Review Article

Arterial Oxygen Saturation: A Vital Sign?

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Abstract

The physical examination is a key part of a continuum that extends from the history of the present illness to the therapeutic outcome. An understanding of the pathophysiological mechanism behind a physical sign is essential for arriving at the correct diagnosis. Early detection of deteriorating physical/vital signs and their appropriate interpretation is thus the key to achieve correct and timely management. By definition, vital signs are *"the signs of life that may be monitored or measured, namely pulse rate, respiratory rate, body temperature, and blood pressure."* Vital signs are the simplest, cheapest and probably the most inexpensive information gathered bedside in outpatient or hospitalized patients. The pulse oximeter was introduced in the 1980s. It is an accurate and non-invasive method for the measurement of arterial hemoglobin oxygen saturation (SaO2). Pulse oximetry-based arterial oxygen saturation can be effectively used bedside in in-hospital and ambulatory patients with diagnosed or suspected lung disease. The present pandemic of COVID-19 should be considered as a wake-up call. Articles related to arterial oxygen saturation and its importance as a vital sign in patient care were searched online especially in PubMed. Available studies were studied in full length and data was extracted. Discussion: A. Clinical Utility of Oxygen Saturation Monitoring: There are many studies reporting the clinical applicability and usefulness of pulse oximetry in the early detection of hypoxemic events during intraoperative and postoperative periods. B. Role of clinical expertise accompanied by knowledge of physiology: A diagnostic sign is useful only if it is interpreted accurately and applied appropriately while evaluating a patient. The World Health Organisation also appreciates these facts and published "The WHO Pulse Oximetry Training Manual." Understanding the physiology behind and overcoming limitations of the diagnostic sign by clinical expertise is important. While using pulse oximetry, a clinician needs to keep in mind the sigmoidal nature of the oxygen-Hb dissociation curve. Considering these benefits of SaO2 measurement, there have been several references in the past to consider oxygen saturation as the fifth vital sign. In the present pandemic oxygen saturation i.e., SpO2 (arterial oxygen saturation) measured by pulse oxymeter, has been the single most important warning and prognostic sign be it for households, offices, street vendors, hospitals or governments. Measurement of trends of SaO2 added with respiratory rate will provide clinicians with a holistic overview of respiratory functions and multidimensional conditions associated with hypoxemia.

Keywords: *COVID-19, oxygen saturation, physical examination, pulse oximetry, vital signs*

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Background

The physical examination is a key part of a continuum that extends from the history of the present illness

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to the therapeutic outcome. An understanding of the pathophysiological mechanism behind a physical sign is essential for arriving at the correct diagnosis.[1] Early detection of deteriorating physical/vital signs and their appropriate interpretation is thus the key to achieve correct and timely management. According to studies, alterations in vital signs occur several hours before a significant adverse event occurs.[2] Hence vital signs have been the

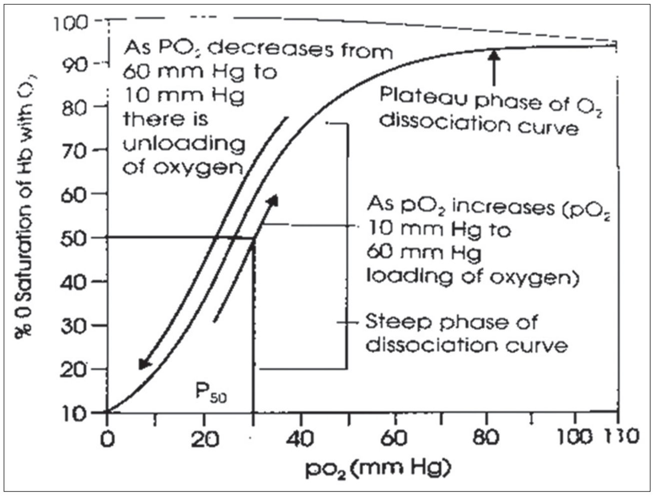

Figure 1: Oxygen-hemoglobin dissociation curve

most accurate predictors of clinical deterioration.[3] By definition, vital signs are "*the signs of life that may be monitored or measured, namely pulse rate, respiratory rate, body temperature, and blood pressure*."[4] Vital signs are the simplest, cheapest and probably the most inexpensive information gathered bedside in outpatient or hospitalized patients. Initially, the pulse and respiratory rate were the only vital signs reflecting crucial physiological functioning. The addition of body temperature and blood pressure with pulse and respiratory rate occurred over time after the instruments namely thermometer and sphygmomanometer became reusable, non-invasive, accurate, and most importantly inexpensive.[5]

The pulse oximeter was introduced in the 1980s. It is an accurate and non-invasive method for the measurement of arterial hemoglobin oxygen saturation (SaO2). The technique uses a light source and a detector to measure the difference in absorption at the two wavelengths that are transmitted through the blood. The only other way to assess oxygenation is by blood gas analyzer after percutaneous arterial puncture. This requires trained personnel and a laboratory setup.[5] Pulse oximetry-based arterial oxygen saturation can be effectively used bedside in in-hospital and ambulatory patients with diagnosed or suspected lung

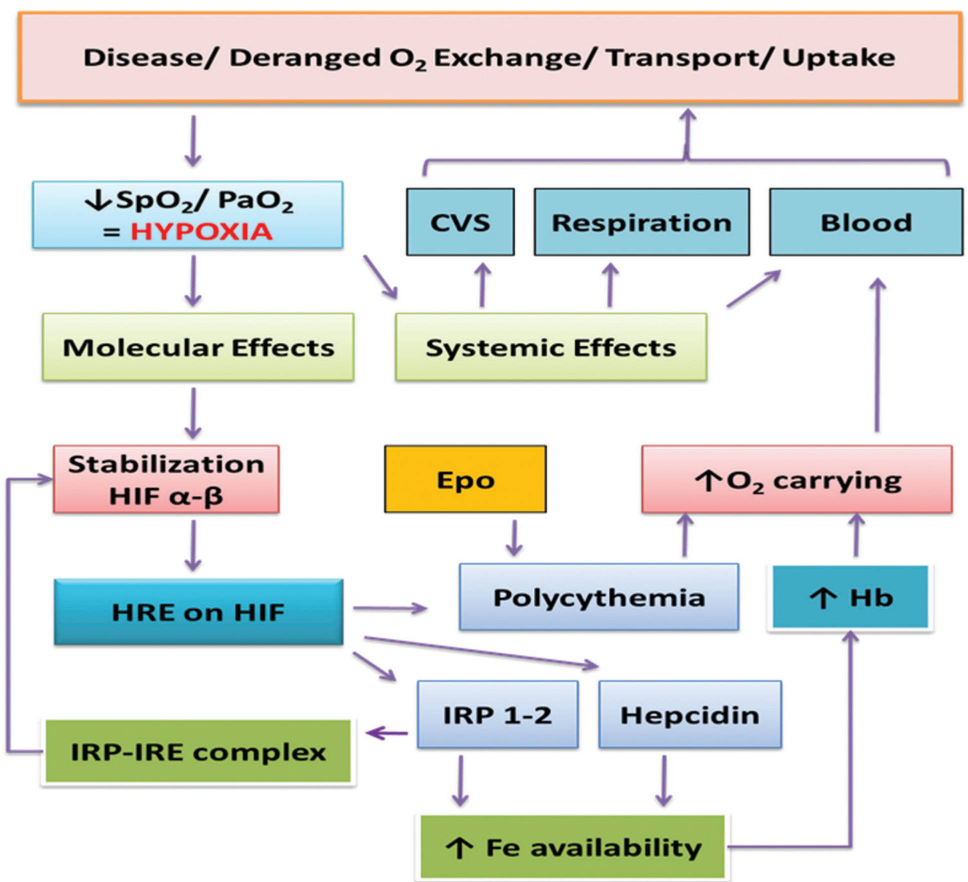

Figure 2: Systemic and biochemical changes in response to hypoxia

disease. The present pandemic of COVID-19 should be considered as the wake-up call. Over 262 million people have been affected worldwide. Arterial oxygen saturation was the most important parameter used to screen, admit and assess the prognosis of the COVID-19-affected patients.

Aim and Objectives

The above fact gave the authors an impetus to explore the helpfulness of non-invasive pulse oximetry-based arterial oxygen saturation as a vital sign in physical examination. Articles related to arterial oxygen saturation and its importance as a vital sign in patient care were searched online especially in PubMed. Available studies were studied in full length and data was extracted.

Discussion

Clinical utility of oxygen saturation monitoring

It has been over 25 years since a US study observed that 86% of hospital case presentations had information regarding oxygen saturation.[5] A systematic review, that evaluated value of vital sign trends in predicting and monitoring clinical deterioration, did not recommend continuous monitoring of the vital signs but did conclude that vital signs including oxygen saturation play an important role in emergency departments and in the wards, to determine patients at risk of clinical deterioration based on Early warning scores (EWS).[2] Early warning scores of pulse oximetry levels have been implemented to accurately detect high-risk cases, both pediatric and geriatric.[6,7] These scores generally utilize the current value of the vital signs and do not include trends of vital signs over time. A multicentric study in ward patients concluded that adding current values of oxygen saturation and trends of oxygen saturation together significantly increased the accuracy of models designed to detect critical illness, ICU transfer, and death.[3] The same study also found that the model containing the trends of vital signs over time had a higher Area under Curve (AUC) than a model containing only current values of the vital signs. Thus considering vital signs over time would be more accurate, if not continuous, than a cross-sectional value. This finding highlights an important concept of clinical decision-making that deteriorating trends of a vital sign is an indicator of deteriorating body functions. Thus the accuracy with which these trends of vital signs are noted is also of paramount importance. There are many studies reporting the clinical applicability and usefulness of pulse oximetry in the early detection of hypoxemic events during intraoperative and postoperative periods,[8] in monitoring patients with mechanical ventilation, obstructive sleep apnea, hypotension, asthma, acute respiratory distress, COPD, pneumonia, and other cardiopulmonary disorders.[9] Low pulse oximetry values have also helped physicians triage patients and order evidence-based investigations like chest radiography, arterial blood gas measurements, and spirometry and prescribe treatment accordingly.[7]

Role of clinical expertise accompanied by knowledge of physiology

A diagnostic sign is useful only if it is interpreted accurately and applied appropriately while evaluating a patient.[9] The World Health Organization also appreciates these facts and published "The WHO Pulse Oximetry Training Manual."[10] Understanding the physiology behind and overcoming limitations of the diagnostic sign by clinical expertise is important. While using pulse oximetry, a clinician needs to keep in mind the sigmoidal nature of the oxygen-Hb dissociation curve. As shown in Figure 1, low oxygen-hemoglobin-saturation (SaO2) of 88% approximates a partial pressure of oxygen (PaO2) of 60 mm Hg; even small decrements thereafter reflect considerable tissue hypoxia, even though the number is numerically not very low.[11]

The vice versa is also true. A severely anemic patient with SaO2 of 100% may deceivingly be non-hypoxic, although the tissue O2 delivery is reduced to half.[12] The peripheral arterial chemoreceptors in the carotid and aortic bodies are exposed to very high rates of blood flow and thus are primarily activated by a reduction in arterial partial pressure of oxygen (PaO2) other than the arterial partial pressure of carbon dioxide (PaCO2) and pH. Therefore, the receptors are not stimulated in conditions such as anemia or carbon monoxide poisoning, in which the PaO2 reaching the receptors is generally normal, even though the cumulative O2 delivery to tissues is markedly decreased.[9,13] Hence in such instances it's the observers' duty to clinically correlate all the signs before making an interpretation. Since the anemic patient shall simultaneously have tachycardia and hyperdynamic circulation. Thereby relying on only one sign for interpretation is not advisable. Based on clinical experience a study had hypothesized a correlation between SpO2 levels with PaO2 levels which can help clinicians predict PaO2 levels by just measuring SpO2 values.[14] It should be noted that a physical finding is often influenced by the presence or absence of other coexisting pathophysiological findings. Thus observer related variability should be controlled to proficiently use a diagnostic sign.[1] Of course, the development of technologically advanced multi-wavelength oximeters with lower signal-to-noise ratio may prove to be more accurate and useful in detecting disorders.[8]

Molecular basis of hypoxia

The molecular mechanism behind a hypoxia thereby alterations in SpO2 are explained below. Hypoxia has many system effects like increased stroke volume, cardiac output, increase in ventilation, etc., These systemic changes occur in concurrence with the biochemical changes in response to hypoxia. Explained in detail below in Figure 2.[15]

HIF is continually expressed and promptly destroyed in euoxic settings, whereas prolyl hydroxylation and proteasomal degradation are inhibited under hypoxic conditions, resulting in HIF stabilization and accumulation. The HIF-subunit is then translocated to the nucleus, where it dimerizes with HIF, attaches to hypoxia response elements in HIF-target genes, and triggers transcription. It is also known that hemoglobin concentration increases depending on the severity of hypoxia represented by PaO2. Furthermore, it has recently been discovered that IRP-IRE binding regulates HIF-2 post-translationally. Because HIF-2 is the most important HIF isoform in controlling Epo, it may act as a negative-feedback regulatory mechanism during iron deficit, limiting Epo stimulation of erythropoiesis until iron supply is sufficient to allow successful red blood cell formation. Functional variations resulting from common genetic variation or the availability of cofactors like iron, for example, may thus influence the clinical response to any such physiological or pathological disruption. Thus to find out diseases, it's important to first screen hypoxia. The respiratory rate might not be an efficient sign in high-altitude residents.

Considering these benefits of SaO2 measurement, there have been several references in the past to consider oxygen saturation as the fifth vital sign.[3,5-7,12,16] In the present pandemic, oxygen saturation i.e., SpO2 (arterial oxygen saturation) measured by pulse oxymeter,[10] has been the single most important warning and prognostic sign be it for households, offices, street vendors, hospitals or governments.

Conclusion

SaO2 is an important, simple, user-friendly, inexpensive, and reliable parameter for clinical assessment of deterioration or improvement in the health of the patient. There is ample scientific evidence and proof of its practical utility. Measurement of trends of SaO2 added with respiratory rate will provide clinicians with a holistic overview of respiratory functions and multidimensional conditions associated with hypoxemia. Hence, steps should be taken to incorporate SaO2/SpO2 as the fifth vital sign.

Implications

Further research in SpO2 and PaO2 is needed to establish the correlation between SpO2 levels and the required dose of oxygen therapy. Proper guidelines in these regards will further benefit the patients.

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Conflicts of interest

There are no conflicts of interest.

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