The effects of oxygen therapy in patients presenting to an emergency department with exacerbation of chronic obstructive pulmonary disease

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ABSTRACT

Objective: To elucidate oxygen administration practices in the setting of acute exacerbations of chronic obstructive pulmonary disease (COPD) and compare these practices with those recommended in internationally accepted guidelines.

Design: Retrospective audit.

Participants and setting: 65 patients admitted to a Melbourne university teaching hospital via the emergency department (ED), identified through medical records by a discharge diagnosis (discharged between 1 June and 30 September 2005) of acute exacerbation of COPD (AECOPD). Those included had respiratory function test results consistent with British Thoracic Society guidelines for the diagnosis of COPD.

Main outcome measures: Length of stay, need for high dependency unit (HDU) admission, use of non-invasive ventilation (NIV), and use of arterial blood gas (ABG) tests.

Results: Our audit showed that 95% of patients defined as retaining carbon dioxide received oxygen at a flow rate greater than 2 L/min. This process began in the ambulance and continued in the ED, often without monitoring of ABG levels. Length of stay was significantly longer ($P = 0.029$); need for NIV on admission greater ($P = 0.0124$); and rate of admission to the HDU higher ($P = 0.0124$) in patients who achieved a partial pressure of arterial oxygen (PaO_2) ≥ 74.5 mmHg compared with those with a PaO_2 < 74.5 mmHg.

Conclusions: The vast majority of patients with AECOPD presenting to our university teaching hospital receive oxygen therapy outside of internationally accepted guidelines, often without monitoring of ABG levels. The use of high-flow oxygen may contribute to an increased length of stay, more frequent admission to HDU and greater use of NIV among patients who achieve a higher PaO_2.

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Chronic obstructive pulmonary disease (COPD) is a common disorder affecting up to 2.6 million Australians, with affected patients occupying 1000 hospital beds daily in Australia.[1] Management of the exacerbations that characterise COPD is described in several international guidelines. Common to these guidelines is the recommendation for controlled oxygen therapy to treat hypoxaemia.[2-4] The COPDX Plan published in this Journal in 2003 recommends administering a fraction of inspired oxygen (FIO_2) of 0.28 (about equal to 2 L per minute of oxygen via nasal prongs, or a Venturi mask set at an FIO_2 of 0.28) or less until the arterial tension of respiratory gases is determined by arterial blood gas (ABG) sampling.[3] This recommendation is based on the knowledge that increasing arterial oxygen tension in patients with hypercapnic respiratory failure causes deleterious changes to alveolar ventilation and gas exchange, resulting in worsening acidosis[5,6] that, in turn, leads to higher morbidity and mortality.[7,8]

A study from the United Kingdom has shown that controlled oxygen delivery is not emphasised in ambulance and nursing staff education, and is often overlooked by emergency and intensive care physicians.[9] Our anecdotal experience was similar, and we undertook an audit of patients presenting to our university teaching hospital with an acute exacerbation of COPD (AECOPD) to determine: (i) the proportion of patients who received care consistent with international guidelines; and (ii) whether not adhering to such guidelines resulted in differing outcomes for patients.

METHODS

We undertook a retrospective audit of patients admitted after presenting to the emergency department (ED) with AECOPD. Patients discharged between 1 June and 30 September 2005 with a diagnosis of AECOPD were identified. Included patients had respiratory function test (RFT) results (either before or after admission) consistent with the British Thoracic Society (BTS) definition of COPD (ie, forced expiratory volume in 1 second [FEV_1] less than 80% of predicted, and forced expiratory ratio less than 70%).[4]

Data on oxygen delivery, triage category, ABG test results, length of stay, admission destination, mortality, and patient demographic information were recorded. Patients who were included were classified as retaining carbon dioxide if they had a partial pressure of arterial CO_2 ($PaCO_2$) of greater than 45 mmHg recorded either on admission or previously. Patients with chronic hypercapnia or hypercapnia associated with respiratory acidosis were included.

Statistical analysis

Data were analysed using GraphPad Prism 4 (GraphPad Software, San Diego, Calif, USA) and Microsoft Excel 2002 (Microsoft Corporation, Redmond, Wash, USA); multivariate analysis was carried out using SPSS (SPSS Inc, Chicago, Ill, USA). The two-sample *t* test was used to compare continuously valued data. Analysis of variance was used to compare means between three or more groups, with the *P* value derived from the F test addressing the null hypothesis of equality of means across groups at the population level. The χ^2 test was used to address the null hypothesis of no association between categorical variables based on the corresponding contingency table. Means are reported with SDs, and confidence intervals are at the 95% level.

RESULTS

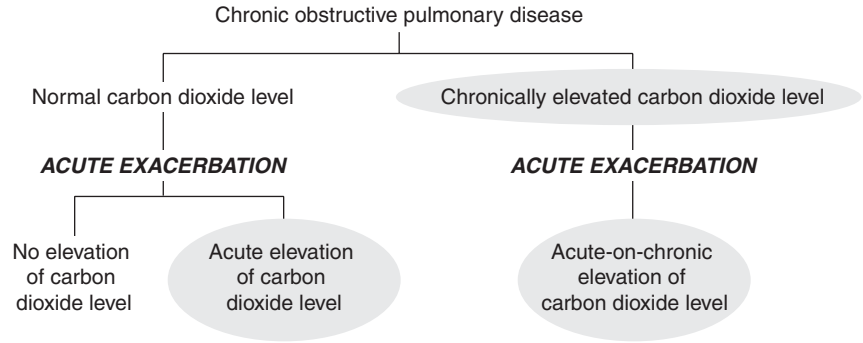
One hundred potentially eligible patients were identified, and 35 of these were excluded (20 had not had RFTs, nine did not have RFT results consistent with BTS guidelines, and six were not admitted through the ED). The demographic charac-

1 Demographic characteristics of the 65 patients included in the study

Characteristic	Finding
Mean age (years)	72.4±8.5
Deaths	3 (4.6%)
Mean FEV_1 (L)	1.05±0.41
Mean FVC (L)	2.16±0.75
Patients in:	
Triage category 1	4 (6%)
Triage category 2	19 (29%)
Triage category 3	31 (48%)
Triage category 4	11 (17%)
Mean length of stay (days)	6.7±5.8
Mean lowest pH recorded in ED	7.33±0.10
Mean highest PaO_2 recorded in ED (mmHg)	112.4±98.0
Mean highest $PaCO_2$ recorded in ED (mmHg)	55.2±2.8

FEV_1 = forced expiratory volume in 1 second. FVC = forced vital capacity. ED = emergency department. PaO_2 = partial pressure of arterial oxygen. $PaCO_2$ = partial pressure of arterial carbon dioxide.
*Patients were triaged according to the Australasian Triage Scale.[10]
Means are expressed with SDs. ◆

2 Patients classified as retaining carbon dioxide (grey shading)



3 Comparison of the 41 patients who retained carbon dioxide on the basis of whether they received oxygen at > 4 L per minute or ⩽ 4 L per minute

	Oxygen flow rate		
Variable	> 4 L/min	⩽ 4 L/min	*P*
Number of patients	28 (68%)	13 (32%)	
Mean age (years)	70.9±9.8	69.5±9.7	0.656
Deaths	2 (7.1%)	0	0.479
Mean FEV_1 (L)	0.93±0.37	0.90±0.28	0.797
Mean FVC (L)	1.93±0.68	2.11±0.91	0.486
Patients in:			
Triage category 1	2 (7%)	2 (15%)	
Triage category 2	14 (50%)	2 (15%)	
Triage category 3	10 (36%)	6 (46%)	
Triage category 4	2 (7%)	3 (23%)	
Patients who had ABG tests	19 (68%)	10 (77%)	0.142
Mean lowest pH recorded in ED	7.31±0.08	7.27±0.09	0.207
Patients with acidosis	14 (74%)*	7 (70%)†	0.127
Patients with pH < 7.25	7 (37%)*	1 (10%)†	0.034
Mean highest PaO_2 recorded in ED (mmHg)	162.7±128.5	65.96±21.2	0.027
Mean highest $PaCO_2$ level recorded in ED (mmHg)	66.8±21.4	59.0±21.0	0.354
Mean length of stay (days)	8.11±5.90	4.39±2.26	0.034
Patients who had NIV on admission	11 (39%)	3 (23%)	0.033
Patients admitted to HDU or ICU	11 (39%)	3 (23%)	0.033

FEV_1 = forced expiratory volume in 1 second. FVC = forced vital capacity. ABG = arterial blood gas. ED = emergency department. PaO_2 = partial pressure of arterial oxygen. $PaCO_2$ = partial pressure of arterial carbon dioxide. NIV = non-invasive ventilation. HDU = high dependency unit. ICU = intensive care unit.
*19 patients tested. † 10 patients tested.
Patients were triaged according to the Australasian Triage Scale.[10] Means are expressed with SDs. ◆

teristics of the remaining 65 patients are shown in Box 1.

Oxygen therapy

Of the 65 patients, 53 arrived by ambulance. Forty-nine of these (92%; 95% CI, 82%–97%) received oxygen at a flow rate greater than 2 L per minute in the ambulance, and 18 (34%; 95% CI, 23%–43%) had previously documented hypercapnia. Once in the ED, 52 patients (80%; 95% CI, 68%–88%) received oxygen at a flow rate of > 2 L per minute. After 3 hours in the ED, 38 of the 65 patients (58%; 95% CI, 46%–70%) were exposed to oxygen at > 2 L per minute, with 19 (29%; 95% CI, 20%–41%) on room air, 22 (34%; 95% CI, 24%–46%) on nasal prongs, 13 (20%; 95% CI, 12%–31%) on facemask and 11 (17%; 95% CI, 10%–28%) on non-invasive ventilation (NIV).

Arterial blood gas sampling

ABG samples were taken from 43 patients (66%; 95% CI, 54.0%–77%) in the ED. All four patients in triage category 1 (100%; 95% CI, 48%–99%) had ABG tests. Corresponding numbers of patients in triage categories 2, 3 and 4 who had ABG tests were 11/19 (58%; 95% CI, 36%–77%), 21/31 (68%; 95% CI, 50%–81%) and 7/11 (64%; 95% CI, 35%–85%). Patients were triaged according to the Australasian Triage Scale.[10]

Thirty of the 65 patients presenting to the ED (46%; 95% CI, 35%–58%) had ABG results showing hypercapnia, either chronically (18 patients) or in association with respiratory acidosis (12 patients). Of these 30 patients with previously documented CO_2 retention, 14 (47%) had ABG tests in the ED, all of which showed hypercapnia. An additional 11 patients (with no previous documentation of hypercapnia) were shown to have hypercapnia on ABG testing in the ED; this gave 25 ABG samples showing hypercapnia. A total of 41 patients had recorded hypercapnia (30 previously documented and 11 newly documented). These 41 patients were classified as retaining CO_2 (see Box 2). Of note, 18 of the 65 patients

4 Comparison of patients with high and low partial pressure of arterial oxygen (PaO_2)

Variable	High PaO_2 (≥74.5 mmHg)	Low PaO_2 (<74.5 mmHg)	*P*
Number of patients	22 (51%)	21 (49%)	
Mean age (years)	69.3 ± 10.5	73.7 ± 7.9	0.127
Deaths	3 (14%)	0	0.083
Mean FEV_1 (L)	0.95 ± 0.35	1.08 ± 0.42	0.285
Mean FVC (L)	2.15 ± 0.76	2.07 ± 0.71	0.728
Patients in:			
Triage category 1	4 (18%)	0	
Triage category 2	8 (36%)	3 (14%)	
Triage category 3	8 (36%)	13 (62%)	
Triage category 4	2 (9%)	5 (24%)	0.033
Mean lowest pH recorded in ED	7.30 ± 0.11	7.35 ± 0.08	0.060
Patients with acidosis	14 (64%)	8 (38%)	0.200
Patients with pH < 7.25	6 (27%)	2 (10%)	0.157
Mean highest $PaCO_2$ recorded in ED (mmHg)	58.1 ± 20.1	52.2 ± 22.9	0.384
Mean length of stay (days)	11.18 ± 10.36	5.91 ± 2.59	0.029
Patients who had NIV on admission	12 (55%)	3 (14%)	0.012
Patients admitted to HDU or ICU	12 (55%)	3 (14%)	0.012

FEV_1 = forced expiratory volume in 1 second. FVC = forced vital capacity. ED = emergency department. $PaCO_2$ = partial pressure of arterial carbon dioxide. NIV = non-invasive ventilation. HDU = high dependency unit. ICU = intensive care unit.
Patients were triaged according to the Australasian Triage Scale.[10] Means are expressed with SDs. ◆

presenting with COPD (28%; 95% CI, 18%–40%) had an ABG sample showing respiratory acidosis (pH < 7.35). Twenty-two patients (34%; 95% CI, 24%–46%) did not have an ABG test at any stage during their ED admission.

Of the 41 patients classified as retaining CO_2, only two (5%; 95% CI, 2%–16%) received oxygen at a flow rate of 2 L per minute or less (≤ 2 L/min, as per COPDX guidelines[3]), while 13 (32%; 95% CI, 20%–47%) received oxygen at 4 L or less per minute (≤ 4 L/min, consistent with BTS guidelines[4]). Because of the small number of patients receiving oxygen at 2 L or less per minute, the group of patients retaining CO_2 was further analysed by using an oxygen flow rate of 4 L per minute as a cut-off. Oxygen at 4 L per minute was delivered exclusively by means of nasal prongs. When flow rates of 5 L per minute or greater were used, the means of delivery was almost always a facemask, and when NIV was used, the FIO_2 was set at 0.4 or higher. Results are shown in Box 3.

In the ED, patients with AECOPD are often treated with high-flow oxygen because of hypoxia. All COPD patients who had an ABG test were analysed in terms of highest achieved partial pressure of arterial oxygen (PaO_2) to see if correcting hypoxia improved outcomes (Box 4). The median value for PaO_2 was 74.5 mmHg. Patients were divided into those with PaO_2 greater than or equal to, and less than 74.5 mmHg. The group with the higher PaO_2 had significantly more patients in higher triage categories ($P = 0.033$), a longer stay in hospital ($P = 0.029$), greater need for NIV on admission ($P = 0.0124$) and a higher rate of admission to the high dependency unit (HDU; $P = 0.0124$). The multivariate linear regression model showed that pH ($P = 0.012$) and PaO_2 ($P = 0.012$) were predictive of length of stay, while triage category and FEV_1 were not. After adjusting for severity of exacerbation (ie, pH), PaO_2 was a significant predictor of length of stay ($P = 0.033$). No factors were found to be significantly confounding the use of NIV or admission to the HDU.

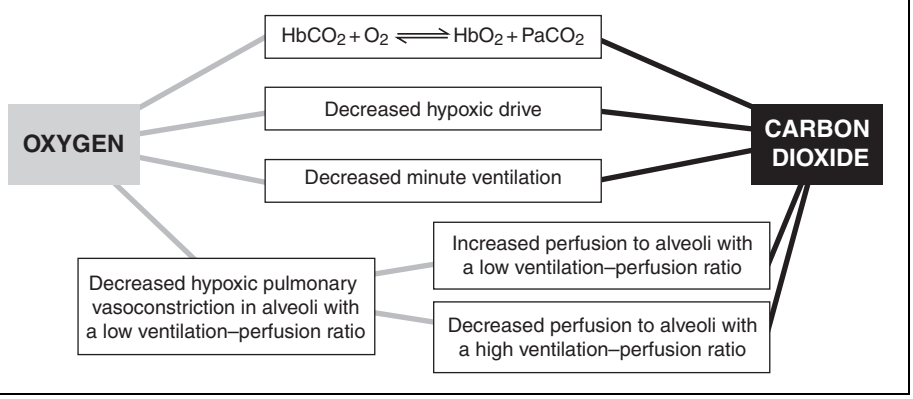
DISCUSSION

There are a number of potential biases in our audit. Because of its retrospective nature, we were reliant on accurate documentation for our results. The charting of oxygen delivery methods and respiratory rate was variable, which made analysing oxygen administration according to length of exposure or minute ventilation difficult. Use of discharge diagnosis as an identifier creates a selection bias by which patients with milder exacerbations of COPD, managed as outpatients, were excluded. Although we cannot prove causation between the parameters measured, several observations can be made.

Our findings confirm that uncontrolled oxygen therapy is commonplace at our university teaching hospital. The use of oxygen flow rates greater than 4 L per minute in patients with high CO_2 levels was associated with a significant increase in length of stay ($P = 0.034$), a greater need for NIV ($P = 0.033$), and a higher admission rate to the HDU ($P = 0.033$). Use of more than 4 L of oxygen per minute was associated with severe acidosis in patients with AECOPD known to retain CO_2 ($P = 0.034$). This association has been shown previously in a similar group of patients.[9]

Increased oxygen delivery promotes retention of CO_2 through numerous mechanisms (Box 5). The most important of these

5 Mechanisms contributing to retention of carbon dioxide in acute exacerbation of chronic obstructive pulmonary disease



are generally considered to be an increase in ventilation–perfusion mismatch secondary to reduced hypoxic vasoconstriction[11-13] and a reduction in ventilation on removal of a hypoxic stimulus.[13,14]

Our audit shows that the administration of high-flow oxygen usually begins in the ambulance. At the time of writing, no specific guideline exists for oxygen administration by ambulance officers.[15] High-flow oxygen therapy is continued in the ED, where more than 80% of patients with AECOPD receive oxygen at more than 2 L per minute. This occurs in an ad-hoc fashion, with no formal method for prescribing oxygen. Furthermore, 22/65 patients receiving oxygen at more than 2 L per minute (34%; 95% CI, 24%–46%) did not have an ABG test. This highlights the need for more judicious use of ABG tests in monitoring patients who present with AECOPD at our university teaching hospital.

Emergency staff often use high-flow oxygen on the basis that patients presenting with AECOPD are profoundly hypoxic. Our audit showed that patients who achieved a higher Pa_{O_2} were significantly more likely to have NIV on admission, significantly more likely to require HDU admission, and to stay longer in hospital. More research is needed to further delineate the relationship between high Pa_{O_2} and patient oucomes.

We used a collaborative approach between respiratory and emergency physicians to disseminating information about the treatment of AECOPD, to improve outcomes by:

- liaising with ambulance services about oxygen delivery guidelines;
- educating patients about oxygen delivery;
- establishing an alert system in the ED for at-risk patients; and
- repeating the audit after implementing the above strategies.

CONCLUSION

The delivery of oxygen to patients with AECOPD and monitoring the effects with ABG testing is still a major issue at our university teaching hospital. Results of our retrospective audit suggest that administering high-flow oxygen to patients with AECOPD may contribute to the observed differences in length of stay, need for NIV and admission to the HDU, highlighting the importance of controlled oxygen therapy in managing this common disease.

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COMPETING INTERESTS

None identified.

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