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Assessment of hypoxemia detection by pulse oximeter in COVID 19 associated pneumonia

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ABSTRACT
Background - Pulse oximeters are in extensive use since the beginning of the COVID 19 pandemic. Their utility to detect hypoxia has been varying across studies.To study the ability of pulse oximeter to detect hypoxia in 40 COVID 19 pneumonia subjects.
Methods - We studied the utility of pulse oximeter reading of 90 and 92 to detect hypoxia in 40 COVID 19 patients.
Results - Pulse oximetry (SpO2) showed about 1.77% more value than ABG(SaO2) on the average. It had a sensitivity of 50% and a specificity of 76.09% to detect hypoxia at a pulse oximeter reading of SpO2 < 90% and a sensitivity of 65% and a specificity of 61.6% to detect hypoxia at a pulse oximeter reading of SpO2 < 92%.
Conclusions - Our study showed that the pulse oximeter may not accurately detect hypoxia in COVID 19 pneumonia subjects. Hence its reading needs cautious interpretation.
Keywords: Pulse oximeter; COVID 19; SARS CoV-2; hypoxia; hypoxemia; oxygen saturation; happy hypoxia

I. BACKGROUND

Worldwide the COVID 19 (Corona Virus Infectious Disease 2019) causing SARS-CoV2 has killed millions of people. COVID 19 primarily affects the lung. In severe cases it could lead to hypoxia and death. The detection of hypoxia is aided by the pulse oximeter and Arterial blood gas analysis(1). Some shortcomings of these devices have been brought out in various studies in different contexts (2). One of such study showcases a harrowing case series of three patients who showed 'Happy hypoxia', where pulse oximeters simply failed to show the actual hypoxia(3). We assessed the utility of pulse oximeters in patients with SARS-CoV2 pneumonia.

II. MATERIALS AND METHODS

We recruited 48 COVID 19 pneumonia patients at the ICU of Great Eastern Medical School and Hospital, Ragole from July to August 2020. Sample size was calculated to detect a bias of at least 2% between SpO2(Oxygen saturation by pulse oximeter – **Dr Trust** Series) and SaO2(Oxygen saturation by Arterial Blood Gas analyser - **ABL FLEXRadiometer** Medical, Copenhagen, Denmark installed in the ICU) with 80% power. The patients were diagnosed according to the W.H.O criteria(4). Patients with previous cardio respiratory disorders were excluded. The pulse oximeter applied to the finger and blood for arterial blood gas analysis(was taken at the same time. The SpO2 value was compared against the SaO2 value from ABG analysis. Bland Altman analysis was used for direct comparison of quantitative values. Sensitivity and specificity of pulse oximeter on detecting hypoxia [defined as SaO2 < 90% and defined as a PaO2 < 60 mm Hg] (5) was calculated. Statistical analysis was performed with IBM SPSS Statistics for Windows, version 21 (IBM Corp., Armonk, N.Y., USA). Data is presented with median and range. The p value was calculated with the Mann Whitney U test. Written informed consent was taken from the patients for the study. The study was approved by the Institutional Ethical committee at GEMS and Hospital [90/IEC/GEMS&H/2020].

III. RESULTS

Amongst the 40 patients who consented to participate in the study, the mean age of the subjects was 58.67±11.74 years with 30.3% women. The mean SpO2 was higher (95±5.47) than the mean SaO2 (91.35±13.19). p=0.0383. 95% CI 0.2 to 7.10.

Bland Altman analysis revealed a bias of 1.77% and the limits of agreement -24.51% and 28.04% (Figure 1)

Pulse oximetry (SpO2) shows about 1.77% more value than ABG(SaO2) on the average, it may show a reading as high as 28.04 above the ABG and as lower as 24.51 than ABG at the extremes.

In our study ABG analysis (SaO2 < 90 measurement had 100% sensitivity and specificity in detecting PaO2 < 60 mm Hg).

But pulse oximetry, with a sensitivity of only 50%, has poor ability to detect hypoxia at a reading of SpO2 < 90%. At an SpO2 reading cutoff at 92 the sensitivity rose only to 65%.(Table 1)

With a specificity of 76.09% the ability of pulse oximeter reading of SpO2 < 90% to point out hypoxia was less. When the cutoff was taken at SpO2 < 92%, it presented even higher proportion of 30.4% has havinghypoxiaeven when there were non hypoxemic.

The ROC curve therefore showed an AUC of 0.5which reiterates the poor utility of the pulse oximeter in detecting hypoxia in COVID patients.The statistical correlation between SpO2 and SaO2 was poor (r=0.16).

IV. DISCUSSION

We studied the performance of pulse oximeter in 40 patients with COVID pneumonia and found that pulse oximetry erred in detecting hypoxia.

On average the pulse oximeter showed 1.77% higher value than SaO2. A previous study with children showed a bias of 3.3%(6), while older studies reported a bias of 1.7 to 2.5(7). This bias is dangerous. It would show patients with hypoxia as not having hypoxia. This may be one of the reasons for the happy hypoxia highlighted with extensive use of the pulse oximeters in the COVID 19 pandemic.

At both the cutoff SpO2 values of 90 and 92 pulse oximetry failed to detect hypoxia when there was hypoxia and also showed hypoxia when there was none. There was a poor correlation between SpO2 and SaO2 or PaO2 values. Similar results have been found in COVID 19 patients in a recent study(8).

In COVID 19, the arterial hypoxemia is thought to be induced by intrapulmonary shunting, dysregulated hypoxic pulmonary vasoconstriction, impaired lung diffusion, and formation of intravascular microthrombi. This causes tachypnea and hyperpnea. The consequent CO2 wash out shifts the oxygen dissociation curve to the left. So SpO2 is high even with suboptimal PaO2. The alveolar gas equation also shows that there is a higher SpO2 recording in this type of pathology(3).

Early in the disease, the lung mechanics are well-preserved and there is no increased airway resistance or dead space ventilation. There is no CO2 build up (the key driver for dysnea) and the patients are unaware of the hypoxia until late. This happy hypoxemia is also noted in high altitude sickness(3).

A recent study with COVID patients suggests that parameters such as high ferritin and fibrinogen levels which are acute phase reactants may be associated with poor performance of pulse oximetry(8).

Other reasons for decreased pulse oximeter accuracy with hypoxemia include paucity of reliable human calibration data during extreme hypoxia and an increased proportion of reduced hemoglobin in hypoxia, which can produce errors in the absorption ratio(9).

An Australian study performed in 2020 showed that the ROC curve for SpO2 < 92% had 100% sensitivity and 84.4% specificity for detecting SaO2 < 90%, and 95.1% sensitivity and 90.0% specificity for detecting PaO2 < 60 mmHg(5). But our ROC data suggests minimal utility of SpO2 in detecting hypoxia. The heterogeneity of the patients in the australian study and therefore their pathophysiologies may have contributed to the results.

There are limitations to this study. First, the single center nature of the study decreases generalizability and then the small sample size also decreases the power of the study.

Hypoxia detection with pulse oximeters has been found to be variable in different contexts (3,5–9). Some studies show that they accurately detect hypoxia while some others show otherwise. Our study suggests that the pulse oximeter has significant limitations in assessing hypoxia in COVID patients, hence its role needs to be re-evaluated.

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Declaration of Interest
The authors report no conflict of interests
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Figure Legends

Figure 1: Bland Altman graph of SpO2 vs SaO2

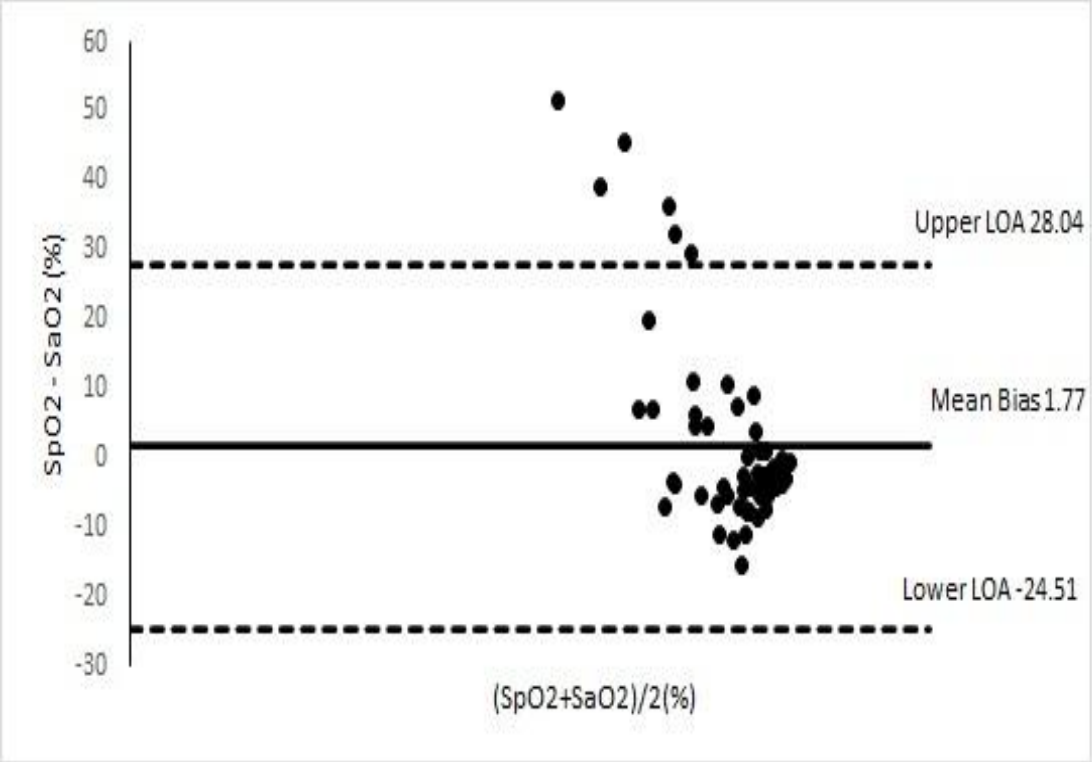

Table 1: Sensitivity and Specificity of pulse oximeter

Ability for SpO_2 <90% to detect SaO_2 <90%			
	SaO_2 <90%		Results
SpO_2 <90%	Yes	No	Sensitivity

Yes	10	11	50% Specificity 76.09% Positive likelihood ratio 2.091 Negative likelihood ratio 0.6571 Accuracy: 68.18%
No	10	35	
Total	20	46	
Ability for SpO_2 <92% to detect SaO_2 <90%			
	SaO_2 <90%		Results
SpO_2 <92%	Yes	No	Sensitivity 65% Specificity 69.57% Positive likelihood ratio 2.1357 Negative likelihood ratio 0.5031 Accuracy 68.18 %
Yes	13	14	
No	7	32	
Total	20	46	