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Accuracy of Pulse Oximeter at Different Sensor Locations in Patients with Viral Pneumonia: Comparison of Finger and Earlobe

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Abstract

Since the advent of the COVID-19 pandemic, there has been a significant surge in patients admitted to emergency departments exhibiting hypoxemia yet showing no signs of dyspnea. This intriguing presentation sparked our hypothesis that SpO_2 measurements derived from the index finger may not reliably estimate the actual peripheral blood oxygen saturation.

To substantiate our hypothesis, we orchestrated a study that compared the efficacy of SpO_2 monitoring at two different sensor locations: the earlobe and the traditionally used index finger. Our objective was to scrutinize the variation in these measurements against the gold-standard reference of arterial blood gas (ABG) analysis. We were particularly interested in understanding whether the measurement site would impact the precision of the SpO_2 readings and, consequently, the clinical decision-making process.

Our results revealed that the earlobe-based pulse oximetry readings demonstrated a higher congruence with the SaO_2 values derived from the ABG analysis when compared to finger-based measurements, particularly in patients with mild to moderate COVID-19 symptoms. However, for patients exhibiting PaO_2/FiO_2 ratios less than 250, the index finger measurements were found to be more precise.

Our findings contribute to the evolving understanding of optimal pulse oximetry sensor locations, offering clinicians a more nuanced perspective when interpreting SpO_2 readings in the context of viral pneumonia such as COVID-19. This could potentially refine the assessment of patient condition and enhance the effectiveness of clinical decisions in a critical care environment.

Keywords: Happy hypoxia; COVID-19; Silent hypoxia; Pulse oximetry; Micro thrombosis.

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Introduction

In recent years, the focus on diagnostic biomarkers as a pivotal tool for diagnosing a spectrum of diseases - ranging from cancer to infectious diseases - has gained significant momentum [1]. The emergence of the COVID-19 pandemic has further highlighted the crucial role of these diagnostic indicators, particularly concerning hypoxia, a condition characterized by low oxygen saturation (SpO_2) levels in the body.

An intriguing phenomenon observed since the onset of the COVID-19 pandemic is the presentation of many patients to emergency departments with surprisingly low SpO_2 measures, yet without commensurate respiratory distress or cognitive decline [22,23]. This paradoxical condition, wherein patients appear comfortable despite critically low oxygen levels, has been colloquially termed "happy hypoxia" [5-7].

Our study was primarily driven by the hypothesis that SpO_2 measurements via the index finger, a conventional site for pulse oximetry, may not accurately reflect the true peripheral blood oxygen saturation in COVID-19 patients. We conjectured that a more central location, specifically the earlobe, might provide a more precise estimation of blood oxygen saturation.

To test our hypothesis, we meticulously designed a study wherein SpO_2 monitoring was performed via earlobe and compared against the gold standard - the right index finger-clip pulse oximeter. We further validated these readings with a simultaneous arterial blood gas (ABG) analysis to ensure the reliability of our findings.

Methods

Following the acquisition of informed consent, our study encompassed 27 COVID-19 patients. These participants were admitted to the infectious diseases ward between January and February 2021. The inclusion criteria centered on adult patients diagnosed with COVID-19 pneumonia through SARS-CoV-2 reverse transcriptase polymerase chain reaction (RT-PCR) testing, and subsequent admittance to the infectious diseases ward.

Several conditions defined our exclusion criteria, including patients' inability to tolerate 3 minutes of respiration without supplemental oxygen and any drop in SpO_2 levels below 80%. Additional exclusion factors involved a body temperature less than 35°C, pre-existing conditions known to affect pulse oximetry accuracy such as sickle cell disease or congenital methemoglobinemia, and patients requiring high inotropic support.

The SpO_2 measurements were carried out using a cardiac monitoring device's pulse oximeter, with the sensor placed on both the finger pad and earlobe. Prior to taking measurements, patients were kept off supplemental oxygen for a 3-minute interval to establish a baseline. Simultaneously, an arterial blood sample was obtained from the femoral artery to enable arterial blood gas (ABG) analysis.

After collecting initial measurements, patients were adequately ventilated using face masks at a rate of 5 L/min. After a minimum of 3 minutes and confirmation of SpO_2 stabilization, measurements were again captured from the earlobe and finger. Additionally, a complete blood count (CBC) was collected to ascertain hemoglobin and red blood cell counts, contributing to a comprehensive patient health profile.

We further incorporated a review of patients' initial CT scores, calculated based on the methodology proposed by Li et al. This involved assigning a score ranging from 0 to 5, according to the extent of viral infiltrates in each lung lobe [8]. By integrating this multidimensional approach, our study aimed to provide a thorough understanding of SpO_2 measurement accuracy at different sensor locations in COVID-19 patients.

Results

Our study included 27 patients, whose mean age was 50, with a standard deviation of 11.2. The mean chest CT score, indicating the extent of the lung damage, was 14.6, with a standard deviation of 3.2.

Upon analysis of the SpO_2 measurements using the Wilcoxon's Signed Ranks test, we identified significant differences between the SpO_2 values measured at the earlobe and finger. When patients received supplemental oxygen, the mean SpO_2 measured at the earlobe was 96.1 (SD: 3.0), significantly higher than the mean SpO_2 of 91.4 (SD: 3.0) measured at the finger. The statistical test yielded a Z score of -2.81, with a p-value of 0.005, indicating this difference was statistically significant.

Table 1: Baseline characteristics of study participants.

Variable	Value
Age	50 ± 11.2
Sex	
-male	24(88.9%)
-female	3(11.1%)
Smoking	6(22.2%)
BMI	28.6 ± 3.4
Pulse Oximeter data	
SpO_2 without oxygen (%)	
-Finger	85.4 ± 3.0
-Ear	92.7 ± 4.1
SpO_2 with oxygen (%)	
-Finger	91.4 ± 3.0
-Ear	96.1 ± 3.0
Vital Signs	
-SBP (mmHg)	134 ± 10
-DBP (mmHg)	87 ± 13
-HR	91 ± 13
-RR	27 ± 5
-T (°C)	37.2 ± 0.6
ABG	
-pH	7.45 ± 0.04
-pCO_2 (mmHg)	31.9 ± 5.3
-HCO_3- (mmol/L)	21.9 ± 1.9
-pO_2 (mmHg)	55.9 ± 11.6
-SpO_2 (%)	88.5 ± 7.9
Hb (g/dL)	14.7 ± 1.7
RBC *10^6	5.1 ± 0.7
-PaO_2/FiO_2	279 ± 39
CT score	14.6 ± 3.2
Hospital Stay (day)	11 ± 5

Moreover, even without supplemental oxygen, the earlobe readings displayed.

Compared to 85.4 (SD: 3.0) at the finger, with a Z score of -2.82 and a p-value of 0.005, further emphasizing the significance of this difference.

As can be inferred from Table 1, the arterial blood gas (ABG) analysis, which serves as the gold standard, generally aligned more closely with the SpO_2 values measured via the earlobe

than those taken from the finger. This observation was consistent for all but two patients in our study. Notably, these two exceptions had PaO_2/FiO_2 values less than 250, indicating severe hypoxemia.

These results suggest that pulse oximetry readings taken from the earlobe are more accurate and reliable for most patients with viral pneumonia, presenting important implications for patient monitoring during the COVID-19 pandemic.

Conclusion and clinical implications

Since the emergence of COVID-19, numerous biomarkers have been studied for diagnosing both acute and chronic stages of the disease [4,9,10]. Previous investigations have highlighted the potential inaccuracies of pulse oximetry readings under conditions of severe and rapid O_2 desaturation, hypotension, hypothermia, dyshemoglobinemia, and poor blood perfusion [11,24,25].

In our study involving COVID-19 patients, the earlobe was found to be a more reliable site for pulse oximetry readings than the finger pad. Specifically, average blood oxygen saturation measurements obtained from the earlobe aligned more closely with SaO_2 values ascertained by arterial blood gas (ABG) analysis.

This pattern was consistent across our patient sample, with only two exceptions. These two patients, who had PaO_2/FiO_2 values less than 250, reflect findings by Clayton and colleagues [13], who found finger sensor readings were more reliable among patients with severe hypoxemia.

Recent investigations have shed light on the pathology of COVID-19, illuminating how SARS-CoV-2 invasion and subsequent host immune responses can lead to endothelial damage, which can, in turn, induce microvascular thrombosis and microcirculation disorders – conditions found in 91.3% of post-mortem COVID-19 patients [14].

Many clinical trials have confirmed the presence of microcirculatory dysfunction in sepsis, often resulting from NO (nitric oxide) dysregulation, endothelial damage, and functional impairments among various cell types present in the microcirculation [15,16].

In another study focusing on athletes post-training, capillary blood samples taken from the finger pad showed consistently higher lactate concentrations than those from the earlobe taken concurrently [17]. High lactate levels indicate tissue hypoxia, poor perfusion, reduced blood pH, and oxygen debt – conditions conducive to lactate production [6,18].

Our findings, when considered in light of these studies, suggest that the finger pad's microvasculature is more susceptible to acute illnesses than that of the earlobe. This observation holds significance considering recent revelations about the role of COVID-19 in inducing micro-thrombosis and significant perfusion abnormalities, especially in cases of severe viral pneumonia [12,26] (Figure 1).

Further evidence demonstrates that even patients with low Wells scores show signs of perfusion defects in lung segments and subsegments, especially those with persistently high d-dimer levels or exertional dyspnea in the post-COVID phase. Moreover, outpatients with mild-to-moderate COVID-19 have an increased thrombotic risk and are often recommended for anticoagulant prophylaxis during their illness [19].

Thus, our research and the cited studies suggest that thrombotic events play a significant role even in mild COVID-19 cases. In contrast to the earlobe, the finger pad appears more susceptible to hypoxic changes, affirming our initial hypothesis and underlining the necessity for further research in this area.

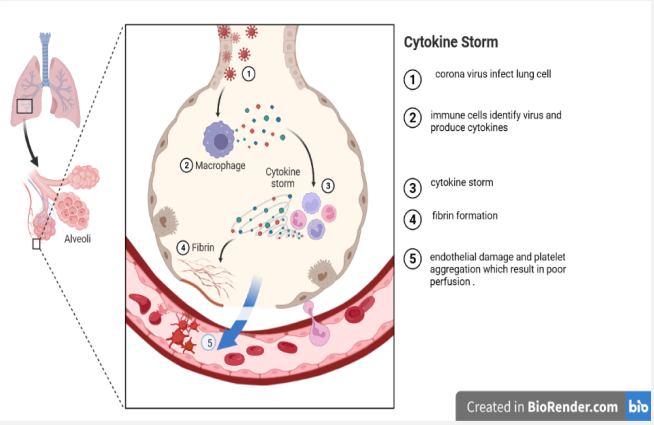

Figure 1: Pathophysiology of microcirculatory changes in COVID-19.

We assume that these extensive thrombi in the capillaries and poor peripheral perfusion may cause the underestimation of the true Spo_2 measured through finger pulse oximetry. Compared with the finger pad, the earlobe might benefit from straighter and more central arterial circulation, being less amenable to false SpO_2 interpretations through pulse oximeter devices.

Thus, we recommend earlobe pulse oximeter measurements in patients admitted to the emergency room for triage of mild to moderate COVID-19; the greater difference between ear and finger measurement predicts a more serious patient's condition. However, larger studies are needed to confirm our results.

Declarations

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Consent to participate: The patients have consented to participate in this study.

Consent for publication: The participant has consented to the publication of this study.

Availability of data and material: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Code availability: Not applicable.

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