Hypercapnia and oxygen therapy in older asthmatic patients

Joseph Y.S. Ting

Excessive oxygen administration in hypercapnic chronic obstructive pulmonary disease predisposes to worsening respiratory failure during intercurrent respiratory illness. Chronic hypercapnia is thought to downregulate carbon dioxide chemoreceptor sensitivity, adversely affecting respiratory function/mechanics and worsening ventilation–perfusion inequality. These patients are dependent on hypoxic drive to maintain adequate spontaneous respiration. Whether an analogous situation occurs in asthma in older adults is unknown. These conditions may be difficult to differentiate clinically, and both may respond adversely to the administration of excessive oxygen in the presence of chronic hypercapnia. Although unrestricted oxygen is beneficial and safe in children and young adults with asthma, it may lead to progressive hypercapnia in older patients with asthma, a potential risk highlighted by this case. To avert progressive hypercapnia, oxygen therapy that is carefully adjusted to achieve adequate, but not maximal, tissue oxygenation may be a safer strategy than unrestricted oxygen use in older asthmatic patients. However, the correction of hypoxia overrides strategies to avert oxygen-related hypercapnia. *European Journal of Emergency Medicine* 11:355–357 © 2004 Lippincott Williams & Wilkins.

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Introduction

The effects of unrestricted oxygen administration in elderly patients with severe late-onset chronic asthma is undetermined, in contrast to its detrimental effects on spontaneous respiration in chronic obstructive pulmonary disease (COPD) patients with chronic hypercapnia.

Case report

An 80-year-old woman was admitted with chest tightness for the exclusion of myocardial infarction. Chest auscultation revealed moderate air entry with bi-basal crackles and no wheeze. Except for a blood pressure of 200/100 mmHg, the rest of her cardiovascular examination was normal. There was no acute ischaemic change on serial electrocardiogram and the troponin-I levels did not rise. There was no history of ischaemic heart disease or risk factors for pulmonary thromboembolism.

There was a long history of severe late-onset asthma, with premorbid spirometry of a forced expiratory volume in 1 s (FEV_1) of 0.37 l (23% predicted) and a forced vital capacity of 0.74 l (27% predicted). There was no history of direct or indirect exposure to cigarette smoking. She was maintained on 10 mg prednisone daily but had no home oxygen requirement, mobilized independently and was self-caring. Other medical problems included well-controlled, non-insulin-dependent diabetes mellitus, poorly controlled hypertension, gastro-oesophageal reflux, and osteoporosis. Her medications were inhaled salbutamol, ipratropium bromide, budesonide and salmeterol; theophylline, zafirlukast, prednisone, metformin, glipizide, ramipril, lansoprazole, calcitriol and rofecoxib.

That evening, she became gradually more hypertensive to 250/95 mmHg. Oxygen 6 l/min was applied by nursing staff, after which she rapidly became unresponsive. Her pulse rate was 88 beats/min, arterial oxygen saturation (Sa_{O_2}) 78%, respiratory rate 30 breaths/min, and temperature 36°C. The blood sugar level was 11 mmol/l. There was no wheeze. Although severe hypertension responded well to intravenous hydralazine, her consciousness level did not improve. She had not received parenteral narcotics or beta-blockers before her deterioration.

The decision not to ventilate the patient mechanically was made in consultation with her family, in view of the possibility of a catastrophic brain-stem event, her age, and poor respiratory function. Sa_{O_2} deteriorated further to 66%. Arterial blood gases (ABG) on room air showed pH 7.10 [relative risk (RR) 7.35–7.45], arterial carbon dioxide tension (Pa_{CO_2}) 139 (RR 36–45 mmHg), arterial oxygen tension (Pa_{O_2}) 37 (RR 70–80 mmHg), bicarbonate 42 (RR 22–29 mmol/l), and base excess +6.8 (RR −3.0–4.0 mmol/l), consistent with acute-on-chronic respiratory failure. Chest X-ray showed left basal atelectasis and consolidation. Intravenous ceftriaxone was commenced.

The patient received regular inhaled salbutamol, ipratropium bromide, and budesonide, as well as intravenous

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hydrocortisone. The Sa_{O_2} improved to more than 90% after oxygen was reduced to 3 l/min, but she had recurrent apnoea. Repeat ABG demonstrated worsening respiratory acidosis and hypercapnia despite improved oxygenation (pH 6.96, Pa_{CO_2} 154 mmHg, Pa_{O_2} 94 mmHg, bicarbonate 33 mmol/l, base excess + 1.1 mmol/l). A paradoxical improvement in Pa_{O_2} achieved by reducing delivered oxygen strongly suggested that over-treatment with oxygen had a harmful effect in this setting.

The patient remained unresponsive with pinpoint non-reactive pupils. There was symmetrical hypotonicity, arreflexia and absent plantar responses. She was not hypoglycaemic at any stage, and severe hypertension had responded well to treatment. The most likely diagnosis was considered to be a brain-stem cerebrovascular event associated with central hypercapnic hypoxic respiratory failure and reduced consciousness.

A non-contrast computed tomography head scan performed on the morning of the second admission day demonstrated an equivocal low-density lesion in the brainstem (this was absent on subsequent scans, suggesting an artefact). Oxygen was reduced to 2 l/min. Soon thereafter, her neurological state improved rapidly, and her recovery was complete by the morning of the third admission day.

ABG on air after recovery showed pH 7.39, Pa_{CO_2} 58 mmHg, Pa_{O_2} 54 mmHg, bicarbonate 34 mmol/l, base excess + 7.1 mmol/l. The patient was discharged on 1 l/min home oxygen. Pulmonary function was improved at discharge (FEV_1 0.68 l, forced vital capacity 0.93 l) and she remains independent and self-caring.

A sleep study demonstrated no obstructive sleep apnoea. Increased apnoeic and hypopnoeic events that were associated with hypercapnia did not increase arousal, consistent with reduced respiratory centre sensitivity to carbon dioxide.

Discussion

This elderly patient suffered unexpected acute-on-chronic respiratory failure related to long-standing asthma despite an admission for chest pain. She was at high risk of severe deterioration from asthma, given previous severe episodes, an intercurrent Pa_{CO_2} greater than 97 mmHg and pH less than 7 [1]. Acute deterioration in consciousness led to an initial diagnosis of brain-stem dysfunction with centrally mediated respiratory failure. This was revised after she made a complete neurological recovery.

Respiratory acidosis and hypercapnia during acute exacerbation of asthma and COPD leads to neurological and cardiorespiratory dysfunction, such as altered consciousness, tachycardia and hypertension [2–4]. These clinical manifestations are associated with increased mortality [5]. Hypertensive encephalopathy was unlikely as her consciousness level remained poor despite improved hypertension.

Hypoxia is more rapidly harmful to tissues than hypercarbia, and if both are present, hypoxia requires more urgent correction with supplemental oxygen, even at the expense of worsening hypercarbia [6]. Hypercapnia indicates respiratory fatigue and warrants the consideration of assisted ventilation [7,8]. Although oxygen in addition to bronchodilators and steroids are effective in acute severe asthma in children and young adults [7,8], our case illustrates the potential for older asthmatic individuals to deteriorate with unrestricted oxygen administration. In these situations, respiratory failure, hypoxia and hypercapnia improve with a careful reduction in oxygen concentration that is still capable of maintaining acceptable tissue oxygenation ($Sa_{O_2} > 90\%$).

Whether unrestricted oxygen administration predisposes to hypercapnia and worsening respiratory failure in severe asthma in older adults is unclear [9]. Chien *et al.* [10] found that the administration of 100% oxygen [fractional inspired oxygen (FI_{O_2}) 100%] for 20 min in moderate asthmatic patients with respiratory alkalosis and hypocarbia led to carbon dioxide retention. Hypercapnia was worse the more severe the episode of asthma. There was no confounding effect from bronchodilators in that study, as oxygen was commenced before bronchodilators. As FEV_1 remained stable during the study period, progressive hypercapnia was not felt to be caused by progressive asthma. As in our case, several patients became less hypercapnic as oxygen was reduced.

A safe FI_{O_2} threshold before ABG measurement for acute severe asthma in the elderly remains undetermined. There are no studies on oxygen safety in elderly asthmatic patients. Ford and Rothwell [9] and McFadden and Lyons [11] found an FI_{O_2} up to 35% effective in young adults with moderate to severe asthma without predisposing to hypercapnia. FI_{O_2} up to 60% safely relieves hypoxia during normocapnic exacerbation of asthma in adults [8].

As Sa_{O_2} less than 90% occurs in less than 2% of asthma exacerbations, adequate oxygenation can usually be attained with oxygen starting at 2–4 l/min [10]. Slowly increasing oxygen administration to maintain a Pa_{O_2} greater than 60 mmHg is recommended in acute asthma [9,12] and COPD [2], especially when there is pre-existing or worsening hypercapnia [8,13]. This reduces the risk of worsening hypercapnia while maintaining adequate oxygenation [14]. Sa_{O_2} and Pa_{O_2} monitoring

using pulse oximetry and ABG, respectively, during oxygen titration averts hypoxia [9].

Late-onset asthmatic individuals with a Pa_{CO_2} greater than 45 mmHg may be at risk of worsening hypercapnia with unrestricted oxygen administration [8]. This may evolve within minutes [13,15]. Our patient's recovery demonstrates the capacity of the older hypercapnic asthmatic patient to recover with simple measures such as reduced oxygen administration [2,16,17], although assisted ventilation will often be required [18] if hypercapnia is acute and reflects fatigue rather than over-oxygenation.

The effect of chronic hypercarbia on respiratory drive in asthma is not known, unlike in COPD, in which acute-on-chronic and chronic hypercapnia dampens the hypoxic respiratory drive [2,3,5,13–15,19]. Unrestricted oxygen administration in a COPD patient with chronic hypercapnia leads to centrally mediated alveolar hypoventilation, reduced hypoxic drive, and worsening respiratory acidosis [3,10,13,20]. Chronic hypercapnia results in reduced chemosensitivity to carbon dioxide and increased reliance on hypoxic drive to maintain breathing during an intercurrent respiratory illness [2,14,17,20–22]. In these patients, unrestricted oxygen suppresses the hypoxic drive leading to reduced minute ventilation and carbon dioxide retention [14,20]. Worsening ventilation–perfusion mismatch and increased dead space ventilation were found to be significant in more recent studies [13,23].

COPD patients with chronic hypercapnia experience worsening respiratory acidosis the more the Sa_{O_2} is corrected above 92% [5]. Westlake *et al.* [2], Aubier *et al.* [13], Donald [16], and Prime and Westlake [17] described respiratory deterioration in chronically hypercapnic patients after unrestricted oxygen therapy, which improved with reducing oxygen administration. A chronic Pa_{CO_2} of more than 50 mmHg increases the risk of progressive hypercapnia in stable COPD [15], and titrated oxygen therapy aiming to maintain the Sa_{O_2} at 90–92% is recommended [3].

Conclusion

Unrestricted oxygen administration is beneficial in children and young adults with asthma, but may lead to progressive hypercapnia in older asthmatic individuals [7], a potential risk highlighted by this case. It is difficult to differentiate between COPD and asthma in elderly patients, and both conditions may deteriorate in response to over-oxygenation. This risk is reduced by carefully titrated oxygen therapy that provides adequate tissue oxygenation without provoking progressive hypercapnia. However, ensuring adequate tissue oxygenation should take precedence over averting progressive oxygen-induced hypercapnia.

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