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Anaesthesia & Critical Care Medicine Journal
ISSN: 2577-4301

Intraoperative Fraction of Inspired Oxygen: An Enigma to be Unravelled

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Editorial

Volume 4 Issue 4

Received Date: October 17, 2019

Published Date: October 26, 2019

DOI: 10.23880/accmj-16000163

Editorial

To date, plethora of randomized controlled trials have been done to find out clinical impact of fraction of inspired oxygen (FiO_2) used in perioperative period. The oxygen has been in use in providing anaesthesia since ages. In current day practice, oxygen's use has become an integral part of giving safe anaesthesia. Let alone general anaesthesia (GA), oxygen is almost invariably used even in regional anaesthesia and procedural sedation and analgesia (PSA) in varying concentrations depending upon various factors like depth of sedation, age, respiratory depression and patient's condition etc. The ideal FiO_2, that it should be used at, is still dubious. However, many of us use oxygen, dogmatically in perioperative period, which is affected by one's clinical experience, training and local practice, etc.

Previously, there was a misbelief that oxygen administration, even at higher concentrations, affects the clinical outcome positively. In past few decades, as we have grown in our comprehension about deleterious effects of oxygen, its concentration (FiO_2) and roll per se is being overwhelmingly challenged.

As of now, it has been tried to weigh the benefits versus risks of oxygen use by systemic reviews and meta-analyses, yet ambiguity prevails due to dearth of outright conclusions and evidence based guidelines. In the current review, a critical appraisal is attempted to analyse advantages and disadvantages of different oxygen concentration, taking dual nature into consideration through a literature search in medical database i.e. PubMed, Web of science, google scholar.

Recently, WHO released recommendations, pertaining perioperative use of oxygen as to reduce the incidence of surgical site infections (SSIs), based on a meta-analysis of RCTs and unanimity among experts [1]. The WHO upheld the use of FiO_2 of 0.8 in intubated patients and for few hours after surgery, which drew widespread flak from anaesthesiologists and researchers [2,3].

Oxygen has been in use as a carrier gas for inhalational anaesthetics since the inception of nitrous oxide and ether in anaesthesia practice [4]. In the beginning, O_2 was used at room air concentration but with advent and introduction of contemporary equipments, higher fractions of O_2, were started being taken into consideration. At the time of induction, preoxygenation with 100% O_2, to increase the time for airway instrumentation has become a routine practice, which is subsequently followed by FiO_2 of 0.4-0.5 while maintenance [5]. This is not only constrained to difficult airways, since hypoxia is one of the most dreaded and formidable event that anaesthesiologists come across. Despite being heavier and denser than nitrogen, oxygen, even at these high concentrations does not affect airflow dynamics significantly [6].

The scepticism about appropriate FiO_2 in perioperative period has escalated ever since the dual nature of O2 has come to the light. Radical oxygen metabolites (ROMs), produced by incomplete reduction of O_2, cause structural damage to DNA, epithelium, endothelium and eventually ending up with organ damage like brain, lungs etc [7,8]. However, a number of factors affect the clinical end result like: concentration,

duration of use and age etc. [7] among aforementioned factors, age is an important one, as individuals of extreme age are very sensitive to the detrimental effects of high O_2 concentrations.

The dictum that endorses higher FiO_2 in perioperative period is the roll of ROMs in immune system. Superoxide and hydrogen peroxide have a pivotal role in defence against bacterial activity by combining with chloride to form hypochlorous acid, and by inciting gene expression of proinflammatory cytokines [9,10]. Therefore, by supplementing oxygen at higher concentration, cellular immunity may be strengthened specially in context of general anaesthesia (GA) as GA is believed to have an alleviating effect on the immunity [10-12].

Hyperoxia affects the pulmonary and systemic vascular resistance greatly. With high oxygen tension, pulmonary vascular resistance decreases, while systemic resistance rises. This results in preferential regional redistribution of blood flow to lungs [13]. This redistribution has ameliorating effect on high ventilation-perfusion (V/Q) mismatch, since it increases total available surface area for gaseous exchange [14]. Nonetheless, high FiO_2 is seldom recommended, as it mitigates systemic blood flow (cerebral and coronary blood flow are of utmost importance) due to rise in systemic vascular resistance and therefore oxygen's availability in smaller capillaries is lowered [15]. As oxygen is mainly transported by haemoglobin, which already remains fully saturated at normal inspired O_2 fraction; high FiO_2 increases O_2 content of blood inconsequentially [16]. Thereby, high FiO_2 increases the potential risk of tissue hypoxia due to reduced capillary perfusion and advantage in prevention of SSIs by producing of ROMs also goes off.

Ventilatory heterogeneity is inevitable in anaesthesia due factors like: mechanical ventilation, position during surgery, pain, muscle relaxation, respiratory depression etc [17,18]. When oxygen is used at higher concentration, it promotes repeated alveolar collapse called absorption atelectasis. When used in high concentration, O_2 rapidly replaces nitrogen from lungs and a very high pressure gradient develops between alveoli and pulmonary capillaries, which facilitates rapid diffusion of O_2 across diffusion surface to capillaries, resulting in cyclical collapse of alveoli [19,20]. FiO_2 of 0.8 is generally considered threshold for this and sometimes atelectasis may not even respond to recruitment manoeuvres [21-23].

Use of high FiO_2 in neonate and infants, may have severe repercussions as their organs, especially brain and lungs are very sensitive for getting affected adversely by ROMs. Broncho-pulmonary dysplasia, bronchial hyper reactivity, retinopathy of prematurity, pulmonary hypertension and fibrosis are few common and devastating consequences [24,25]. Moreover, unloading of oxygen from fetal haemoglobin is affected adversely, which is attributed to higher affinity of fetal haemoglobin for oxygen, therefore despite having higher oxygen content in blood, tissue hypoxia may ensue [26]. Oxygen therapy is critical in congenital heart diseases like acyanotic heart diseases, where preferential regional redistribution of blood to lungs increases shunt fraction and lowers cardiac output and systemic perfusion [27]. As infants are not privileged with a decent functional residual capacity, which is ascribed to anatomical characteristics of their respiratory system (chest wall is more compliant and lungs have higher elastic recoil), they are prone for hypoxia while managing airway. Henceforth, preoxygenation with 100% oxygen is advocated in routine practice [28]. However, this practice facilitates alveolar collapse as per the mechanism of absorption atelectasis.

Nowadays, the prevalence of chronic obstructive pulmonary disease (COPD) has rise due to progressive changes in environment and lifestyle. Use of oxygen is crucial and challenging in patients because of potential of oxidative stress [28]. Moreover, CO_2 has a pivotal role in maintaining respiratory drive so patient may hypo ventilate when higher FiO_2 is used in perioperative periods.

Conclusion

The rationale behind using oxygen in perioperative period is to maintain adequate tissue oxygenation and to parry catastrophes during airway handling. Because of dual nature of this gas, it's often considered a double edged sword as hypoxia is one of the most feared nightmares, while on the other extreme; hyperoxia virtually affects almost every organ system detrimentally. Therefore, one should be conversant about consequences or repercussions when using oxygen. The ideal perioperative O_2 concentration is still a matter of debate and while determining the same, age specific aspects of oxygen demand and toxicity should be taken into consideration. A higher FiO2, not more than 80%, may be used in challenging situations like airway instrumentation or while recovering from anaesthesia, while 30-35% is considered adequate in maintenance of anaesthesia.

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WHO's recommendation of use of higher FiO2 (>0.8), could not be validated and they eventually decided to change it from strong to moderate recommendation. Since conspicuous conclusions have not been reached at, and data remained contentious, more comprehensive researches are to be undertaken to figure out beneficial and harmful effects of perioperative use of oxygen at different concentrations.

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