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Excessive Oxygen Administration During General Anesthesia

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Introduction

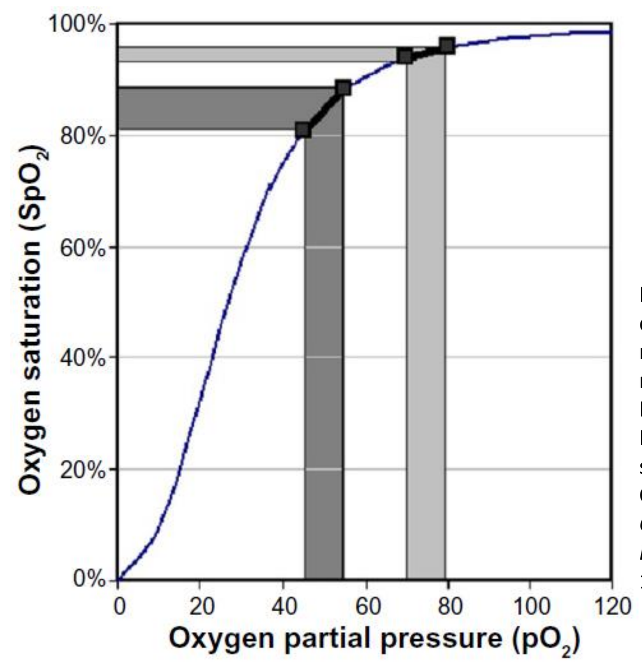
Nearly all patients undergoing general anesthesia will be administered oxygen and 83% of patients will be exposed to potentially preventable hyperoxemia (Suzuki et al., 2018).

Physiological changes occur within the body when exposed to supranormal oxygen levels.

Nurse Anesthetists must evaluate the potential risk and benefit of oxygen therapy.

A ***systematic review of the literature*** was completed to provide evidence-based practice guidance to Anesthesia Providers regarding the use of perioperative oxygen administration.

Oxyhemoglobin Disassociation Curve



Note: Oxyhemoglobin disassociation curve for visual representation of PaO_2 change in relationship to SpO_2 change. From "Mieczkowski, B., & Ezzie, M. (2014). Update on obstructive sleep apnea and its relation to COP., *International Journal of Chronic Obstructive Pulmonary Disease, 9*(1), p. 352. doi: 10.2147/COPD.S42394"

Methodology

A systemic computerized search was completed using the following:

- University of New England Library Services website
- Google Scholar
- MEDLINE Pubmed
- Nursing & Allied Health Database
- ScienceDirect
- UpToDate

34 articles were included: 20 primary research

- 1 Cochrane review
- 2 meta-analyses
- 5 systematic reviews of the literature
- 6 review articles
- 8 studies included were published before 2015

Harms of Hyperoxia

Reactive Oxygen Species (ROS)

- Hyperoxia ***exhausts the antioxidant system*** within the body creating an excess of ROS, resulting in oxidative stress (Ottolenghi et al., 2019).

Oxidative stress causes damage to DNA, lipid peroxidation, and altered protein function creating dysfunction in the structural integrity of cells throughout the body.
(Ottolenghi et al., 2019; Spoelstra-de Man et al., 2015)

Pulmonary

- After two hours of exposure to FiO_2 of 0.60, lung tissues of mice showed that ***significant pulmonary apoptosis in both type I and II cells*** as a result of mitochondrial and nuclear DNA damage suggested to be a result of ROS (Kundumani-Sridharan et al., 2019).
- When exposed to hyperoxia, alveolar macrophages underwent apoptosis, reducing the availability of macrophages in the lungs and leading to a resultant inflammation (Bezerra et al., 2019).
- Hypoxic pulmonary vasoconstriction is abolished within minutes of exposure to supplemental oxygen (Horncastle & Lumb, 2019).
- High alveolar oxygen concentrations in areas with a low ventilation-perfusion ratio result in the rapid absorption of oxygen and ***collapse of the alveoli***, or absorption atelectasis (Staehr-Rye et al., 2017).
- Supplemental oxygen administration in patients that have received opioids was noted to be associated with an ***increased incidence of respiratory depression*** and apneic events, including a higher end-tidal carbon dioxide level as well as a faster reduction in minute ventilation and respiratory rate (Niesters et al., 2013).

Cardiac

Cardiac myocytes experience substantial damage when exposed to hyperoxia.
(Hafner et al., 2017)

- A correlation was found between hyperoxia and the production of vascular endothelial growth factor, suggesting that hyperoxia, constant or intermittent exposure, can ***stimulate vascular remodeling of the heart*** resulting in an altered cell shape, suggesting a change in function (Hafner et al., 2017).
- Modification of the sarcoplasmic reticulum as a result of ROS within the cardiac myocyte may promote intracellular calcium overload, causing a direct negative ionotropic effect leading to ***cardiac contractile failure and cellular death*** (Spoelstra-de Man et al., 2015).
- Hyperoxia was shown ***to decrease epicardial coronary blood flow*** and increase coronary vascular resistance (Stub et al., 2015).

Vascular Smooth Muscle

- Hyperoxia has a ***direct vasoconstrictive effects*** on the vascular smooth muscle by inducing closure of adenosine triphosphate dependent potassium channels, or by stimulating L-type calcium channels as a result of ROS (Spoelstra-de Man et al., 2015).
- Oxidative stress has also been found to ***decrease the levels of nitric oxide synthesis***, decreasing the ability to promote vasodilation within the vasculature, worsening vasoconstriction; myocardial perfusion and oxygenation are directly impacted (Ottolenghi et al., 2019).

Benefits of Hyperoxia

Surgical Site infection

Tissue oxygenation was found to be ***inversely related to surgical site infection rates*** in a noninterventional, prospective study conducted in 1997 by Hopf et al.

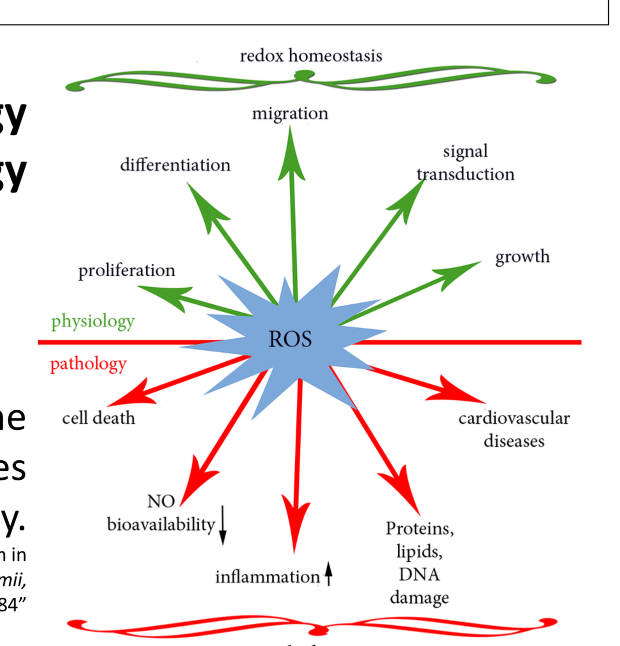
Post Operative Nausea and Vomiting

Oxygen was found to reduce the incidence of PONV in patients receiving volatile anesthetics **WITHOUT** antiemetic therapy (Schwarte et al., 2019).

Safety Margin

Preoxygenation with 100% FiO_2 replaces the nitrogen within the functional residual capacity with pure oxygen, providing ***6 times more oxygen reserve compared to breathing room air*** (Puig et al., 2017).

Reactive Oxygen Species Physiology and Pathophysiology



Note: Visual diagram to demonstrate the various effects of reactive oxygen species within the body.
From "Dymkowska, D. (2016). Oxidative damage of the vascular endothelium in type 2 diabetes- the role of mitochondria and NAD(P)H oxidase. *Postepy Biochemii, 62* (2), 116-125. https://www.researchgate.net/publication/330848984"

Conclusion

Oxygen is not harmless.

In the perioperative setting, anesthetists must be vigilant in **titrating** oxygen to avoid hyperoxia as well as hypoxia. Individualizing patient care for specific patient needs, especially in the delivery of oxygen, is critical to reducing the detrimental effects of hyperoxia.

Recommendations

Titrate to a goal oxygen saturation of 94-98%.
(Gerber et al., 2019; Karalapillai et al., 2020)

The use of 90-100% FiO_2 for ***preoxygenation*** during induction, for the benefit of safe apnea time, appears to outweigh the risk of 3-5 minutes of hyperoxia, especially in the obese and potentially difficult airway populations (Su et al., 2020).

Providing deliberate individualized oxygen therapy, while weighing the risks and benefits, is a great start to a controversial and emotionally challenging topic.

Credits

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