ORIGINAL ARTICLE

Comparison of SpO_2 on different fingers of hands and effect of local temperature on SpO_2 by pulse oximeter in healthy adults

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Abstract

Background: Pulse oximeter is a simple, cost effective and routinely used instrument to measure the peripheral oxygen saturation (SpO_2). *Aim and Objectives*: To compare SpO_2 values among all the fingers of both hands and also the effect of local change in temperature on SpO_2 values. *Material and Methods:* Study was done on 40 healthy volunteers between the ages of 18 to 45 years. SpO_2 was measured using same pulse oximeter from every finger of both hands after waiting for 1 minute and also after immersing the hands in 15°C and 45°C water bath for 5 minutes. A gap of 15 minutes was kept between cold and hot water bath immersion to bring back normal temperature. *Results:* There were significant differences ($p < 0.05$) in SpO_2 values between middle finger and thumb and between ring finger and thumb in right hand, and between left middle finger and right thumb, between left little finger and right thumb and between right ring finger and left thumb. SpO_2 values showed a significant decrease ($p < 0.05$) between normal temperature and cold in right index and middle fingers and left index, middle and little fingers and between normal temperature and hot in right index, middle, ring fingers and left middle finger. *Conclusion:* It can be hypothesized that difference in perfusion due to supply by different arteries may be one of the contributing factors for this variation in values between fingers. Vasoconstriction may be the reason for significant decrease in SpO_2 when hand is immersed in cold water. Increased arterio- venous shunt resulting in increased pulsatile venous flow might have resulted in decrease in SpO_2 on exposure to heat.

Keywords: Peripheral oxygen saturation, pulse oximeter, SpO_2, local temperature

Introduction

The amount of oxygen in arterial blood is indicated by the peripheral capillary oxygen saturation or saturation of peripheral oxygen (SpO_2). An economical and non-invasive method to measure SpO_2 is pulse oximetry. Pulse oximeter works on the basis of the principle that light absorption properties of Oxyhaemoglobin (O_2Hb) and Deoxyhaemoglobin (HHb) are different. O_2Hb absorbs more of red and less of near infra-red light than HHb. Oxygen content in the artery has been detected by pulse oximeter alone because during systole and diastole arterial blood volume varies which changes the light absorption property. As the blood volume of capillaries and veins as well as the skin, bone, fat etc remains constant it would not produce any deflection in pulse oximeter. An adequate pulse is

essential to correctly measure SpO_2 using pulse oximeter [1].

Pulse oximeter provides early warning of hypoxaemia. Especially during perioperative and intraoperative periods pulse oximeter is being used to detect hypoxaemia [2-5]. During the peak of covid era also pulse oximeter was the most used tool to monitor the respiratory condition of patients. This also helps in titrating Fractional Inspired Oxygen Concentration (FIO_2) in patients on mechanical ventilation [6-7]. An assessment score for sequential organ failure can be computed utilizing the SpO_2 to FIO_2 ratio (S/F ratio) to measure severity of organ dysfunction [8].

Pulse oximeter comes with few limitations also. Inconsistent wave tracing in pulse oximeter monitor in ICU shows that SpO_2 reading is unreliable. Similarly, portable pulse oximeter can have suboptimal readings. Low amplitude in pulse oximeter tracing can be due to poor finger perfusion from vasoconstriction, hypovolemia, poor cardiac output, arterial compression etc. It can result in intermittent drop outs and unstable SpO_2 readings. Carbon monoxide poisoning and sickle cell anaemia can result in falsely normal or elevated SpO_2. Venous pulsations, excessive movement, intravenous pigmented dyes, inherited forms of abnormal haemoglobin, fingernail polish and severe anaemia can cause false low SpO_2. Some of the causes like sulfhemoglobinemia, methemoglobinemia, poor probe positioning and sepsis or septic shock can lead to false low or high SpO_2. A completely normal SpO_2 even in optimal environment does not exclude ventilation or gas exchange problems because pulse oximeter cannot measure partial pressure of carbon dioxide (pCO_2) and alveolar- arterial oxygen difference [1].

Study by Basaranoglu *et al*. presented that significant differences exist in the SpO_2 values on different fingers of hands. The study was carried out on 37 volunteers who were found to have higher SpO_2 values in middle finger and thumb of right hand [9]. Mizukoshi *et al*. state that 80% of health professionals selected index finger for attachment of pulse oximeter as their first option. The investigation, that involved 20 volunteers, also found that perfusion index was highest in the middle finger but there was no significant difference in SpO_2 between each finger [10]. In another study conducted among 518 patients with various illnesses, there had been a significant difference in measurement of SpO_2 from different fingers [11]. Skin pigmentation and finger choices had no significant impact on oxygen saturation measurement in healthy volunteers [12]. A pulse oximeter measures the oxygen saturation of blood at a temperature in between core and peripheral temperatures. If the patient is very cold as in ICU patients where the temperature is maintained at 20 ± 2°C, the pulse oximeter may show decreased SpO_2 value [13-14]. But a study by Schramm *et al*. showed that local hyperthermia decreased SpO_2 and local hypothermia increased SpO_2 [15].

Clayton *et al*. showed that changes in body temperature will not substantially alter the SpO_2 value [16]. As the outcomes from several investigations are inconclusive, we aimed to understand the difference in SpO_2 values in all fingers of both hands and effect of local temperature on SpO_2.

Material and Methods

Sample size for the study was calculated using G-power for dependent t test [16]. For two-tailed test with medium effect size (0.5) and alpha 0.05, and

power 0.8, the sample size was estimated as 34. After approval from Institutional Ethics Committee (No. IEC/14/45/21), the investigation was conducted on 40 healthy volunteers between the ages of 18 to 45 years. Written informed consent was obtained from all the participants. As chances of arteriosclerosis increase after 45 years of age, individuals above 45 years were excluded from the investigation. Volunteers who were pregnant or else menstruating on the day of recording, smokers, those with hypotension or hypertension, bradycardia, anaemia, those who had radial or else ulnar arterial failure in Allen test, those who had applied nail polish on finger nails or undergoing treatment for any conditions were also excluded from the study. A proforma including the medical history of volunteer was filled up initially. After taking a rest for 5 minutes, each participant's SpO_2 was assessed utilizing a pulse oximeter (CONTEC CMS50D). Every SpO_2 measurement was conducted while participants were in seating position. Their pulse rate and Blood Pressure (BP) were also measured. SpO_2 measurements were done from all fingers of both hands at normal temperature (30°C).

Measurements of each finger were recorded after 1 minute of waiting. A 15°C and a 45°C waterbath were prepared to immerse the hands for 5 minutes. SpO_2 recording was done rapidly after withdrawing the hands from waterbath and drying. A gap of 15 minutes was given between hot and cold-water immersion to bring back the normal temperature.

Statistical analysis

Statistical Package for the Social Sciences version 26 was employed to analyze the data. Descriptive statistical methods, frequency percentage, and mean ± standard deviation were used to present the data. Mean difference was estimated using independent *t*-test and Analysis of Variance (ANOVA). The value of $p < 0.05$ was regarded as statistically significant.

Results

Table 1 displays the demographic data of 23 females and 17 males included in this study. Mean age of the subjects was 22.3 ± 1.04 years. SpO_2 values obtained from all the fingers of both hands were compared (Tables 2 and 3).

Mean pulse rate, systolic BP and diastolic BP were 90 ± 9.83 beats/min, 116.55 ± 7 mm Hg and 77.2 ± 6.8 mm Hg, respectively. Highest SpO_2 value was obtained from right ring finger (98.775 ± 0.58) and lowest from left thumb (98.2 ± 0.88). There was significant difference in the SpO_2 values obtained

Table 1: Demographic data of volunteers

Gender	
Female	23 (57.5)
Male	17 (42.5)
Age (in years)	22.3 ± 1.043
Dominance	
Left	4 (10)
Right	36 (90)
PR (beats/min)	90 ± 9.834
SBP (mmHg)	116.55 ± 7.002
DBP (mmHg)	77.2 ± 6.58

**Frequency (%) and Mean ± SD Age in years, PR- Pulse Rate in beats/min, SBP- Systolic Blood Pressure in mmHg, DBP- Diastolic Blood Pressure in mmHg.*
Handness was assessed by asking the hand they prefer for unmanual task.

from different fingers of right hand (p = 0.026). Similarly, a significant difference was present in the SpO_2 values obtained from all fingers on left side (p = 0.024).

There were significant differences (p < 0.05) in SpO_2 values between right middle finger and right thumb (p = 0.037), between right ring finger and right thumb (p = 0.006), between left middle finger and right thumb (p = 0.011), between left little finger and right thumb (p = 0.018) and between right ring finger and left thumb (p = 0.023). No significant difference was found in SpO_2 between right hand and left hand (p = 0.785). SpO_2 levels did not significantly differ by blood group, age, or gender. Differences in SpO_2 values before and after cold water and hot water immersion were tested using ANOVA (Table 4).

Comparison of SpO_2 values between normal temperature and cold exhibited a significant difference in right index (p = 0.049), right middle (p = 0.003), left index (p = 0.031), left middle (p = 0.028) and left little fingers (p =0.012). SpO_2 values between normal temperature and hot also showed significant differences in right index (p =0.003), right middle (p = 0.001), right ring (p = 0.001) and left middle fingers (p = 0.002). Details of demography and experimental values are provided as supplementary data.

Table 2: Comparison of SpO_2 values obtained from all fingers of right hand and left hand

	Mean ± SD	RT	RI	RM	RR	RL	*p*
RT	98.201 ± 1.017	-					
RI	98.650 ± 0.622	0.056					
RM	98.675 ± 0.615	0.037*	0.998				0.026*
RR	98.775 ± 0.576	0.006*	0.943	0.947			
RL	98.525 ± 0.784	0.29	0.943	0.895	0.556	-	
	Mean ± SD	**LT**	**LI**	**LM**	**LR**	**LL**	***p***
LT	98.200 ± 0.882	-					
LI	98.601 ± 0.632	0.071					
LM	98.700 ± 0.607	0.011*	0.966				0.024*
LR	98.551 ± 0.677	0.152	0.998	0.863			
LL	98.675 ± 0.572	0.018*	0.988	0.998	0.925	-	

**Significant at p value < 0.05(RT- right thumb, RI- right index finger, RM- right middle finger, RR- right ring finger, RL- right little finger, LT- left thumb, LI- left index finger, LM- left middle finger, LR- left ring finger, LL- left little finger). Anova post hoc bonferroni was used to analyse the significance of difference.*

Table 3: Comparison of SpO_2 values between right and left hands

	LT	LI	LM	LR	LL	*p*
RT	0.998	0.272	0.36	0.272	0.11	0.785
RI	0.196	0.998	0.998	0.999	0.999	
RM	0.998	0.999	0.999	0.998	0.999	
RR	0.023*	0.985	0.99	0.985	0.998	
RL	0.999	0.999	0.999	0.999	0.997	

**Significant at p value < 0.05RT- right thumb, RI- right index finger, RM- right middle finger, RR- right ring finger, RL- right little finger, LT- left thumb, LI- left index finger, LM- left middle finger, LR- left ring finger, LL- left little finger. Anova post hoc bonferroni was used to analyse the significance of difference.*

Table 4: Comparison of SpO_2 values of each finger between normal temperature, cold and hot

		Cold	Normal	Hot
RT	**Mean ± SD**	98.23 ± 0.891	98.20 ± 1.018	98.18 ± 0.931
	p	0.894	0.875	
RI	**Mean ± SD**	98.28 ± 1.062	98.65 ± .622	97.98 ± 1.21
	p	0.049*	0.003*	
RM	**Mean ± SD**	98.30 ± 0.823	98.68 ± 0.616	98.10 ± 0.900
	p	0.003*	0.001*	
RR	**Mean ± SD**	98.50 ± 0.784	98.78 ± 0.577	97.98 ± 1.074
	p	0.078	0.001*	
RL	**Mean ± SD**	98.35 ± 0.864	98.53 ± 0.784	98.28 ± 1.012
	p	0.280	0.117	
LT	**Mean ± SD**	98.25 ± 0.954	98.20 ± 0.883	98.03 ± 0.974
	p	0.756	0.360	
LI	**Mean ± SD**	98.28 ± 0.905	98.60 ± 0.632	98.18 ± 1.279
	p	0.031*	0.061	
LM	**Mean ± SD**	98.23 ± 1.121	98.70 ± 0.608	98.33 ± 0.764
	p	0.028*	0.002*	
LR	**Mean ± SD**	98.33 ± 1.228	98.55 ± 0.677	98.40 ± 0.778
	p	0.305	0.279	
LL	**Mean ± SD**	98.13 ± 1.137	98.68 ± 0.572	98.48 ± 1.012
	p	0.012*	0.253	

**Significant at p value < 0.05RT- right thumb, RI- right index finger, RM- right middle finger, RR- right ring finger, RL- right little finger, LT- left thumb, LI- left index finger, LM- left middle finger, LR- left ring finger, LL- left little finger. Dependent t test was used to analyse the significance of difference.*

Discussion

In arterial blood, the normal range for oxygen saturation is 97% to 99%. Pulse oximetry is a non-invasive and economical tool to measure SpO_2 which is being used frequently for continuous and intermittent monitoring. Pulse oximeter reading is considered reliable between 70% to 100 % SpO_2. It consists of a probe and a microprocessor unit. Fingers are the first choice of site for measurement of SpO_2 using pulse oximeter [17]. There are no specific guidelines saying which finger of which hand should be used to place the probe of pulse oximeter. Most care givers use either right index or middle fingers for SpO_2 measurement using pulse oximeter [18].

Our investigation revealed that some of the fingers on the right and left hands had significantly different SpO_2 levels. Earlier studies have revealed that significant differences can occur in the perfusion index of various fingers. Thumb and index fingers receive perfusion from Radial Artery (RA), ring and little finger from Ulnar Artery (UA) and middle finger from both ulnar and radial. This can result in differences in perfusion in various fingers. The SpO_2 value may be impacted by changes in the pulse oximeter tracing caused by variations in perfusion. This can be presumptively the cause for the significant difference in the SpO_2 values from different fingers. According to our study, highest SpO_2 was recorded from right ring finger followed by left middle finger and lowest was recorded from both the thumbs. While the RA is more superficial and non-dominant, the UA is larger and is the major artery of the human forearm [19]. As most of the volunteers had right hand dominance and UA is the dominant artery of forearm, right ring finger will receive maximum perfusion causing highest SpO_2 value. Middle finger is receiving double perfusion from radial and ulnar artery causing second highest SpO_2 value. Since only 4 volunteers had left dominance, we couldn't identify the difference in SpO_2 values between right-hand and left-hand dominant subjects.

In our study, when hand was immersed in cold water, significant decrease in SpO_2 was found in right index, right middle, left index, left middle and left little fingers. According to Raltson *et al.,* if body temperature is not 37°C, accuracy of pulse oximeter is affected as the absorption spectra of haemoglobin are shifted [20]. When immersed in cold water, vasoconstriction occurs resulting in decreased perfusion which also contributes to the decrease in SpO_2 values.

Similarly, when hand is immersed in hot water, we expected an increase in SpO_2 value due to vasodilation. But in our study, we found that when temperature of hand was increased SpO_2 significantly decreased in index, middle and ring fingers of right hand, and middle finger of left hand. According to Broom *et al*., when there is vasodilation in hyperaemic period, SpO_2 significantly decreases [21]. Pulse oximeter measures arterial oxygen saturation and excludes non pulsatile flow in veins and capillaries. But when there is vasodilation, arterio-venous shunt increases and blood flow through capillaries and veins also increases resulting in pulsatile flow which will also be detected in pulse oximeter. When the hands are locally warmed there can be further opening of arterio-venous shunt which decreases SpO_2 [15]. Hence the decrease in SpO_2 due to local warming of hand is most likely caused by change in the venous pulsatile signal due to increased arterio-venous shunt.

Our study suggests that a proper guideline should be there as to which finger and which hand (dominant or non-dominant) should be used to measure SpO_2 using pulse oximeter as significant differences are seen in the SpO_2 values measured from different fingers. During anaesthesia and post anaesthetic period, peripheral temperature of patients will decrease which can result in false decrease in SpO_2 level. Similarly, hyperthermia as in fever can cause a false decrease in SpO_2 level which will be interpreted as actual fall in oxygen saturation resulting in unnecessary treatment. In some clinical conditions like sepsis, vasodilation because of reduced systemic vascular resistance may falsely decrease the SpO_2 value. Health care providers must be informed of the potential inaccuracies that may arise while measuring SpO_2 using a pulse oximeter. They should know that pulse oximeter might not be giving a true reflection of oxygen saturation and always has to be correlated clinically.

Conclusion

SpO_2 measurement using pulse oximeter showed a significant difference between some of the fingers, with maximum SpO_2 in right ring finger and minimum in left thumb. As the measurement of SpO_2 by pulse oximeter depends on pulsatile flow, difference in perfusion in the fingers may be the reason for the same. Alteration in peripheral limb temperature can cause changes in SpO_2 values falsely. In our study, both increase and decrease in the peripheral temperature significantly decreased SpO_2 in some of the fingers. Health professionals should appreciate the limitations of pulse oximeter as many factors can give spurious SpO_2 values. Understanding other components that can influence SpO_2 and correlation of SpO_2 values with handedness are future research plans for this study.

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