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REVIEW

Acute oxygen therapy: a review of prescribing and delivery practices

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Abstract: Oxygen is a commonly used drug in the clinical setting and like other drugs its use must be considered carefully. This is particularly true for those patients who are at risk of type II respiratory failure in whom the risk of hypercapnia is well established. In recent times, several international bodies have advocated for the prescription of oxygen therapy in an attempt to reduce this risk in vulnerable patient groups. Despite this guidance, published data have demonstrated that there has been poor uptake of these recommendations. Multiple interventions have been tested to improve concordance, and while some of these interventions show promise, the sustainability of these interventions are less convincing. In this review, we summarize data that have been published on the prevalence of oxygen prescription and the accurate and appropriate administration of this drug therapy. We also identify strategies that have shown promise in facilitating changes to oxygen prescription and delivery practice. There is a clear need to investigate the barriers, facilitators, and attitudes of clinicians in relation to the prescription of oxygen therapy in acute care. Interventions based on these findings then need to be designed and tested to facilitate the application of evidence-based guidelines to support sustained changes in practice, and ultimately improve patient care.

Keywords: chronic obstructive pulmonary disease, COPD, type II respiratory failure, oxygen therapy, prescribing, hypoxia, hypercapnia

Introduction

Oxygen is a commonly used drug in the clinical setting[1–4] and unquestionably saves lives. However, its use must be carefully considered. Like any drug, it may cause harm when used inappropriately.[4,5] In practice, a common misconception that "you can't give too much oxygen"[1,3] or "oxygen won't hurt"[4] has emerged. This has led to higher levels of oxygen therapy being delivered to patients who are critically unwell or who complain of dyspnea,[3] resulting in increased lengths of stay,[6] higher rates of admission to high dependency units,[6] and an increased risk of death.[7,8] Indeed, New[9] states that in the past ambulance crews regarded oxygen as a sort of "medical wet wipe […] not always therapeutic, but never harmful."

The clinical effect supplemental oxygen can have on patients experiencing acute exacerbations of chronic obstructive pulmonary disease (COPD) is now widely known,[10] yet not completely understood.[11] Uncontrolled oxygen administration, particularly when delivered at high concentrations, can result in a worsening of hypercapnia.[12,13] Multiple pathological mechanisms are believed to underlie this phenomenon,[11,12,14,15] with the primary causes being the inhibition of pulmonary vasoconstriction. Resulting in a worse ventilation/perfusion mismatch, and a right-hand shift of the CO_2 dissociation curve (Haldane effect), further increasing

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P_aCO_2.[13,16] Other mechanisms for this phenomenon include further increases in ventilation/perfusion mismatching due to absorption atelectasis and an increased work of breathing due to the higher density of oxygen over air.[17] Initial beliefs that hypercapnia was primarily caused as a result of a "reduced hypoxic drive" have been largely disproved,[18] following the publication of results challenging these earlier hypothesis. In 1980, Aubier et al[18] demonstrated that while minute ventilation initially fell with the administration of high concentrations of oxygen therapy in the COPD patient cohort, this decrease was transient, with minute ventilation returning to levels only marginally lower than when breathing room air initially.

For these reasons, the use of titrated oxygen therapy in this patient group has been advocated for many years. Guidance from the British Thoracic Society (BTS),[17] the Global Initiative for Obstructive Lung Disease[19] and, more recently, the Thoracic Society of Australia and New Zealand[20] advise clinicians to administer oxygen to maintain an SpO_2 between 88% and 92% in an acute hospital setting for patients with COPD and others who are vulnerable. While COPD is the most common chronic disease in clinical practice to cause hypercapnia,[17] other vulnerable patient groups are also at risk. These include those patients with morbid obesity, obstructive sleep apnea, cystic fibrosis, neuromuscular disorders, those with restrictive chest wall deformities, and those using respiratory depressant drugs, such as opioids and benzodiazepines.[17,21] In patients who are not at risk of hypercapnic respiratory failure, recommendations vary between professional bodies, with the BTS[17,21] advocating for maintenance of an SpO_2 between 94% and 98% and the Thoracic Society of Australia and New Zealand[20] recommending maintenance of an SpO_2 between 92% and 96%. Undoubtedly, the accurate delivery of oxygen therapy is important for all patients; however, the deleterious effects of poor clinical practice in this area are most significant and now well documented in those patients who are vulnerable, particularly those with COPD.[7,22–27] Austin et al[7] were the first to show clear evidence of the benefits of administering titrated oxygen (delivered via nasal prongs to achieve an SpO_2 between 88% and 92%) to patients with acute exacerbations of COPD. Their results demonstrated that the delivery of titrated oxygen therapy reduced mortality by 58% when compared with those who received high flow oxygen therapy (delivered via a nonrebreather mask at 8–10 L/min).[7] A retrospective review of ambulance practice, conducted by Cameron et al,[28] illustrates this point. This study demonstrated that 80% of the patients with COPD brought in to the emergency department by ambulance had received high concentrations of oxygen during initial response and transfer. They reported an increased risk of serious adverse outcomes in patients who were both hypoxemic and hyperoxemic when compared to those who were normoxemic. However, hypercapnia and acidosis were more pronounced in the hyperoxemic group.

Many authors[3,11,29–33] and professional bodies[17,20] argue that oxygen should be treated like other drugs with orders for therapy included on a treatment (drug) chart to improve accurate administration. However, prescription of oxygen therapy has been historically poor, and compliance with or adherence to the written prescription has not been consistently demonstrated. This review examines the literature that has explored prescribing practices internationally with a variety of interventions employed in attempts to improve prescription, administration, and consequently patient outcomes.

Oxygen prescription

The adequacy of oxygen prescription within the acute hospital setting has been studied over many years.[34–54] These studies have explored both the presence of a prescription and the adequacy and appropriateness of oxygen prescription in a broad range of patient groups. The literature includes studies specific to vulnerable groups, including those with chronic ventilatory failure, but is not limited to this population with evaluation being undertaken in the general clinical setting. However, since the publication of the BTS Guidelines on acute oxygen administration in 2008, there has been an increasing interest in this topic. Figure 1 depicts a timeline of papers (according to the geographical area that the studies were conducted) that have been published on oxygen therapy prescription and administration practices since 1980. Interestingly, over 27 years, between 1980 and 2007, 17 papers[33,35,41–44,46,47,49–51,53–58] were found that discussed oxygen prescription rates and/or the appropriateness and accuracy of oxygen administration and subsequent monitoring of oxygen therapy. In the 6 years between 2009 and 2015, 12 papers which measured the accurate or appropriate prescription of oxygen therapy have been reported.[34,36–40,45,48,52,59–61] Some of these papers also discussed various interventions that have been tested to improve prescription practices.

Overall, the literature suggests that the practice of prescribing oxygen therapy is poor.[34–39,41–44,46,47,49,51,52]

Country	Number	Color
UK	15	
New Zealand	4	
Canada	3	
USA	2	
Australia	1	
Greece	1	
Malta	1	
Portugal	1	
Singapore	1	

Figure 1 Timeline of papers published on oxygen therapy prescription and administration practices.
Notes: Between 1980 and 2007 (27 years), 17 papers were found. Between 2009 and 2015 (6 years), 12 papers were found. All papers published between 2009 and 2015 measured the accurate or appropriate prescription of oxygen therapy ± various interventions to improve prescription rates.

Various reasons have been proposed for this, including:

- insufficient training and education for medical and nursing staff;[33,39,41,42,47,51,54,62]
- a lack of familiarity with oxygen delivery devices;[51]
- a lack of understanding of the effects, role and dangers of oxygen therapy;[35–37,46,61]
- staff time constraints;[48]
- necessity to maintain SpO_2 >94% due to the "between the flags" track and trigger observations charts;[36]
- practical issues related to space and place for prescribing oxygen;[35,39,61]
- difficulties with changing long established behavior;[36,60]
- patients transferred from other wards/departments with oxygen therapy already in situ;[44]
- lack of enthusiasm by senior clinical staff;[44]
- communication difficulties between doctors and nurses;[36]
- lack of full time staff or staff turnover.[36,38,48,60]

In attempts to improve overall prescription rates, different interventions have been tested in various combinations over different periods of time, with varying degrees of success. Interventions that have been employed are presented in Table 1 and the degree of change achieved pre- and postintervention is presented graphically in Figure 2. These interventions include:

- introduction of oxygen alert stickers;[39,59–61]
- dedicated oxygen order chart;[35]
- clearly delineated section on the drug chart or changes to the drug chart to include space for the transcription of oxygen orders;[34–36,48,60]
- informational posters;[59–61]
- email notification/dissemination of information;[60,61]
- educational session across various clinical specialties and at various key times;[34,36,39,44,48,56,59–61]
- nurse facilitated reminder system;[38]
- development of hospital guidelines/policy to guide practice;[36,42,59,60]
- admission bundle with electronic prescribing system;[45]
- message alerts on computer login screens.[60]

One study[42] demonstrated no or minimal improvement in prescribing practices after implementing an oxygen

Table 1 Interventions that have been tested in attempts to improve oxygen prescription rates

Study (year)	Intervention
Dodd et al[35] (2000)	• Dedicated oxygen order chart • Clearly delineated section on the drug chart or changes to the drug chart to include space for the transcription of oxygen orders
Akbar and Campbell[42] (2006)	• Introduction of hospital guidelines
Hickey[44] (2007)	• Educational sessions
Medford et al[38] (2009)	• Nurse facilitated reminder system
Walters and Nadeem[39] (2009)	• Oxygen alert sticker • Educational sessions
Wijesinghe et al[34] (2010)	• Clearly delineated section on the drug chart or changes to the drug chart to include space for the transcription of oxygen orders • Educational sessions
Khachi et al[59] (2010)	• Oxygen alert sticker • Educational sessions • Informational posters
Nickless and Fallon[60] (2011)	• Development of hospital guidelines/policy to guide practice • Educational sessions • Informational posters • Email notification/dissemination • Message alerts on computer login screen • Oxygen alert sticker
Young and Kostalas[48] (2013)	• Clearly delineated section on the drug chart or changes to the drug chart to include space for the transcription of oxygen orders • Educational sessions
Gunathilake et al[36] (2014)	• Clearly delineated section on the drug chart or changes to the drug chart to include space for the transcription of oxygen orders • Educational sessions • Development of hospital guidelines/policy to guide practice
Rudge et al[61] (2014)	• Oxygen alert sticker • Informational posters • Email notification/dissemination • Educational sessions

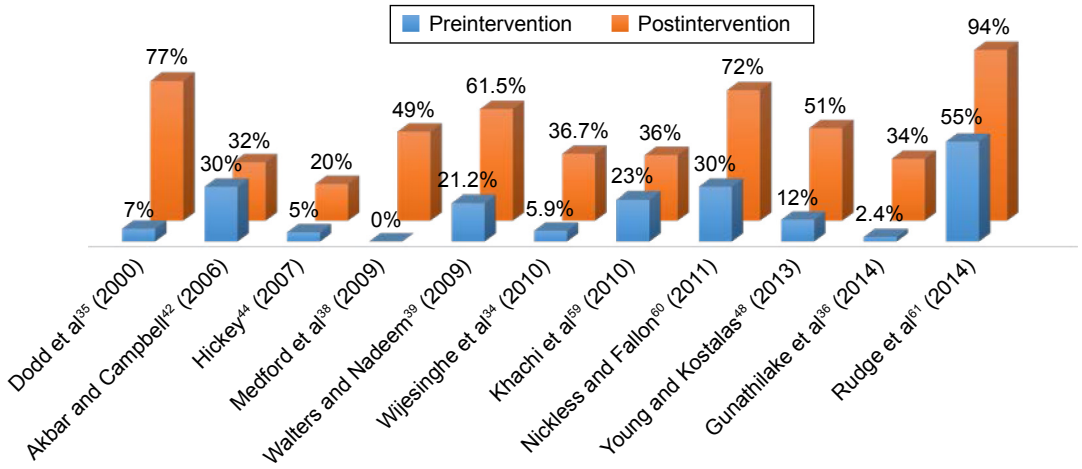

Figure 2 Accurate prescription of oxygen therapy: preintervention–postintervention study results.
Notes: Rates of improvement in prescribing for various interventions.

guideline to inform clinician practice. Despite no change in prescriber behavior, a large improvement was seen in the administration of oxygen according to the prescribed dose (70% vs 95%; *P*=0.043) and in the clinical assessment of all patients commenced on oxygen therapy, that is, increased measurement of pulse oximetry (69% vs 91%; *P*=0.001). The assessment of arterial blood gases for those with respiratory disease improved following the introduction of the guideline (from 65% to 87%; statistical significance was not reported) with even greater improvements seen in the reevaluation of arterial blood gases following initiation of oxygen therapy for the cohort with airways disease, increasing to 68% from 34% (*P*=0.037). The authors[42] concluded that although little change was seen in the prescribing practices of the doctors, practice improvements were seen. Junior doctors reassessed arterial blood gases more frequently and nurses administered the prescribed dose more frequently and used pulse oximetry more often to assess patients after the introduction of the guidelines.[42] Similar improvements in administration and assessment have been seen in some practice areas in other studies[34,38] but not in others[47] in which the presence of an accurate prescription did not improve oxygen administration and assessment practices in these patients.

Rudge et al[61] described a promising quality improvement project that occurred over three cycles which demonstrated dramatic improvements to the accurate prescription of oxygen therapy. Baseline data showed that 55% of patients using oxygen had a valid prescription; this then decreased to 54% following cycle one, but improved to 94% at the end of cycle three. They used four interventions (oxygen prescription chart, oxygen alert stickers, point of care resources, and senior led educational sessions) over a 2-year period on an Acute Medical Unit.[61] While these data are encouraging, there are limitations with the study design; it was a quality improvement audit conducted in one unit of a single hospital and interventions were ongoing both prior to and during the data collection phase.

Similarly, in an earlier audit undertaken by Dodd et al,[35] a large improvement was seen in written prescription practice (before and after implementation of a specific oxygen prescription chart, from 55% to 91%; *P*=<0.001) with the accuracy of these written prescriptions improving significantly (7% vs 77%; statistical significance was not reported) following the implementation of a dedicated chart on which oxygen therapy could be prescribed. The authors argued that junior doctors have inadequate levels of understanding about the effects and potential dangers of oxygen therapy; however, the improvements seen following the implementation of a dedicated oxygen prescription chart appear to indicate that junior doctors complete required documentation appropriately when it is available and the presence of a chart merely prompted this action. Importantly, this was a single-center study and no data in this study examined the adherence of other clinicians (nurses and other medical staff) to accurately deliver the actual prescription. However, the results from the study by Gunathilake et al[36] suggest that appropriate oxygen delivery improved as prescription rates improved. They demonstrated that the number of patients at risk of type II respiratory failure with saturation levels above 92% decreased from 47% at initial audit to 18% (*P*=0.04) following a multicomponent intervention and as prescribing rates increased (2.4% to 34%; *P*=<0.0001).[36] Despite these encouraging results that demonstrate improvements in practice are possible, the sustainability of this behavior has been questioned by Young and Kostalas.[48] They saw a

significant improvement in prescription rates (from 12% to 74%; $P=<0.001$) 3 months following the introduction of an oxygen prescription section on the drug chart and the delivery of an educational session, but at 12 months this had decreased to 51%.

Also of interest is a study by Medford et al[38] who implemented a nurse facilitated reminder system and found that there were relatively high rates of appropriate oxygen administration prior to the implementation of the reminder system, and that these did not change significantly on reaudit 4 months after implementation (70.6% and 76.5%, respectively; $P=0.65$). Here, nurses were empowered to remind doctors to prescribe oxygen therapy. This may indicate that in general, nurses are skilled at delivering the appropriate dose of oxygen despite the absence of a prescription as is indicated by the lack of practice change by the nurses and maintenance of a relatively high rate of appropriate administration of oxygen therapy both before and after the intervention.

Knowledge of oxygen therapy and delivery equipment

Knowledge of oxygen therapy and the equipment used to deliver oxygen may also be barriers to optimal oxygen administration. This has been highlighted in a study conducted by Ganeshan et al[62] who reported that commonly used oxygen delivery devices, for example, nasal cannulae, are easily recognized by doctors and nurses with less frequently used devices, such as nonrebreathing masks, being poorly recognized. In addition, when both medical and nursing clinicians were presented with sample case scenarios, a larger proportion (up 97% and 73% of doctors and nurses, respectively) were not able to accurately prescribe the correct dose of oxygen or the appropriate method for administration of oxygen for some of the scenarios described. Interestingly, this study[62] demonstrated that in four out of the seven case scenarios, nurses' knowledge of the correct delivery devices and oxygen prescription was higher than that of the doctors. Overall, however, knowledge of correct prescriptions was suboptimal.

The authors argue that even if it were compulsory for medical staff to complete written prescriptions of oxygen therapy in wards settings, it is unlikely that staff would be able to prescribe it correctly. These findings are of particular concern in light of the current guideline recommendations.[17,20] Disturbingly, these are not stand alone results and are supported by findings from other studies[63–65] that show there are large gaps in the knowledge of health care staff on various aspects of respiratory therapy. Considering the frequency with which oxygen is administered in an acute hospital setting and the harm that may be caused, interventions to improve the overall knowledge and practice around oxygen therapy and therefore concordance to evidence-based guidelines are urgently required.

Auditing practice

The BTS has conducted audits of prescribing practices within the National Health Service (NHS) since the implementation of the 2008 guidelines. These audits have demonstrated slow but steady improvements in the rates of oxygen prescription. The most recently available data from the 2013 audit[66] demonstrated that 55% of patients who were using oxygen had some form of written order. This is an improvement from the 2008 audit which showed that only 32% of patients had a written order.[66] These data also demonstrate a steady decline (17.5% down to 13.8%) in the number of patients within the NHS who are using oxygen therapy,[66] which could result in improved patient outcomes and substantial savings for the health service. In contrast, an Australian audit demonstrated that as few as 3% of patients with COPD had an existing oxygen prescription despite 79% of patients with COPD receiving oxygen therapy at the time of audit.[27] This improved level of practice in the UK, where regular audits are performed, may indicate that regular auditing and review of clinical practice and practice gaps can lead to improved clinician behavior.

Current recommendations and future directions

The NHS in their latest oxygen safety report[67] suggests that the main safety concerns for oxygen administration relate to the under- and overuse of oxygen, and that these are caused by the inappropriate prescription, monitoring, and administration of oxygen. Like the BTS, the NHS emphasizes the need for the accurate prescription and monitoring of patients with pulse oximetry. Similarly, the 2015 Thoracic Society of Australia and New Zealand guidelines for acute oxygen use in adults also recommend that oxygen therapy is prescribed with a specific record documented in the patient notes and drug chart, the main requirements being the documentation of a target SpO_2 range.

It is clear that there is a need to improve the prescribing practices for all patients across hospital settings. Although the authors have postulated on the reasons behind why evidence-based guidelines are not adhered to, very little data exist examining why high flow oxygen continues to be given in practice (particularly in the prehospital and emergency department setting) or why the written prescription of

oxygen therapy remains low. Medford et al[38] and Hickey[44] suggest that analysis of doctors' views on the prescription of oxygen therapy is needed and that strategies for optimizing the behavior of permanent nursing staff are necessary;[38] however, to date, few data have been published relating to these points. As such, little is known about the barriers or facilitators that exist to improve the implementation of these strategies in practice, yet, published literature from the past 30 years demonstrates that despite a number of interventional strategies aimed at improving practice, it continues to be a challenging practice to change.

The knowledge practice gap is a common phenomenon in health care[68] with some authors[69] suggesting that the provision of guidelines and evidence from research, while necessary, are not sufficient in bridging the knowledge practice gap. Specifically, this has been demonstrated with the oxygen prescription data. A convincing evidence base now exists, yet the consistent application of the evidence (prescription and delivery of low flow oxygen to maintain SpO_2 88%–92% in vulnerable patient groups) is not applied in daily practice. Funk et al[70] argue that determining the perceptions of clinicians is vital in addressing this knowledge–practice gap. Ultimately, clinicians are responsible for the delivery of care. If we are to reduce or eliminate barriers to implementing research knowledge into practice, clinicians' opinions are vital. Tailored interventions while effective can be variable; however, a 2015 Cochrane Review concluded that "interventions tailored to address identified barriers are probably more likely to improve professional practice than no intervention or the dissemination of guidelines alone."[71]

Conclusion

Throughout this review, we have presented international data surrounding current practice for the prescription of oxygen therapy. These data demonstrate that the rates of concordance to recommended practice have seen a necessary change in oxygen prescription; however, there remains substantial room for improvement. This is evidenced in the large audit conducted by Roberts et al[26] in 2010–2011 in which 16,018 patients admitted with acute exacerbations of COPD to hospitals in 13 European countries demonstrated a high level of adherence (85%) to the Global Initiative for Obstructive Lung Disease[72] standards for the management of acute exacerbations of COPD, administering titrated oxygen therapy, to achieve PaO_2 >60 mmHg or SpO_2 >90%.[72] Despite this high level of adherence, >1,623 (10.1%) of the patients across the hospitals received either high flow oxygen or no supplemental oxygen (despite being hypoxic). Many practice gaps exist, which lead to poor patient outcomes. Pilcher and Beasley[32] suggest that there is an entrenched culture of routine and indiscriminate administration of high-concentration oxygen to acutely ill patients. This culture must change and there is a clear need to examine the barriers, facilitators, and attitudes toward oxygen and its prescription in acute care if we are to improve practice and minimize harm in vulnerable patient groups. Effective interventions may assist in translating expert guidelines into clinical practice. These may facilitate the adoption of best practice guidelines and ultimately improve clinical outcomes for COPD and other vulnerable patient groups who are most impacted by poor oxygen administration practices.

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