Things We Do For No Reason™: Supplemental Oxygen for Patients without Hypoxemia

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Inspired by the ABIM Foundation's Choosing Wisely® campaign, the "Things We Do for No Reason™" (TWDFNR) series reviews practices that have become common parts of hospital care but may provide little value to our patients. Practices reviewed in the TWDFNR series do not represent "black and white" conclusions or clinical practice standards but are meant as a starting place for research and active discussions among hospitalists and patients. We invite you to be part of that discussion.

CLINICAL SCENARIO

A 65-year-old woman with hypertension presents to the emergency department with three days of dyspnea, malaise, and pleuritic chest pain. Her temperature is 100.1°F, heart rate 110 beats per minute, and blood pressure 110/60 mm Hg. She is breathing 24 times per minute and has an oxygen saturation (SpO_2) of 94% on room air. Her exam is remarkable for dry mucous membranes and right lower lung crackles. Her nurse places her on 3 L of oxygen per minute via nasal cannula, and her SpO_2 rises to 99%.

WHY YOU MIGHT THINK SUPPLEMENTAL OXYGEN FOR NORMOXEMIC PATIENTS IS HELPFUL

Shortly after the discovery of oxygen in the late 18th century, physicians began using it to treat a variety of conditions including tuberculosis, pneumonia, respiratory failure, and angina. By the 1970s, most medical texts recommended oxygen use in suspected myocardial infarction (MI) because of the theoretical appeal of increasing delivery of oxygen to the heart and other vital organs.[1] Additionally, there is a tendency to believe that supplemental oxygen alleviates dyspnea regardless of etiology or oxygen saturation. Recent studies have shown widespread use of oxygen in scenarios without clear indications and without oxygen saturation goals. A 2010 survey of clinicians managing acute MI found that 98% "always or usually" used oxygen and 55% believed that oxygen "definitely or probably reduces the risk of death."[2] In a Danish prehospital study, supplemental oxygen was used in 34% of ambulance patients even though only 17% of these patients had an SpO_2 less than 94%.[3] A study of critically ill patients found that most of the time, SpO_2 exceeded 98%. Even when the fraction of inspired oxygen (FiO_2) was between 0.3 and 0.4, no one adjusted the oxygen dose.[4]

WHY IT IS NOT HELPFUL TO PROVIDE SUPPLEMENTAL OXYGEN TO NORMOXEMIC PATIENTS

The reflexive use of oxygen in patients with acute respiratory or cardiovascular illness is problematic for several reasons. First, when oxygen saturation is near-normal, the potential benefit from supplemental oxygen lacks physiologic plausibility. More compellingly, evidence exists that hyperoxemia may cause significant harm. Finally, the unnecessary use of supplemental oxygen incurs practical inconveniences and expenses.

To understand why the physiologic basis for reflexive oxygen use is weak, it is important to distinguish hypoxemia (low arterial oxygen tension and hemoglobin oxygen saturation), tissue hypoxia (which can occur from hypoxemia or focal abnormalities in perfusion), and dyspnea (a subjective experience of breathing discomfort). A variety of mechanisms cause dyspnea, most of which do not involve hypoxemia. A patient with acute heart failure may experience severe dyspnea caused by activation of pressure-sensitive J-receptors in the lung, even if oxygen saturation and tissue perfusion are intact. This process will be relieved by reducing pulmonary capillary pressures, but it is unaffected by supplemental oxygen. Coronary occlusion causes hypoxia of the heart muscle, but restoring perfusion is the most effective treatment. The instinct to maximize the oxygen-carrying capacity of the remaining blood flow is understandable. However, in a normoxemic patient, increasing the inspired fraction of oxygen has a marginal effect on oxygen-carrying capacity, since hemoglobin saturation and concentration rather than arterial oxygen tension (PaO_2) predominantly determine oxygen-carrying capacity. On the other hand, supraphysiologic levels of dissolved oxygen may lead to toxicity.[5]

For over a century, we have known the potential harms of hyperoxia. Original studies in animal models showed that hyperoxia led to lung injury, altered hemodynamics, endothelial cell dysfunction, and inflammatory activation.[5] Many of these detrimental effects involve the generation of reactive oxygen species and oxidative stress.[5] High levels of inspired oxygen can also cause increased pulmonary shunting through inhibition of physiologic hypoxic vasoconstriction and due to absorption atelectasis.[6] Oxygen negatively affects cardiovascular

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function by reducing coronary blood flow, increasing systemic vascular resistance, and reducing cardiac output.[1]

Chronic obstructive pulmonary disease (COPD) is the clinical setting in which risks of supplemental oxygen are most well-recognized historically. In patients with COPD at risk for hypercarbia, oxygen titrated to a goal SpO_2 outside 88%-92% is associated with a two-fold risk of mortality.[7] Worsening ventilation-perfusion matching and the Haldane effect (decreased affinity of hemoglobin for carbon dioxide as the PaO_2 rises), rather than the previously theorized decrease in hypoxic drive, are now believed to contribute most to hyperoxia-induced hypercarbia. These unintended consequences may also occur in patients with other forms of acute and chronic lung disease.

The *British Medical Journal* published the first randomized controlled trial of oxygen use in suspected MI in 1976.[1] Patients who received oxygen at 6 L per minute for 24 hours had more episodes of sinus tachycardia without any improvement in mortality, analgesic use, or infarct size.[1] More recent and robust trials comparing outcomes in normoxemic patients randomized to supplemental oxygen versus room air have had similar findings: no difference in mortality, infarct size, or pain ratings.[8,9] One found a significantly increased rate of MI recurrence with the use of oxygen.[8] These data have led the latest guidelines for the management of ST-elevation MI from the European Society of Cardiology to discourage the use of supplemental oxygen unless SpO_2 is <90%.[10]

Two recent trials investigated the effects of hyperoxia in critically ill patients.[11,12] Girardis and colleagues randomized 480 critically ill patients in an Italian medical–surgical intensive care unit to conservative (SpO_2 between 94% and 98% or PaO_2 between 70 and 100 mm Hg) versus conventional oxygenation targets (SpO_2 between 97% and 100% and PaO_2 up to 150 mm Hg). Compared with conventional oxygen targets, conservative oxygen use was associated with an absolute risk reduction in mortality of 8.6% (11.6% vs 20.2%; P =.01).[11] Another trial from 22 centers in France compared outcomes in mechanically ventilated patients with septic shock who received FiO_2 at 1.0 compared with those with oxygen titration to SpO_2 between 88% and 95%. The trial was stopped early for safety concerns. Those in the hyperoxemia group had a higher incidence of serious adverse events (85% vs 76%; P =.02), including pneumothorax, clinically relevant bleeding, myocardial infarction, and arrhythmias, as well as a trend toward increased mortality.[12]

Trials of liberal oxygen use in other settings of acute illness,[13] including ischemic stroke,[14] traumatic brain injury,[15] and post-cardiac arrest,[16] have also linked liberal oxygen use with increased risk of mortality and other adverse events. "Liberal" use in these trials ranged from an FiO_2 of 0.28 (equivalent to 2 L of nasal cannula) to 1.0. Significant secondary outcomes included fewer hospital-free and ventilator-free days in patients with liberal oxygen use. Furthermore, a meta-analysis of 25 trials including over 16,000 patients found dose-dependent toxicity: for every 1% increase in SpO_2 above 94%-96% (the median SpO_2 in the liberal oxygen groups), there was a 25% relative increase in in-hospital mortality.[13]

In addition to the data above, there are practical reasons to avoid unnecessary use of supplemental oxygen. Providing supplemental oxygen to a patient who is not hypoxemic may delay the recognition of cardiopulmonary decompensation by delaying detection of hypoxemia.[6] Beyond the effects of oxygen itself, oxygen delivery methods carry their own potential adverse effects. These include epistaxis (with nasal cannula), claustrophobia (with face masks), decreased mobility, falls, and delirium.[17] Finally, oxygen administration has direct and indirect financial costs, including those of supplies, care coordination, and monitoring.

WHEN SUPPLEMENTAL OXYGEN MIGHT BE HELPFUL

Importantly, the above discussion pertains to normoxemic patients receiving supplemental oxygen. There is no dispute that significantly hypoxemic patients should receive supplemental oxygen. There are also instances where the use of supplemental oxygen in normoxemic patients may be beneficial, such as in carbon monoxide poisoning, decompression injury, gas embolism, cluster headaches, sickle cell crisis, and pneumothorax.[17]

WHAT YOU SHOULD DO INSTEAD

Like any other drug, oxygen should be administered after assessment of its indications, intended benefits, and possible harms. Both significant hypoxemia and hyperoxemia should be avoided. In patients with neither hypoxemia nor the indications above, clinicians should not administer supplemental oxygen. Recent society guidelines can be applied in various clinical contexts. In patients with suspected MI, oxygen should be administered if SpO_2 is <90%.[10] For most other acutely ill patients, clinicians should administer supplemental oxygen if SpO_2 <90%-92% and target an SpO_2 of no higher than 94%-96%,[18-19] as meta-analyses found evidence of harm above this level.[13] Results of randomized trials currently underway should add supporting evidence for more specific oxygenation targets in different patient populations. With respect to implementation, it must be noted that factors beyond physician decision influence the use of supplemental oxygen. Appropriate institutional policies, standards of care, and educational efforts to all hospital providers must be enacted in order to reduce the unnecessary use of supplemental oxygen.

RECOMMENDATIONS

- For most acutely ill patients, do not administer supplemental oxygen when SpO_2 >92%. If supplemental oxygen is used, the SpO_2 should not exceed 94%-96%.
- For patients with suspected MI, only start supplemental oxygen for SpO_2 <90%.
- For patients at risk for hypercapnic respiratory failure (eg, COPD patients), target SpO_2 of 88%-92%.
- Provide supplemental oxygen to normoxemic patients with carbon monoxide poisoning, decompression injury, gas embolism, cluster headache, sickle cell crisis, and pneumothorax.
- Review and revise institutional practices and policies that contribute to unnecessary use of supplemental oxygen.

CONCLUSIONS

In the opening case, the patient is acutely ill and requires further workup. Her current SpO_2 of 99% puts her at risk for adverse events and death, and supplemental oxygen should be titrated down or stopped to avoid SpO_2 greater than 94%-96%. For years, clinicians have erred on the side of using supplemental oxygen, without recognizing its dangers. However, over a century of evidence from pathophysiologic experiments and randomized trials across multiple clinical settings have associated hyperoxemia with adverse outcomes and increased mortality. Professional societies are adopting this evidence into their guideline recommendations, and clinicians should use supplemental oxygen judiciously in their daily practice.

Do you think this is a low-value practice? Is this truly a "Thing We Do for No Reason™"? Share what you do in your practice and join in the conversation online by retweeting it on Twitter (#TWDFNR) and liking it on Facebook. We invite you to propose ideas for other "Things We Do for No Reason™" topics by emailing TWDFNR@hospitalmedicine.org.

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