Original Article

Assessing the SpO_2 in a random population – Looking for the best among fingers

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Abstract

Context: Pulse oximetry is one of the most revolutionary methods used to monitor the patients in the clinical setting, particularly intensive care and anesthesia. We usually use the index or middle finger to measure SpO_2 values, but little is known about the inter-digital differences that exist between the fingers. **Aim:** We aim to compare the peripheral capillary oxygen saturation among fingers of both hands. A total of 93 healthy volunteers aged between 18 and 50 years participated in the study. **Materials and Methods:** Their SpO_2 values were recorded from each finger with at least 1 minute of resting interval. Their blood pressure, heart rate, and body temperature were recorded as well. **Result:** A total of 930 measurements were obtained from 93 volunteers. The highest average SpO_2 value of right-handed volunteers was measured from the left little finger (98.48 ± 0.62) of right-handed volunteers, and it was statistically significant when compared with the right ring finger, right little finger, left thumb, left index, left middle finger, and left ring finger. The highest average SpO_2 from left-handed volunteers was obtained from the right index finger, but it was statistically insignificant. **Conclusion:** We assume ethnic and climatic differences to play a role in contradictory results noted from previous studies conducted, and this needs to be investigated further. It is recommended that multiple readings may be obtained from other fingers as well before coming to any conclusion as inter-finger variability cannot be ignored.

Keywords: Blood oxygen level, critical care, oximetry, oxygen saturation, SpO_2 measurement

Introduction

The pulse oximeter is a reliable and simple instrument that measures peripheral capillary oxygen saturation (SpO_2). It is routinely adopted in current medical scenarios to indicate approximately the level of oxygen in arterial blood. Since its invention, the use of the pulse oximeter has dramatically led to an increase in detection of hypoxemic episodes by almost 19-fold.[1] Apart from being a non-invasive, cheap, and convenient method to monitor oxygen saturations, it also provides an approximate value of heart rate and tissue perfusion. In 2007, the World Health Organization included pulse oximetry as an essential component of its surgical safety checklist for reducing complications.[2]

In this ongoing corona pandemic, where it is primarily the lungs that are getting affected, the usefulness of pulse oximetry cannot be over-emphasized. It is reported in the literature that direct correlations exist between oxygen saturation levels and lung pathology reflected in the morbidity and survival from influenza infection.[3]

Apart from the four vital signs—temperature, blood pressure, pulse rate, and respiratory rate, pulse oximetry has become the 'fifth' vital sign for patient monitoring. The invention and application of pulse oximetry led to a 40-fold reduction in death rates in anesthesia.[2]

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The precision of the pulse oximeter is affected because of use of acrylic nail paints, strong ambient light, low perfusion states as hypothermia, low cardiac output, anemia, carboxyhemoglobinemia, methmoglobinemia, and intravenous dyes can also give false SpO_2 readings.[4]

Earlier, the ear lobule was used for non-invasive monitoring of oxygen saturation, but it soon fell out of favor to use of fingers. Primary care physicians are the first point of contact for any patient in the community, and although the vital assessment of fallacious readings is recorded, it may lead to unnecessary referrals and patient anxiety. Also, especially in post-coronavirus (COVID) illness, when long-term follow-up and monitoring are carried out by primary care physicians, it will be useful to know the best finger for evaluation of SpO_2. However, less is known about inter-digital variability, if any, in the accuracy of detecting true oxygen saturation levels of the body. Thus, we aim to observe if there is a difference among various fingers for the measurement of SpO_2 values.

Methods

Healthy volunteers were recruited in out-patient settings comprising those who visited the hospital for not seeking any medical attention, but some other work, totaling 113.

A written consent was obtained from healthy volunteers aging between 18 and 50 years in July to August 2020. We excluded 20 participants on account of not fulfilling inclusion and exclusion criteria [Table 1] of the study, leaving a final sample size of 93 volunteers. The permission and ethical clearance were taken from the institutional ethical committee.

The volunteers were monitored after 5 minutes of rest at the same place and ambient light with a Nihon-Kohden pulse oximeter, model TL201-T, CE-certified. Simultaneous measurements of blood pressure, temperature, and pulse rate were recorded with the SpO_2 value as well. Finger-tip pulse oximetry SpO_2 readings change with limb temperature. The change in venous oxygen saturation can be explained by temperature-dependent arterio-venous shunts in the periphery.[5] Hence, the ambient temperature ranging between 25 and 27°C and relative humidity <20% were maintained in the room using an air conditioner to negate the effect of ambient temperature on resultant findings. The measurement for each finger was recorded with an interval of 1 minute. The abbreviations used are as in Table 2.

A total of 93 volunteers participated in the study, the demographic and hemodynamic data of which are demonstrated in Table 3.

Statistical Methods

Repeated Anova test was used to compare measurements. If there was a significant result, a post hoc Bonferroni test was used to evaluate all multiple comparisons ($p < 0.05$ was considered as statistically significant, CI 95%).

Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age, 20-50 years	Smoker
Voluntary participation after consent	Blood dyscracias
	DM/HTN/COPD
Having all ten intact digits in both upper limbs	On any chronic medication
	Pregnancy
Negative Allens' test	Peripheral vascular disease or trauma
No clinical anemia/ictreus	Use of nail paint/digital pigmentation

Table 2: Abbreviations for fingers

Right thumb	R1
Right index finger	R2
Right middle finger	R3
Right ring finger	R4
Right little finger	R5
Left thumb	L1
Left index finger	L2
Left middle finger	L3
Left ring finger	L4
Left little finger	L5

Results

A total of 930 comparisons were drawn from 93 healthy volunteers. Demographic and hemodynamic data recorded are displayed in Table 3. Out of 93 volunteers, 91 were right-hand-dominant, whereas two were left-handed, and separate comparisons were drawn for right- and left-hand dominances.

Forty-five comparisons were carried out between fingers each of the right and left hands separately. Among the right-handed volunteers, average SpO_2 readings were ranked as follows: L5>L4>R5>L3>R3>L2>R2>L1>R1>R4. Comparison of SpO_2 values among fingers is shown in Table 4.

Forty-five comparisons were performed among fingers (Repeated Anova, F: 2.371, $P = 0.012$, CD = 0.25). The highest average SpO_2 value was measured from L5 (98.48% ± 0.62), and it was statisticallysignificant when compared with R3, R5, L1, L2, L3, and L4.

Among the left-handed volunteers, average SpO_2 readings were ranked as follows: R2>R3=R4=R5=L1=L2=L3=L4>R1 = L5. Comparison of SpO_2 values among fingers is shown in Table 5. Forty-five comparisons were performed among fingers and were not found to be statistically significant (Repeated Anova, F: 0.457, $P = 0.873$).

Discussion

A revolution in the field of medical care was the development of the pulse oximeter invented by Dr. Takuo Aoyagi,[2] a Japanese

Table 3: Demographic data and hemodynamic values of volunteers	
Age (Years)	**35.32±13.69**
Gender (Male/Female)	66/27
Dominant hand (Right/Left)	91/2
Systolic Blood Pressure (mmHg)	115.9±9.8
Diastolic Blood Pressure (mmHg)	75.91±5.36
Body Temperature (fahrenheit)	98.6±0.2
Pulse	80±7.8

Table 4: Statistical data derived for right-handed volunteers

	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Mean	98.10	98.22	98.26	98.08	98.31	98.19	98.25	98.28	98.43	98.48
D	0.87	0.77	0.81	0.97	0.76	0.77	0.72	0.76	0.76	0.62
R1	1									
R2	0.46	1								
R3	0.29	0.26	1							
R4	0.16	0.15	0.22	1						
R5	0.20	0.34	0.27	0.47	1					
L1	0.10	0.16	0.16	0.48	0.38	1				
L2	0.22	0.32	0.29	0.27	0.21	0.30	1			
L3	0.25	0.31	0.17	0.20	0.21	0.24	0.44	1		
L4	0.24	0.27	0.34	0.05	0.28	0.19	0.21	0.28	1	
L5	0.22	0.22	0.26	0.22	0.36	0.29	0.26	0.31	0.28	1

Table 5: Statistical data derived for left-handed volunteers

	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Mean	98.00	99.00	98.50	98.50	98.50	98.50	98.50	98.50	98.50	98.00
SD	0.00	0.00	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.00
R1	1									
R2	0.16	1								
R3	0.32	-0.06	1							
R4	0.31	0.29	-0.05	1						
R5	0.43	0.23	0.40	0.21	1					
L1	0.07	0.52	-0.31	0.24	0.21	1				
L2	-0.23	0.07	-0.28	0.08	-0.56	0.08	1			
L3	0.17	0.16	-0.05	0.12	-0.13	0.02	0.34	1		
L4	-0.25	-0.10	0.03	0.05	0.21	0.18	-0.05	0.05	1	
L5	0.63	0.02	0.29	0.38	0.19	0.04	-0.04	0.04	0.10	1

bioengineer, whose pioneering work in 1974 led to the invention of the modern first commercially available pulse oximeter in 1981.

Factors known to adversely affect the accuracy of the pulse oximeter include transducer movement, peripheral vasoconstriction, a non-pulsating vascular bed, hypotension, anemia, changes in systemic vascular resistance, hypothermia, the presence of intra-vascular dyes, and nail polish.[6,7]

The pulse oximeter combined with the use of capnography provides a system for respiratory monitoring that is continuous and non-invasive and reflects the state of adequacy of ventilation (alveolar gas exchange) and oxygenation concurrently.[8]

In a study by Pierre Catoire *et al.* (2020), a total of 430 arterial samples were analyzed for SpO_2/FiO_2 ratio. They concluded that SpO_2/FiO_2 ratio can be utilized as a trustworthy tool for hypoxemia screening among patients presenting to the primary care physicians and emergencies, particularly during the COVID-19 pandemic.[8]

According to our results in 91 volunteers with right-handed dominance, L5 had the highest average SpO_2 value with pulse oximetry, whereas in two volunteers with left-hand dominance, R2 had the highest value. However, the finding in left-handed volunteers was not statistically significant.

Compared to previous studies conducted by Basaranoglu *et al.*,[2] 2015 and Mizukoshi *et al.*,[3] 2009, which concluded that the most accurate SpO_2 readings from are from the right middle finger and index finger, respectively, our study results are quite different. Higher perfusion in dominant hands accounted for their findings.

An interesting observation has been made by David Verhoeven *et al.*, where they have concluded that SpO_2 levels measured by pulse oximetry exhibited an inverse correlation with viral loads in the lung.[3] SpO_2 readings clearly and strikingly followed the level of pathology in the lungs and the immune response, demonstrating its utility for assessing the amount of lung inflammation without having the need for sacrificing animals during early infection time points. This can be employed in COVID patient monitoring non-invasively.[9]

In a study by Haimovich *et al.* (2020), a low quick COVID-19 Severity Index score based upon three variables, namely, respiratory rate, pulse oximetry, and oxygen flow rate, was found to be associated with a less than 5% risk of respiratory decompensation in the validation cohort. A significant number of COVID-19 patients deteriorate clinically within 24 hours of presentation. These patients can be accurately predicted with bedside respiratory examination findings with a simple scoring system based on pulse oximetry.[11]

Using a simple theoretical model based upon the Beer–Lambert law, the effect of shifts in wavelength on pulse oximeter accuracy was examined in relation to temperature and found to be negligible over the temperature range studied by Reynolds K J *et al.*[12] However, the same has to be interpreted in light of perfusion variations induced by temperature, especially in sub 20°C environments commonly maintained in intensive care units as it has been observed by W M Schramm *et al.*[13] that finger-tip pulse oximetry SpO_2 readings change with limb temperature. The change in venous oxygen saturation can be explained by temperature-dependent arteriovenous shunts in the periphery. The observed change in SpO_2 probably reflects altered transmission of arterial pulsations to venous blood in the finger.

The potential arrangement of blood supply in hands can never be fully realized because any given hand shows imperfections in its arterial distribution. The palmar arteries in pair are the primary supply to the fingers and are the larger and most consistent to the thumb. The pair is connected by multiple anastomoses in each finger. Like other anastomotic systems, the pair is often unbalanced in size.[14] This irregularity nevertheless follows a definite pattern in the thumb, index, and fifth fingers in the form of predominant arteries lying medially. These arterial supply variations can lead to varied perfusions in digits, thus affecting SpO_2 measurements. The fifth finger often receives a significant supplementary supply on its ulnar side from a dorsal branch of ulnar arising from the proximal wrist.[15] This explains the variation in our study from the work of Basaranoglu *et al.* and Mizukoshi *et al.*[10,11]

Our finding of the highest average SpO_2 value in left little finger needs to be investigated further, especially taking into account ethnic differences, climatic variations, and other factors.

The main limitations of our study are the limited number of subjects both right-handed and particularly left-handed to fully appreciate the reliability of our results.

Conclusions

It can be concluded with confidence that pulse oximetry provides a very reliable method of assessing a patient in a primary care setting along with other vital parameters. In cases where the readings are sub-optimal, it is recommended that multiple readings may be obtained from other fingers as well before coming to any conclusion as inter-finger variability cannot be ignored.

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Conflicts of interest

There are no conflicts of interest.

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