

# Effect of using disposable polyethylene bag as a probe cover or finger cover in pulse oximetry

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## ABSTRACT

**Background:** Consumer-grade pulse oximeters are used to monitor blood oxygen levels (SpO<sub>2</sub>) at home. Sharing a pulse oximeter with family members in isolation centers or home isolation due to COVID-19 may increase the chances of cross-infection. **Aim:** We aimed to find if using commonly available disposable polyethylene covers either on the finger and/or on the pulse oximeter provides the same reading of SpO<sub>2</sub> or not. **Methods:** Two operators measured SpO<sub>2</sub> on 10 healthy subjects with three randomly selected pulse oximeters. Six types of commonly available polythene bags (transparent, translucent, and opaque) were used to cover the fingers and/or device. After measuring the baseline SpO<sub>2</sub> (i.e., without using covers), the measurements were taken with a covered finger, and/or covered oximeter probe. **Results:** The mean age of the research participants (five male, five female) was 23.9 ± 5.11 years. Perfusion index was 9.12 ± 1.63 (males 9.6 ± 1.42, females 8.64 ± 1.85, *P* = 0.38). Black opaque polyethylene bag as finger or probe cover did not detect any signal. There was no difference in SpO<sub>2</sub> reading when a pulse oximeter probe is covered, and/or a finger is covered. There was excellent inter-observer and inter-device agreement. **Conclusion:** Commonly available transparent and translucent polyethylene plastic bags may be used as finger or pulse oximeter cover without compromising the SpO<sub>2</sub> reading. However, an opaque black plastic bag is not suitable for finger or probe cover. These easily available and cheap pulse oximeter covers may be used by multiple patients or family members in an emergency like the COVID-19 pandemic with the potential to prevent cross-infection.

**Keywords:** Blood gas analysis, COVID-19, cross infection, home care services, oximetry, oxygen saturation, patient isolation, polythene

## Introduction

Pulse oximeters are one of the essential equipment used in a critical healthcare setting. Peripheral blood oxygen saturation (SpO<sub>2</sub>) is monitored by these devices.<sup>[1]</sup> The SpO<sub>2</sub> value in these devices is calibrated against direct arterial blood oxygen concentration (SaO<sub>2</sub>). Hence, the SpO<sub>2</sub> can be considered a reliable proxy of SaO<sub>2</sub> with less than 2% error.<sup>[2]</sup>

In critical care settings and during anesthesia, pulse oximeters are used along with other vital monitors. Typically, the finger probe is attached to the monitor by a cable. However, the pulse oximeters used in home health monitoring devices are low-cost standalone devices with a display. The probe has a light sensor on one side and light-emitting diodes on the opposite side.<sup>[3]</sup>

COVID-19 patients are being monitored for oxygen saturation at home using pulse oximeters.<sup>[4]</sup> In India, the Ministry of Health and Family Welfare advises monitoring of oxygen saturation in patients (asymptomatic or with mild symptoms) on home isolation. The current guidelines (updated on 05<sup>th</sup> May 2021) suggest seeking immediate help from a medical officer if the SpO<sub>2</sub> level falls below 95%.<sup>[5]</sup> It is frequent to find that one or more family members are

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simultaneously infected with COVID-19.<sup>[6]</sup> In such a situation, families may find it difficult to buy pulse oximeters for each infected member. In the second wave of the COVID-19 pandemic, the price of pulse oximeters has been increased by a minimum of 150%.<sup>[7]</sup> If each patient in a family isolated in different rooms start using a single pulse oximeter, there may be a potential chance of cross-infection. Hence, we were searching for a low-cost solution to overcome this problem. The solution would help the primary care physicians to suggest to their patients the usage of a single monitor in family members. Also, primary care physicians can use this probe cover for multiple patients in their clinics.

Cheung *et al.*<sup>[8]</sup> found that using a polyethylene plastic cover on the hospital-grade pulse oximeter probe induces a clinically non-significant error.

With this background, our research question was whether using a disposable polyethylene cover either on the finger or on the pulse oximeter provides the same reading of SpO<sub>2</sub> or not.

Our null hypothesis states that there will be no difference between the SpO<sub>2</sub> measured using pulse oximeter with and without probe cover. If we cannot reject the null hypothesis, then we may use the finger cover or probe cover for home healthcare purposes.

## Materials and Methods

### Pre-registration

The project of this study was registered on Open Science Framework (Center for Open Science, Charlottesville, Virginia, USA) before the data collection. The project details of the pre-registration can be found at <https://dx.doi.org/10.17605/OSF.IO/TRM87>.<sup>[9]</sup>

### Sample

This study was conducted following the ethical principles for medical research involving human subjects as suggested by the

World Medical Association Declaration of Helsinki, updated in 2013. This study was conducted on 10 otherwise healthy volunteers recruited as a convenience sample after obtaining written informed consent. The inclusion criteria were any adult (age ≥18 years) providing voluntary written consent for participation. Willing research participants who had any history of smoking, chronic obstructive pulmonary disease, asthma, or any other cardiorespiratory diseases, any deformity, any acute or chronic disease, or any mental disorder were excluded from the study.

### Minimum sample size

For minimum sample size calculation, we have taken three reference studies. Cheung *et al.*<sup>[8]</sup> studied four females and six males. Ackerman *et al.*<sup>[10]</sup> conducted a similar study with ten females. Russell *et al.*<sup>[11]</sup> studied five healthy men for observing the effect of lamination of the oximeter sensors. Hence, we aimed to recruit 10 research participants.

### Materials

We first made a list of available and deliverable pulse oximeters on e-commerce websites. Then we randomly selected three among them by Microsoft Excel 2010®. Devices were procured by the authors from e-commerce websites. Three pulse oximeters that we used in this study were - Dr Trust 210 (Model: SS01, LOT: DRSS01190207; Nureca Limited, NY, USA) [Figure 1a], Gilma Pulse Oximeter (Model: CY901; Stovekraft, Bangalore, India) [Figure 1b], and BPL Smart Oxy (Serial: JATA0F62411BPL; Medical Technologies Private Limited, Kerala, India) [Figure 1c].

Polyethylene (or polythene) plastic bags are commonly used for carrying vegetables and groceries in the regions where we conducted this study. Hence, this would be the most easily available plastic bag that can be used as a finger or probe cover. We took a sample of bags from a nearby grocery market. Six types of polyethylene bags that we used were – opaque black,



**Figure 1:** Three pulse oximeters – (a) Dr Trust (b) Gilma (c) BPL Smart Oxy used to measure SpO<sub>2</sub>. Photographs were taken when a person placed the finger in the oximeter probe without any cover

translucent white, translucent red, translucent yellow, translucent green, and transparent as shown in Figure 2. All the bags were of 52-60  $\mu\text{m}$  thickness (currently permitted thickness of single-usage plastic bag in India).<sup>[12]</sup>

## Measurement

The research participants were studied for anthropometric parameters and  $\text{SpO}_2$  with utmost care about their privacy and comfort. Measurements were carried out in the presence of a same-sex attendant. First, an expert clinician measured the anthropometric parameters (viz., height in cm to nearest 1 mm in portable stadiometer, weight in kg with a device with 100 gm sensitivity, and body fat percentage with bioelectric impedance-based body fat monitor (Omron HBF-701) maintaining precautions.<sup>[13]</sup> Then their systolic and diastolic blood pressure (by OMRON HEM-7120 automatic blood pressure monitor with  $\pm 3$  mm of Hg accuracy; OMRON Healthcare Manufacturing Vietnam Co., Binh Duong Province, Vietnam), resting pulse rate (manually by palpating radial pulse for one minute), and perfusion index (by OXYSAT Finger Tip Pulse Oximeter, Mitocon Biomed, Mumbai, India) was measured thrice and the average was recorded as the final reading.

They were allowed to rest for 5-min in a sitting posture. All measurements were done in a well-ventilated room. The room was illuminated with daylight passing through a translucent curtain. However, there was no direct beam of light at the site of measurement. The research participants sat on a chair and the arm was supported on a table at a lower level of the heart. Nail color, if any, was removed. The patients were instructed not to move their fingers and arm during the measurement.<sup>[14]</sup>

Two operators measured  $\text{SpO}_2$  on 10 research participants. The baseline reading was taken while measuring  $\text{SpO}_2$  without any cover on the finger or probe. The measurement sequence is



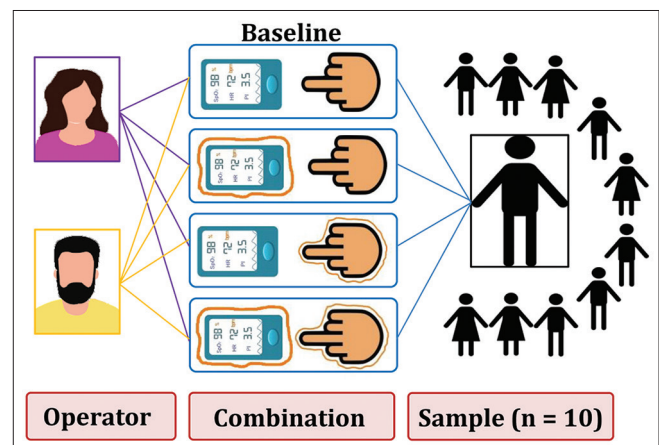
**Figure 2:** Sample of polyethylene plastic bags used to make finger or probe cover. From above downwards, in left column – black opaque, red translucent, green translucent; in right column – white translucent, yellow translucent, transparent. Small pieces of sample polythene bag were placed on a white paper with black bordered boxes with text

shown in Figure 3. The operators measured  $\text{SpO}_2$  sequentially with covered pulse oximeters but with a bare finger, pulse oximeter with a covered finger, and both the pulse oximeter and finger covered. After placing the probe on the middle finger, operators took three readings at 1 min, 1 min 30 sec, and 2 min. The final reading was the average of the three readings. The waiting period of one minute was allowed as pulse oximeters may take some time to show the actual reading after stable pulse wave tracing.<sup>[14]</sup> The rationality of taking three readings was the fluctuation of reading in some instances.

## Statistical analysis

Data were stored and analyzed in Microsoft Excel® 2010 (Microsoft Inc, USA) and GraphPad Prism 6.01 (GraphPad Software, CA, USA). Anthropometric and cardiovascular parameters between males and females were compared using the unpaired *t*-test. Baseline  $\text{SpO}_2$  and  $\text{SpO}_2$  measured with different combinations were compared using one-way analysis of variance (ANOVA) – with repeated measures.

Intra-class correlation coefficient (ICC) was used to find reliability between or among the measurements (single-measurement, absolute-agreement, 2-way mixed-effects).<sup>[15]</sup> For finding agreement among the  $\text{SpO}_2$  measured with different types of polyethylene cover (five types), we considered  $\text{SpO}_2$  values obtained from the first observer measuring with the first pulse oximeter. For finding agreement between the  $\text{SpO}_2$  values obtained from pulse oximeters (three types), we considered the first observer measuring  $\text{SpO}_2$  with the oximeters with red translucent probe cover. For finding inter-observer agreement,  $\text{SpO}_2$  values obtained from the first pulse oximeter with red translucent probe cover were considered. We fixed the following ICC to categorize reliability:  $\leq 0.5$  = poor; 0.51 to 0.75 = moderate; 0.76 to 0.9 = good;  $> 0.9$  = excellent.<sup>[16]</sup> Accepted accuracy was set at 2%. If any combination shows a deviation of  $> 2\%$  of baseline  $\text{SpO}_2$ , it would be considered erroneous. The Bland–Altman plot was used to find the difference between the two



**Figure 3:** Measurement of  $\text{SpO}_2$  by two operators with probe and finger cover combinations. Orange line around the pulse oximeters or fingers indicates polyethylene cover. Each of this measurement was repeated for three types of pulse oximeters

measurements (baseline and measurement of interest). For all tests, a  $P < 0.05$  was considered statistically significant.

## Results

A total of 10 research participants (5 male, 5 female) were measured for the SpO<sub>2</sub>. Their mean age was  $23.9 \pm 5.11$  years (male  $24.2 \pm 5.12$  years, female  $23.6 \pm 5.68$  years). Their anthropometric parameters and basic cardiovascular characteristics are shown in Table 1. BMI of males was higher; however, body fat showed no difference. Systolic and diastolic blood pressure of males was higher, but there was no difference in pulse rate or perfusion index.

Using black opaque polyethylene plastic bag as a finger or probe cover did not detect any signal and oximeters treated the settings as “Finger out.” Hence, we present the finding with five types of polyethylene bags in Table 2. There was no difference in SpO<sub>2</sub>

reading when a pulse oximeter probe is covered, or a finger is covered, or both are covered.

There was excellent reliability among the measured SpO<sub>2</sub> with different types of polyethylene covers (ICC = 0.948), among three types of oximeters (ICC = 0.937), and between observers (ICC = 0.956). All the combinations of probe and finger showed no more than 2% deviation from the baseline SpO<sub>2</sub>. A Bland–Altman plot for first operator and first pulse oximeter is shown in Figure 4 (Bias = 0.134, SD of Bias = 0.413, 95% limit of agreement = -0.675 – 0.943). All other plots are not presented due to similarity and space constraints.

## Discussion

### Major finding

To find a low-cost disposable cover for pulse oximeters or fingers, we found that commonly available disposable polyethylene covers

**Table 1: Anthropometric and basic cardiovascular characteristics of research participants**

Parameters	Overall (n=10)	Male (n=5)	Female (n=5)	t-test, P
Age (mean±SD)	23.9±5.11	24.2±5.12	23.6±5.68	0.87
Height (cm)	160.1±9.86	168.2±5.37	152±5.07	0.001*
Weight (kg)	62.09±14.61	75.42±5.48	48.76±2.52	<0.0001*
BMI (kg/m <sup>2</sup> )	23.92±3.44	26.70±2.26	21.14±1.49	0.002*
Body fat%	27.3±3.34	26±2.73	28.6±3.65	0.24
Pulse rate (bpm)	83.1±7.22	81.6±5.13	84.6±9.24	0.54
Perfusion index (%)	9.12±1.63	9.6±1.42	8.64±1.85	0.38
Systolic blood pressure (mm of Hg)	123.4±7.55	129.4±5.55	117.4±2.7	0.003*
Diastolic blood pressure (mm of Hg)	80.8±6.21	84.6±5.55	77±4.47	0.04*

\*Statistically significant P of unpaired t-test. n: number, SD: standard deviation, BMI: body mass index, bpm: beats per minute, Hg: Mercury

**Table 2: Measured SpO<sub>2</sub> of ten research participants by three oximeters with different combination of covered and uncovered oximeter and finger**

Measurement combination	Type of plastic	Mean±SD					
		Operator <sub>x</sub>			Operator <sub>y</sub>		
		Oximeter <sub>a</sub>	Oximeter <sub>b</sub>	Oximeter <sub>c</sub>	Oximeter <sub>a</sub>	Oximeter <sub>b</sub>	Oximeter <sub>c</sub>
Baseline		98.07±0.52	98.1±0.65	97.8±0.28	98±0.54	98.1±0.65	97.9±0.35
With probe cover	Red translucent	97.97±0.53	97.97±0.6	97.9±0.42	97.97±0.53	97.97±0.6	97.9±0.42
	Green translucent	98±0.59	97.97±0.46	97.93±0.56	98.07±0.62	97.93±0.31	97.97±0.55
	White translucent	97.93±0.44	97.97±0.46	97.77±0.45	98±0.38	97.9±0.39	97.8±0.45
	Yellow translucent	97.93±0.56	97.97±0.6	97.9±0.59	97.93±0.56	97.97±0.6	97.9±0.59
	Transparent	98.07±0.56	98±0.52	98.03±0.6	98.07±0.56	97.93±0.56	98.03±0.6
	ANOVA P	0.78	0.85	0.45	0.87	0.79	0.62
With finger cover	Red translucent	98±0.67	97.97±0.64	97.9±0.61	98.03±0.66	98±0.68	97.97±0.69
	Green translucent	97.83±0.63	97.83±0.59	97.73±0.64	97.9±0.65	97.87±0.59	97.8±0.59
	White translucent	98±0.7	98±0.59	97.97±0.67	98.03±0.69	97.93±0.62	97.97±0.67
	Yellow translucent	98.1±0.72	98±0.72	97.87±0.5	98.17±0.65	97.97±0.73	97.77±0.5
	Transparent	98.03±0.74	97.97±0.67	97.9±0.63	98.03±0.74	97.97±0.65	97.87±0.69
	ANOVA P	0.28	0.47	0.49	0.37	0.67	0.6
With probe and finger cover	Red translucent	97.8±0.45	97.97±0.37	97.83±0.32	97.83±0.48	98±0.35	97.83±0.28
	Green translucent	97.7±0.51	97.8±0.48	97.7±0.4	97.77±0.49	97.77±0.47	97.7±0.4
	White translucent	97.87±0.45	97.87±0.32	97.87±0.32	97.93±0.52	97.87±0.32	97.87±0.32
	Yellow translucent	97.87±0.36	98.03±0.39	97.83±0.36	97.93±0.44	98±0.35	97.87±0.36
	Transparent	97.93±0.6	98±0.52	97.93±0.6	97.97±0.64	98±0.35	97.93±0.6
	ANOVA P	0.09	0.32	0.48	0.37	0.29	0.43

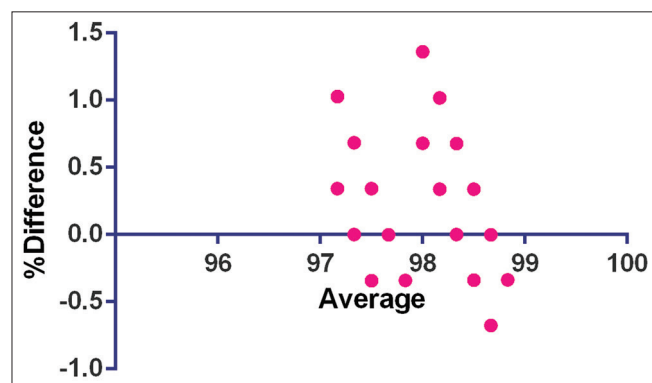
One-way Analysis of variance (ANOVA) with repeated measures was obtained with baseline SpO<sub>2</sub> reading and reading found with different types of cover. Two operators has been designated as x and y. Three oximeters has been designated as a, b, and c

either on the finger and/or on the pulse oximeters do not affect the SpO<sub>2</sub> reading. Our findings suggest that we can use the plastic cover either on the finger of the patient or on the oximeter probe; also, we can combine the two without compromising the accuracy of the oximeters in measuring the SpO<sub>2</sub> in otherwise healthy individuals. However, black opaque plastics should not be used as they would impede the path of the light signals from emitting diode to the sensors. Ackerman *et al.*<sup>[10]</sup> reported that using vinyl gloves does not affect the SpO<sub>2</sub> reading. Hence, it may also be tried. In comparison to vinyl gloves, commonly available plastic bags are cheaper and easily available. Its procurement during any pandemic would be easier.

### The rationality of the finding

Red (660 nm) and near-infrared (940 nm) light, emitted from one side of the pulse oximeter probe, can easily penetrate human tissues. While passing through the tissue of the fingers, red and infrared lights are absorbed by oxyhemoglobin and deoxyhemoglobin. Oxyhemoglobin absorbs a lower amount of red light (scatters more) and a higher amount of infrared light. In contrast, deoxyhemoglobin absorbs a higher amount of red light and a lower amount of infrared light. Another side of the probe contains a photodiode that receives the penetrated light. The sensors can differentiate between the pulsatile signal (from arterial blood) and static signal (from venous blood and tissues). The relative amount of absorbed red and infrared light is then used to calculate the SpO<sub>2</sub> with a programmed algorithm.<sup>[17]</sup>

We are placing plastic in this pathway of light. As the static signals are not discarded by the oximeters, the absorbance by the translucent plastic is also discarded. Hence, there is no interference to the measured SpO<sub>2</sub>. Some oximeter probes have a transparent plastic cover over the actual sensors (Dr Trust 210 and BPL Smart Oxy in our study) and some have exposed sensors (Gilma Pulse Oximeter in our study). This indicates that placing transparent plastic or lamination in the pathway of light does not hamper the reading.<sup>[11]</sup> We found that even translucent plastic does not affect the readings.



**Figure 4:** Bland-Altman plot between the baseline and change (in percentage) in SpO<sub>2</sub> with various combination of finger and/or probe cover. This plot is of first operator and first pulse oximeter (Bias = 0.134, SD of Bias = 0.413, 95% limit of agreement = -0.675 – 0.943)

### Reliability of measurement

We found excellent reliability (ICC > 0.9) among the readings from three oximeters, measurement by two operators, and among different plastic bags. Hence, an oxygen saturation measured by an operator by an oximeter (among the three) with any type of cover we described would have excellent agreement with others.

### Novelty and implication

Where more than one ill family members share one pulse oximeter, there may be chances of cross-infection. Although there is no literature suggesting that the probes of pulse oximeters used by family members contain pathogens, finding from the study in the intensive care unit may be extended for the assumption.<sup>[18]</sup> To prevent this, the best method is to use separate oximeters. However, in resource-limited settings or emergency when procurement of pulse oximeters become difficult like what we have seen in the COVID-19 pandemic, the disposable cover is the easy solution [Figure 5a, b]. Disposable cover with commonly available plastic bags further eases the usage either in families or in resource-limited healthcare facilities.

### Usage in primary healthcare

A pulse oximeter is an essential tool for early detection of decline in oxygen saturation.<sup>[19,20]</sup> Small clinics and private family physicians in-home visits may require monitoring SpO<sub>2</sub>. In clinics, multiple patients may visit and may require measurement of SpO<sub>2</sub>. Cleaning the probe after each use with 70% isopropanol may be time-consuming and require special attention. Furthermore, commercially available wipes used for cleaning the probe may be a problem due to the presence of sebum on the probe sourced from the patients' fingers.<sup>[21]</sup> Hence, the disposable probe or finger cover may be used in clinics to prevent cross-infection. Family physicians may also use the cover to avoid disinfecting the probe after a in-home visit.<sup>[22,23]</sup> This would save the time of the physician and potential damage to the oximeter sensors by accidental moisture-related damage by disinfectant.



**Figure 5:** Disposable polyethylene bag (red translucent) cover – (a) on finger and (b) on the pulse oximeter probe

## Limitation

This study has several limitations. We took an otherwise healthy sample for our study. Their SpO<sub>2</sub> is supposed to range from 94%-100%.<sup>[24]</sup> We did not test the covers in any patient with hypoxemia due to any disease or high altitude. However, as the oximeters work on the same optical principle in all levels of oxygen saturation, the effect of using covers would be the same in hypoxemic patients that we found in our study. Moreover, this may further be studied in the future. Various plastic bags that we used for this study may not be available in all corners of the country or world.<sup>[25]</sup> Concerning our study, authorities are suggested to carry out a quick pilot study in their area with available resources for error-free usage of the probe or finger cover.

## Conclusion

We used some commonly available polyethylene plastic bags to make finger cover or pulse oximeter probe cover. An opaque black plastic bag is not suitable for finger or probe cover as light cannot pass through it. Transparent and translucent covers, when used during measurement of SpO<sub>2</sub> on apparently healthy subjects, showed no difference in reading with the baseline reading of SpO<sub>2</sub>. Hence, available similar transparent or translucent similar polyethylene plastic bags may be used as finger or pulse oximeter cover. This disposable, cheap, and easily available disposable probe or finger cover may be used when one pulse oximeter is shared among ill family members or patients in resource-limited hospitals or isolation centers. This may potentially reduce the cross-infection.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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