg. Oxygen can cause CO ₂ retention in COPD patients	Not a systematic review
Murphy, Mackway-Jones <i>et al</i> , 2001	Expert opinion	-	-	Oxygen therapy in the breathless patient	Risk of hypoxia greater than risk of hypercapnia in patients with dyspnoea. In COPD patients SpO ₂ should be between 90-92%	Expert opinion. Lacks data to support main findings
New, 2006	Literature review	-	-	Oxygen therapy in COPD patients	Almost impossible to obtain PaCO ₂ >100mmHg without oxygenation. Need for large scale well controlled trial. Further research required into cause of CO ₂ retention – contributing factors include hypoxic pulmonary vasoconstriction, absorption atelectasis, respiratory depression and the Haldane effect. SpO ₂ should be maintained between 85-92%	Not a systematic review
Urwin <i>et al</i> , 2004	Single case study	1	64	Patient with undiagnosed COPD in the prehospital and A&E setting	Not all COPD patients are identified in the community. Hypercapnia cannot be monitored in prehospital setting. Effects of hypercapnia reversible if managed promptly and appropriately	Low level of evidence and limited applicability to population

This literature review reaches the same finding of a recent Cochrane systematic review, in that no prehospital randomised controlled trials have been completed to determine the ideal oxygen concentration for the treatment of acute exacerbations of COPD. Audits performed by Durrington *et al* and Denniston *et al* promote restricting FiO₂ ≤ 0.28 in patients with COPD in the prehospital setting. Several other studies report hypoxia in COPD patients is of greater concern, promoting the titration of oxygen to maintain a SpO₂ at least above 85% and more commonly between 90-92%. However, there is a lack of high quality evidence to adequately determine the most appropriate level of oxygen for provision to patients with exacerbation of COPD.

Discussion

The articles regarding oxygen for COPD patients in the prehospital setting have flaws in methodological design, resulting in potential confounders and bias. This limits the conclusions that can be drawn from the data. The articles presented promote two main methods of delivering oxygen. One method is to control oxygen through fixed low concentrations. The alternative theory is to use pulse oximetry to determine an adequate flow rate.

An article in favour of fixed inspired oxygen in COPD patients is a prospective audit by Denniston *et al.* The study found an association between high flow oxygen therapy and both respiratory acidosis and mortality.¹ However, the experiment design was unable to control the severity of disease in patients, which is a major confounding factor. Medical provision of a higher FiO_2 can simply indicate a patient with greater impairment in respiration which is associated with higher mortality rates, when compared to more stable COPD patients.

Durrington *et al* performed an audit of COPD patients before and after implementing controlled oxygen ($\text{FiO}_2 \leq 0.28$). The results show a significant reduction in patients receiving high flow oxygen in the prehospital setting following the implementation of restricted oxygen guidelines, however no changes occurred in complication rates or mortality. Joosten *et al* retrospectively reviewed 65 patients with exacerbations of COPD and found that patients with a higher partial pressure of oxygen ($\text{PaO}_2 \geq 74.5 \text{ mmHg}$) had a number of complications. These included a higher triage category, longer length of stay, greater need for non-invasive ventilation and higher admission to the high dependency unit.³ Limitations mentioned in the methodology of each study suggest it would be premature to restrict the oxygen flow to COPD patients in the prehospital setting based on the results presented. A more rigorous experiment design such as a randomised controlled trial is necessary for accurate conclusions about the most suitable oxygen flow rates for COPD patients in the prehospital setting.

The alternative method of controlling oxygen flowrates in COPD patients is to obtain target oxygen saturation levels via pulse oximetry rather than providing a fixed concentration of oxygen. Plant *et al* performed a one year prospective prevalence study to investigate the number of COPD patients admitted to hospital with respiratory acidosis. Plant *et al* found that 47% of the 983 patients were hypercapnic and a total of 20% had respiratory acidosis. The authors found no association between acidosis and mortality rates, however a high PaO_2 was associated with worse acidosis. Plant *et al* concluded that PaO_2 should be maintained between 7.3-10kPa (55-75mmHg) to decrease the risk of acidosis and ensure adequate tissue oxygenation, equating to a SpO_2 of 85-92%.

Gomersall *et al* performed a small randomised controlled trial of 38 patients in intensive care with acute exacerbations of COPD. Oxygen was titrated in two groups, to attain either a $\text{PaO}_2 > 9.0 \text{ kPa}$ (70mmHg) or $\text{PaO}_2 > 6.6 \text{ kPa}$ (50mmHg). There were no significant differences in mechanical ventilation, mortality, median length of hospital stay, PaCO_2 or pH between the groups. A confounding factor in this study is the use of doxapram (respiratory stimulant) if $\text{pH} < 7.26$.⁵ The absence of significant respiratory depression could be linked to the use of doxapram in this study. Similar numbers of patients in each group received doxapram, 5 patients in group with $\text{PaO}_2 > 6.6 \text{ kPa}$ (50mmHg) and 4 patients in group with $\text{PaO}_2 > 9.0 \text{ kPa}$ (70mmHg). Gomersall *et al* concluded the dangers associated with oxygen therapy to correct hypoxaemia in COPD patients may be overstated.

Physicians specialising in Emergency Medicine, Chest and Intensive Care (North West Oxygen group) have developed guidelines regarding oxygen therapy for patients with acute

breathlessness through expert consensus on a systematic review of the literature. The North West Oxygen group recommend that COPD patients being transported to hospital by ambulance should maintain an oxygen saturation between 90-92% to minimise the risk of hypercapnia. Kelly *et al* analysed the correlation of pulse oximetry saturation with arterial oxygen saturation in patients with acute exacerbations of COPD. This study analysed 64 sample pairs found a high correlation between measures with a correlation coefficient of 0.91.¹⁵ However there was only fair agreement between results when displayed on the Bland-Altman plot. The authors suggest that an oxygen saturation of 92% can be used as a screening cut-off for systemic hypoxia, with a sensitivity of 100% and a specificity of 86%. Other studies also conclude that pulse oximetry is sufficiently accurate for use in the prehospital setting when $SpO_2 \geq 88\%$ and is an effective tool in detecting hypoxaemia.

The following recommendations have been made based on the preceding discussion and data obtained from this literature review:

1. Randomised controlled trials are required to definitively establish a safe oxygen prescription for patients with acute exacerbation of COPD in the prehospital setting.
2. There needs to be widespread access to pulse oximetry for all paramedic personnel to obtain a target oxygen delivery in COPD patients with a SpO_2 between 90-92%. This should also include paramedic understanding of physiology and limitations of pulse oximetry.

Conclusion:

There is clearly a lack of high quality evidence regarding the most appropriate oxygen prescription for patients with acute exacerbation of COPD. Controlling oxygen by providing $FiO_2 \leq 0.28$ can potentially lead to hypoxaemia. A more accurate and practical method for paramedics to titrate oxygen requirements is through maintaining an oxygen saturation between 90-92%, thereby preventing hypoxaemia and decreasing the risk of worsening respiratory acidosis. Further investigation and examination are recommended following this literature review. Randomised controlled trials are required in the prehospital setting to establish the level of oxygen that can be safely prescribed to patients with acute exacerbation of COPD. Widespread access to pulse oximetry should be provided to paramedic personnel to ensure patients receive a level of oxygen that prevents hypoxia and limits the risk of hypercapnia.

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Conflict of Interest:

None

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