Original Article

The acute use of oxygen therapy in adults

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Abstract

Over the last decade there has been an increasing realisation that oxygen should be considered a drug which is prescribed for specific indications to achieve a specific oxygen saturation range, and that the response needs to be monitored to guide ongoing therapy. This realisation has led to the development and promotion of guidelines which provide simple, practical and evidence-based recommendations for the acute use of oxygen in adults in clinical practice. In this commentary the Thoracic Society of Australia and New Zealand (TSANZ) oxygen guidelines are reviewed, and the key concepts and recommendations are presented.

Key words

Adult, Guideline; Hyperoxaemia; Hypoxaemia; Oxygen

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Abbreviations

ABG:	Arterial blood gas
BTS:	British Thoracic Society
COPD:	Chronic obstructive pulmonary disease
CPAP:	Continuous positive airway pressure
ED:	Emergency department
FiO_2:	Fraction of inspired oxygen
HDU:	High dependency unit
HFNC:	High flow nasal cannulae
ICU:	Intensive care unit
MDI:	Metered-dose inhaler
NIV:	Non-invasive ventilation
$PaCO_2$:	Arterial partial pressure of carbon dioxide
PaO_2:	Arterial partial pressure of oxygen
SaO_2:	Arterial oxygen saturation measured by arterial blood gas
SpO_2:	Arterial oxygen saturation measured by pulse oximetry
TSANZ:	Thoracic Society of Australia and New Zealand

Oxygen is one of the most commonly administered medications in patients receiving emergency or hospital based care. It is probably also one of the most commonly misused medications, being frequently administered in high concentrations to patients who are not hypoxaemic and in whom its use is not indicated. This has led to calls for oxygen to be considered a medication that is prescribed and administered for specific indications, delivered through a specific device, at specific flow rates to achieve a documented target oxygen saturation range, with regular monitoring of the patient's response.[1-3] It has also led to the development and publication of evidence-based guidelines by professional societies such as the British Thoracic Society (BTS)[4,5] and the Thoracic Society of Australia and New Zealand (TSANZ).[6]

The key concept on which the guidelines have been based is that there are risks associated with both hypoxaemia and hyperoxaemia, leading to the recommendation that oxygen should be prescribed only if required, and if so, to within a target oxygen

saturation range. In the TSANZ guidelines this practice has been referred to with the colloquial term 'swimming between the flags'.[6] In this commentary the TSANZ oxygen guidelines for acute oxygen use in adults are reviewed. The use of long term domiciliary oxygen for patients with severe chronic respiratory disease is not addressed, and it is recommended that the BTS guidelines for home oxygen use in adults are reviewed.[7]

Key Concepts

There are a number of key concepts on which the TSANZ guidelines are based. The first is that oxygen therapy is a treatment for hypoxaemia, not breathlessness. Oxygen therapy does not relieve the sensation of breathlessness in the absence of hypoxaemia. This has been shown in numerous clinical settings, with no clinical benefit of oxygen over room air for chronic obstructive pulmonary disease (COPD) patients with breathlessness who do not have severe hypoxaemia,[8] or refractory breathlessness in the palliative setting.[9] Furthermore, routine high concentration oxygen therapy does not improve outcomes compared with room air or titrated oxygen therapy to relieve hypoxaemia, in the treatment of acute coronary syndrome,[10] and hyperbaric oxygen does not reduce mortality risk after stroke.[11]

The second concept is that both hypoxaemia and hyperoxaemia may cause harm. Hypoxaemia is both a marker of the risk of a poor outcome due to the severity of the underlying disease(s) that has caused hypoxaemia, and an independent risk factor of poor outcome.[12,13] While no absolute safe lower limit of hypoxaemia can be set, due to the differing clinical situations in which hypoxaemia can occur, oxygen therapy which achieves an arterial partial pressure of oxygen (PaO_2) of at least 50 mmHg would prevent immediate life threatening risk from hypoxaemia.[14]

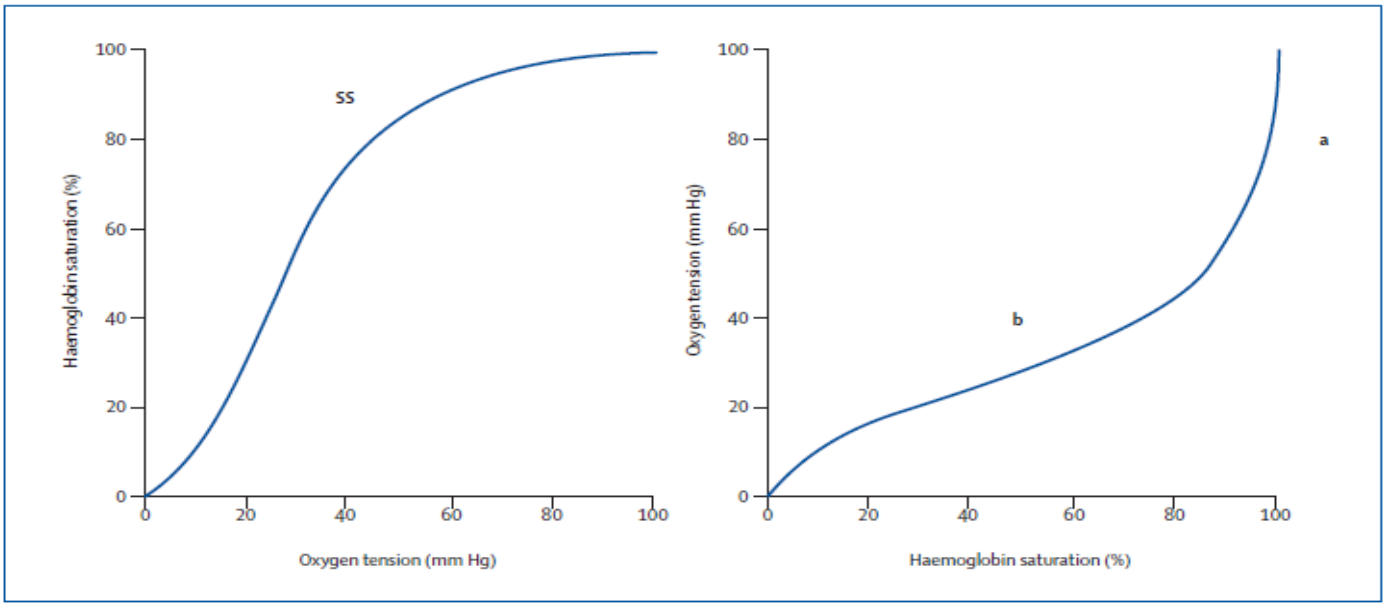
Risk associated with high concentration oxygen can relate to both the high fraction of inspired oxygen (FiO_2) administered and the level of hyperoxaemia resulting from the high FiO_2. Potential risks include adverse respiratory (increased arterial partial pressure of carbon dioxide ($PaCO_2$), absorption atelectasis and direct pulmonary toxicity), cardiovascular (increased systemic vascular resistance and blood pressure, reduced coronary artery blood flow, reduced cardiac output), cerebrovascular (reduced cerebral blood flow) effects, and increased reperfusion injury due to increased reactive oxygen species.[1,3,15,16]

These competing risks at both ends of arterial oxygen tension have led to the 'swimming between the flags' concept of titrating oxygen therapy to within a specific target oxygen saturation range. It has also led to the proposal to realign the haemoglobin oxygen dissociation curve, to make the 'slippery slope' of oxygen desaturation less prominent, and accentuate the beneficial characteristics, enhancing both the pick-up of oxygen despite cardiovascular disease, and the drop off of oxygen to the tissues despite falling oxygen saturations (Figure 1). Through this different perspective of the haemoglobin oxygen dissociation curve, it might be possible to overcome the entrenched practice of doctors and other health professionals to administer high flow oxygen to breathless patients, regardless of whether hypoxaemia is present or not, for fear that the patient might get close to the 'slippery slope'.[3,17]

The third and related concept is that to achieve a target oxygen saturation range, pulse oximetry needs to be available in all clinical situations in which oxygen is used. However, clinicians need to be aware that the use of pulse oximetry to guide the titration of oxygen therapy is limited by its variable accuracy estimating arterial oxygen saturation (SaO_2) in acutely ill patients, with oximetry measurements both over and under estimating SaO_2, with wide limits of agreement.[18-20]

The fourth concept is that the use of high concentration oxygen in a breathless patient in an attempt to protect against hypoxaemia in the event of a subsequent deterioration has the potential to delay the recognition of such a deterioration.[21] This clinical approach may provide a false reassurance that the patient is stable. This is because there is unlikely to be any major change in vital signs[22] or a marked decrease in SpO_2 as assessed by pulse oximetry[23] until a potentially life-threatening situation has developed. At this stage there is limited opportunity to further increase the oxygen therapy while medical review and an intervention such as transfer to a high dependency unit (HDU) or intensive care unit (ICU) is undertaken. This is illustrated by the hypothetical modelling of a patient deteriorating following presentation with pneumonia (Figure 2).

Figure 1: *Oxygen haemoglobin dissociation curve (reproduced with permission from reference 3)*



Left=traditional representation with "slippery slope" marked (SS)
Right=curve realigned to show the two key characteristics: (a) haemoglobin maintains high levels of saturation despite marked reductions in arterial oxygen tension, and (b) oxygen tension remains relatively preserved as oxyhaemoglobin saturation declines. These characteristics result in pick-up of oxygen by haemoglobin being maintained despite reduced oxygen tension, and delivery of oxygen to tissues being maintained despite progressively falling oxyhaemoglobin saturation.

Similarly, if a patient who requires a high FiO_2 to maintain adequate SpO_2 deteriorates there is limited capacity to increase FiO_2 to avoid life threatening hypoxaemia. For this reason, it is recommended that patients who need high FiO_2's should receive senior clinician review and transfer to an area where there are appropriate numbers of competent staff able to provide more intensive monitoring and therapy.

Recommendations

Based on these concepts 10 key recommendations were made for the use of oxygen therapy, as follows:

1. Pulse oximetry should be available in all clinical situations in which oxygen is administered to patients. While acknowledging the variable accuracy of SpO_2 in critically ill patients, an SpO_2 of $\geq$92% is a practical lower threshold to rule out hypoxaemia, defined as an SaO_2 <90%[19] or a PaO_2 <60mmHg (8 kPa).[18]
2. In the immediate assessment of an acutely unwell patient, oxygen saturations should be measured by oximetry, pending the availability of blood gas results if required. Arterial blood gas (ABG) measurement should be considered in the following situations:
   - Critically ill patients with cardiorespiratory or metabolic dysfunction
   - In patients with an SpO_2 <92% in whom hypoxaemia may be present
   - Deteriorating oxygen saturation requiring increased FiO_2
   - Patients at risk of hypercapnia (see below)
   - Breathless patients in whom a reliable oximetry signal cannot be obtained.

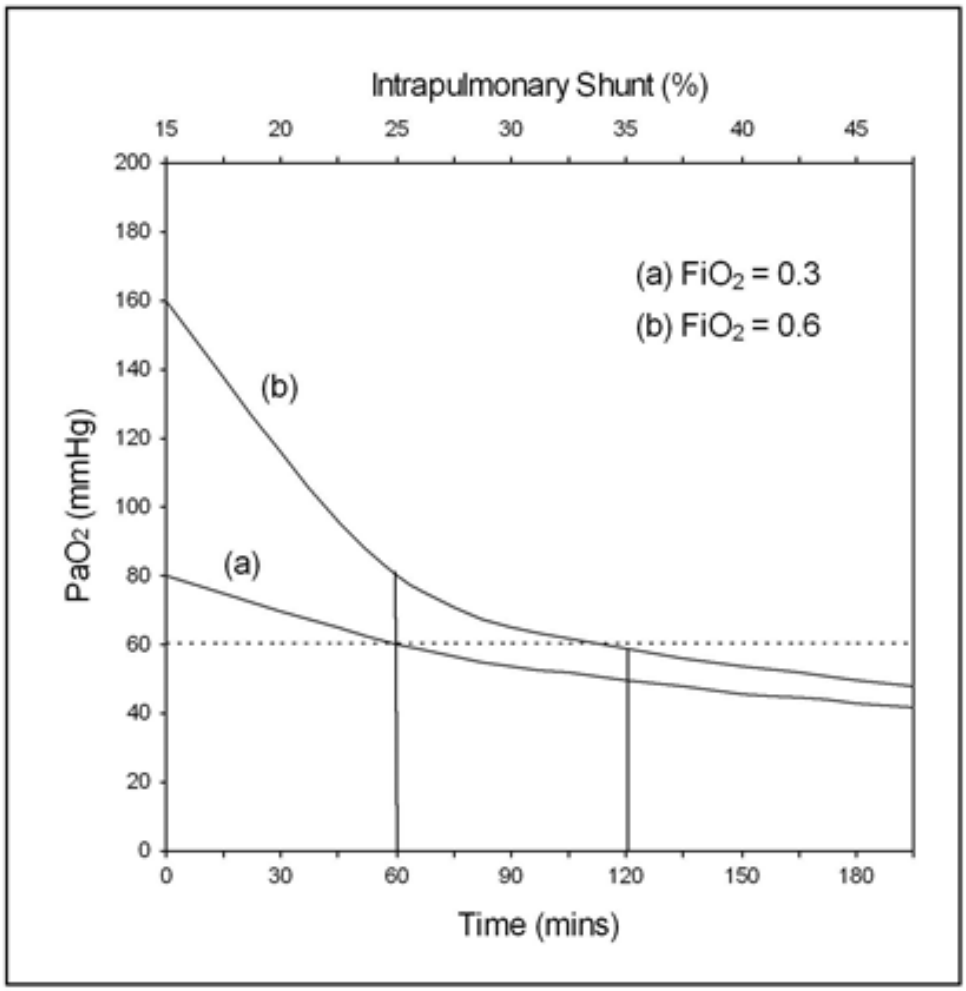
   Peripheral venous blood gas analysis is a less invasive test, however it does not provide an accurate estimate of $PaCO_2$ or PaO_2.[24] It does, however, provide rapid clinically important information to assess acutely unwell patients, including pH, lactate, glucose, haemoglobin, sodium and potassium. In addition it provides a venous partial pressure of carbon dioxide which if less than <40 mmHg, effectively rules out hypercapnia.[24]
3. A specific oxygen prescription should be

documented in the patient records and the drug chart.[25] The main requirement for an oxygen prescription is documentation of the target SpO_2 range.

4. An SpO_2 target of 88% to 92% is recommended in exacerbations of COPD[26] and other conditions associated with chronic respiratory failure (such as obesity hypoventilation syndrome,[27] bronchiectasis, cystic fibrosis,[28] neuromuscular disease and chest wall deformities such as severe kyphoscoliosis). Where there is diagnostic uncertainty as to whether COPD is the primary cause of the exacerbation, it may be preferable to titrate oxygen therapy to the 88-92% SpO_2 target range.[26,29,30]
5. In the presence of hypoxaemia in other acute medical conditions not associated with chronic respiratory failure, oxygen should be administered to achieve a target SpO_2 range of 92% to 96%.[31,32] There is considerable rationale for this range which is lower than the 94 to 98 % range recommended in the BTS guidelines.[33]
6. Patients who need an estimated FiO_2 of $\geq$0.40 (such as $\geq$6 litres per minute via a simple face mask) to maintain an adequate SpO_2 should receive senior clinician review and may require transfer to a facility such as an HDU, where there are appropriate numbers of competent staff able to provide more intensive monitoring and therapy.
7. Patients who need an estimated FiO_2 of $\geq$0.50 (such as $\geq$8 litres per minute via a simple face mask) to maintain an adequate SpO_2 should receive ICU review and most will require ICU transfer.
8. For most patients standard nasal cannulae are the preferred method of oxygen delivery, with the flow rate varied to achieve the target oxygen saturation. The main advantages of nasal cannulae are the ability to give nebulised bronchodilator at the same time as oxygen administration, and to prescribe oxygen at variable flows to achieve a target saturation range rather than a fixed FiO_2. Humidified high flow nasal cannulae (HFNC) are an alternative to standard low flow nasal cannulae or high flow masks for oxygen delivery.[34,35] There are no established evidence-based recommendations to guide appropriate clinical use in adults, however currently some centres recommend HFNC only in the emergency department (ED), HDU or ICU.
9. In COPD and other conditions associated with chronic respiratory failure, if bronchodilator is required, the preferred methods of administration are via an air-driven nebuliser or via a metered dose inhaler (MDI) ± a spacer, with supplementary nasal oxygen continued as required.[26,36] The reason for this is that the administration of bronchodilator via an oxygen-driven nebuliser has the potential to cause an increase in $PaCO_2$.[37,38]
10. In patients with hypercapnic respiratory failure, in whom an ABG measurement shows a pH <7.35 and $PaCO_2$ >45 mmHg, non-invasive ventilation (NIV) or invasive ventilation should be considered.[39-42] COPD patients with a pH <7.26 managed with NIV require more intensive monitoring with a low threshold for intubation (if appropriate).[42] In patients with severe cardiogenic pulmonary oedema continuous positive airway pressure (CPAP) should be considered.[43] It is recommended that patients receiving ventilatory support are located in a ward area such as an HDU, ICU, a close observation unit or monitored bed unit, where there are adequate numbers of staff experienced in ventilatory support to provide an appropriate level of monitoring and titration of therapy.[39]

A practical assessment and treatment algorithm was developed, encompassing these key concepts and recommendations, as displayed in Figure 3. It is suggested that the algorithm is modified as required to meet the needs of different health care settings.

Figure 2: *Case example illustrating the potential for the 'prophylactic' administration of high flow oxygen to delay recognition of deteriorating cardiorespiratory function (reproduced with permission from reference 21)*

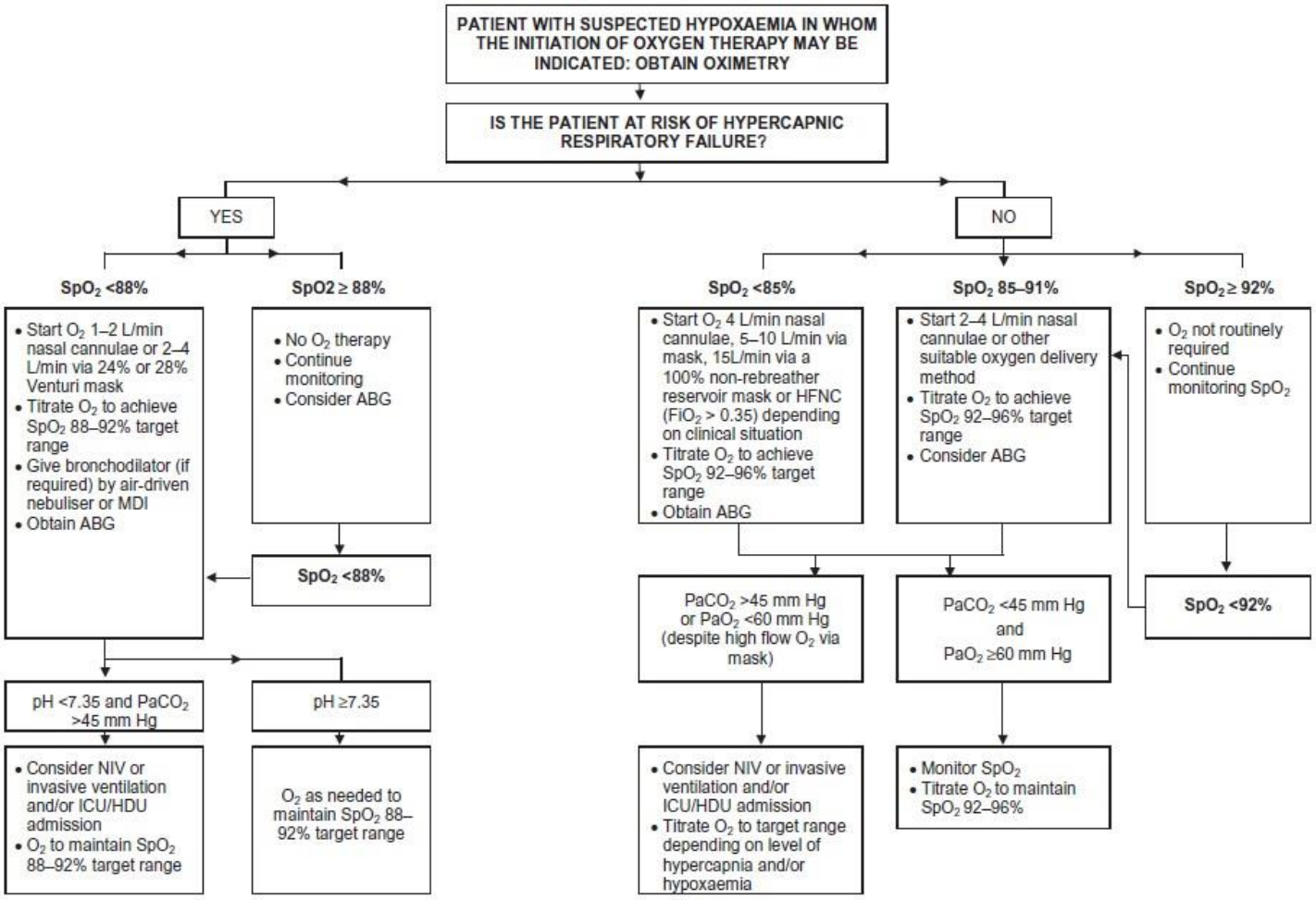


The hypothetical case example of a patient with community acquired pneumonia presenting to medical care with a baseline SpO_2 of 88% (PaO_2 58mmHg). The patient then deteriorates, with the intrapulmonary shunt increasing at a rate of 1% per 6 minutes. Two initial therapeutic approaches to oxygen therapy are considered, with an FiO_2 of (a) 0.3 and (b) 0.6.

In example (a), with an FiO_2 of 0.3, the time required for the PaO_2 to decrease from 80mmHg (SpO_2 95%) to <60mmHg (SpO_2 <90%) is around 60 minutes. At this stage, with the same rate of increasing intrapulmonary shunt, an increase in FiO_2 from 0.3 to 0.6 will maintain the PaO_2 above 60mmHg for about a further 60 minutes.

In example (b), if the patient receives an FiO_2 of 0.6 it would take around 120 minutes for the PaO_2 to decrease to <60mmHg (SpO_2 <90%). At this stage, with the same rate of increasing intrapulmonary shunt, there will be a further deterioration in PaO_2 despite maintenance of the FiO_2 at 0.6.

Figure 3: *Treatment algorithm for oxygen therapy (reproduced with permission from reference 6)*



Conflict of interest

Richard Beasley has received research funding from Fisher & Paykel Healthcare. Richard Beasley is a member of the TSANZ and BTS Adult Oxygen Guidelines Groups.

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