

FACTORS INFLUENCING PULSE OXIMETRY AS COMPARED TO FUNCTIONAL ARTERIAL SATURATION IN MULTI-ETHNIC SINGAPORE

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ABSTRACT

Noninvasive oximetry provides continuous monitoring of arterial oxygen saturation and hence, early detection of hypoxia. This has proved to be a useful adjunct to patients' safety, and is considered indispensable in certain settings. However, errors may be present in the pulse oximeter estimation (SpO_2) of arterial oxygen saturation (SaO_2), which may be due to various parameters. We have studied a multi-ethnic population where the skin pigmentation is different, and also under different conditions comparing SpO_2 with SaO_2 . Our results showed that SpO_2 estimation of SaO_2 amongst the three racial groups (Chinese, Malays, and Indians) varied significantly (ANOVA, $p < 0.05$). The over-estimation was more pronounced by hypoxic conditions and jaundice. Haemoglobin and systolic blood pressure did not affect the difference between SpO_2 and SaO_2 .

Keywords: pulse oximetry, skin pigmentation, hypoxia.

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INTRODUCTION

Noninvasive oximetry is a standard piece of monitoring equipment in the intensive care setting and in operating theatres for the assessment of oxygen saturation. It provides continuous monitoring of oxygen saturation and is clinically useful for alerting the user to the presence of hypoxia. The pulse oximeter has proved useful in wide applications including detection of airway obstruction, detection of sleep apnoea, exercise testing of pulmonary patients, for mechanically ventilated patients, detection of hypoxia during instrumentations like bronchoscopy, and monitoring in oxygen therapy.

Errors in pulse oximeter estimation of arterial oxygen saturation may be due to several factors, either technical or physiological. There have been recent studies demonstrating the importance of skin pigmentation on the accuracy of pulse oximetry⁽¹⁻³⁾, although an earlier study did not show any effect from skin pigmentation⁽⁴⁾. Hypoxic conditions may also contribute to the error⁽¹⁻³⁾. We therefore studied the factors that may affect the reliability of pulse oximeter measurements prospectively in our multi-ethnic population.

METHODS

Thirty-three patients admitted to the medical intensive care unit in the National University Hospital, Singapore were studied. Three different brands of pulse oximeter were employed: Nellcor, Simed, and Critikon.

When arterial blood was drawn for blood gas determination, the following factors were noted: pulse oximetry oxygen

saturation (SpO_2), systolic blood pressure, haemoglobin concentration, bilirubin levels, temperature, and race. The arterial oxygen saturation (SaO_2) was measured on the Nova Stat Profile 3 pH/blood gas analyser. This represents functional oxygen saturation and not fractional oxygen saturation as would be given with a co-oximeter.

STATISTICS

Results are expressed with mean \pm standard deviation. Differences within groups were compared by analysis of variance (ANOVA), and differences between any two groups were compared by Wilcoxon-signed rank.

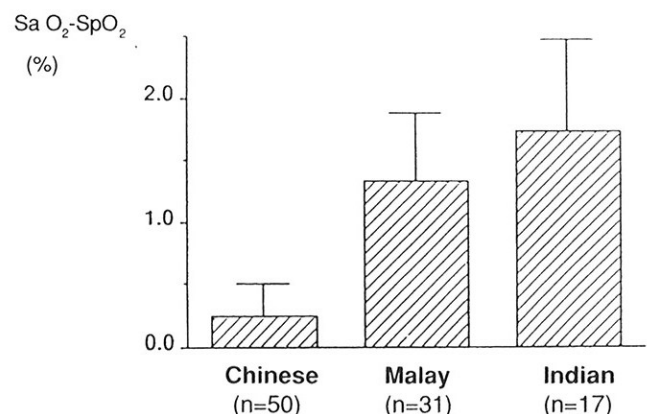
RESULTS

There were 22 Chinese patients, 6 Malay patients, and 5 Indian patients. The patients' ages ranged from 27 to 92 years (mean, 56.4 years).

One hundred and fifty readings were taken in the 33 patients. SaO_2 was significantly correlated with SpO_2 ($r = 0.785$, $p < 0.01$). Overall, there was a tendency for SpO_2 to be greater than SaO_2 (mean SpO_2 - SaO_2 difference, $0.82\% \pm 2.6\%$; range, -4.9% to 10.5%). The three different pulse oximeters gave similar readings when tried on the same patients.

The effect of ethnic origins were evaluated in the non-jaundiced patients. This demonstrated a significant difference between the groups (ANOVA, $p < 0.05$) with the Indian group having the greatest difference between SpO_2 and SaO_2 (Fig 1).

Fig 1 - Effect of ethnicity on SpO_2 - SaO_2 difference.
There is a significant different between the groups (ANOVA, $p < 0.05$).



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Fig 2 - The SpO_2 - SaO_2 difference increases with increasing hypoxia (ANOVA, $p=0.0001$).

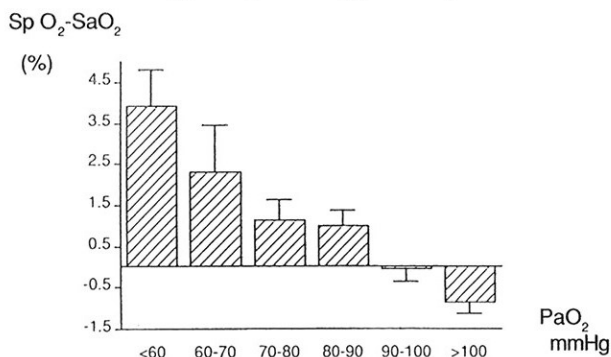
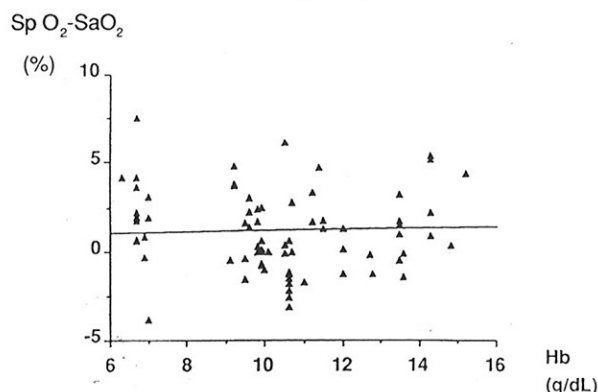


Fig 3 - There is no correlation between haemoglobin (Hb) levels and SpO_2 - SaO_2 difference.



Overall, SpO_2 - SaO_2 differences were significantly more with increasingly hypoxic conditions (Fig 2). This still held true for the Chinese and the Malay groups of patients when analysed separately (ANOVA, $p<0.05$ and $p=0.0001$ respectively).

Patients with elevated bilirubin levels ($>17\mu\text{mol/L}$) had larger SpO_2 - SaO_2 differences (Wilcoxon signed-rank, $p<0.001$) compared to non-jaundiced patients (1.2% versus 0.85% respectively).

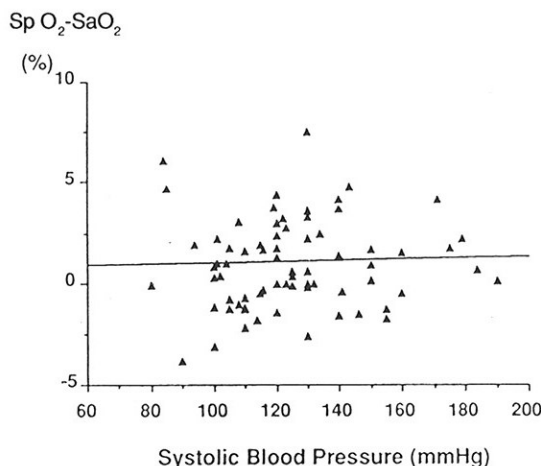
The haemoglobin concentration was available in 77 readings, with a mean concentration of 10.4 ± 2.4 g/dL (range, 6.3 to 15.2). There was no correlation between the haemoglobin concentration and SpO_2 - SaO_2 (Fig 3). The systolic blood pressure was recorded in 73 readings, with a mean value of 125 ± 25 mmHg (range, 80 to 190). The value of systolic blood pressure did not correlate with SpO_2 - SaO_2 differences (Fig 4).

DISCUSSION

Noninvasive oximetry is probably one of the most significant recent development in patient monitoring. Its usage has been widely applied since its original application in aviation research to assess the oxygenation of pilots during high altitude flying. Oximetry provides a noninvasive method of continuous monitoring of oxygen saturation of arterial haemoglobin, and facilitates the detection of hypoxaemia before clinical signs are apparent. Pulse oximeters are portable, easy to use, require no calibration, and can be operational very quickly which is useful in an emergency situation. In some situations it may be even preferable or even more accurate than arterial blood gas estimation because of the associated anxiety that may accompany arterial puncture especially in children.

Noninvasive oximetry has progressed from the rather cumbersome original ear oximetry which needed a bloodless and

Fig 4 - There is no correlation between systolic blood pressure and SpO_2 - SaO_2 difference.



compressed ear as a zero reference point to the current machines which have convenient probes that can be attached to the patient's finger, toe or ear for an extended period of time with good tolerance. The current day oximeters are pulse oximeters which is based on differential absorption of red and infra-red light by oxyhaemoglobin and reduced haemoglobin. The pulsatile tissue component is assumed to consist solely of arterial and arteriolar blood, and the signals are then processed to give a value for oxygen saturation. In situations where carboxyhaemoglobin or methaemoglobin are present, the oxygen saturations readings are erroneous. Carboxyhaemoglobin is recognised as oxyhaemoglobin, while methaemoglobin in high concentrations has a large absorbance which will cause the reading to be 85% regardless of the patient's oxygen saturation. Other possible sources of errors are the effects of ambient light interference, optical shunting, motion artifact, and low perfusion.

We investigated the effect of skin pigmentation on the accuracy of pulse oximetry, along with the effects of hypoxia, jaundice, systolic blood pressure, and haemoglobin levels. Our results demonstrated a difference amongst the three different ethnic groups (Chinese, Malays, Indians) when the patients were not jaundiced. The difference between SpO_2 and SaO_2 appeared to increase with darker skin pigmentation. Wang and Poh (1985) however, found no significant difference in their study of 31 patients in Singapore consisting of 22 Chinese, 6 Malays, and 3 Indians⁽⁴⁾. They, however, used a combination of methods (spectrophotometrically and calculated) to assess SaO_2 and combined the two groups together. This may explain the reason for their different conclusion. In the American blacks on the other hand, SpO_2 has been demonstrated to be different from SaO_2 especially in hypoxic conditions⁽¹⁻³⁾. We found that jaundiced patients had greater differences in their saturations which would support the hypothesis that skin colouring affects oximetry readings.

The partial pressure of oxygen in the blood significantly affected the difference between SpO_2 and SaO_2 . The difference appears to be more apparent in hypoxic conditions, which is consistent with the findings of other groups⁽¹⁻³⁾. This findings was still valid for the Chinese and Malay groups when the groups were analysed separately. The reason for the Indian group showing no statistical difference as a result of hypoxia is probably related to the small sample size ($n=17$). Therefore, in hypoxic conditions, the pulse oximeter should only be used to follow the trend of oxygen saturation and is unreliable in predicting the actual partial pressure of oxygen.

Systolic blood pressure and haemoglobin levels did not cause any significant difference between SpO_2 and SaO_2 . However, in low perfusion conditions where there is an expected difference, the pulse oximeter probably indicated a low signal intensity and this reading was disregarded, or there was no reading at all. In this way, the effect of hypotension was probably negated. This is also reflected in the main systolic blood pressure being 125 mmHg with a range of 80 to 190 mmHg indicating that most of the readings were done during periods of normotension. Severe anaemia (4.7 g/dL and 3.0 g/dL) has been cited in a case report⁽⁶⁾ to cause errors in estimation but this is substantially lower than our haemoglobin values.

Discrepancies may arise between SaO_2 compared with SpO_2 . This commonly arises because functional SaO_2 has not been appropriately corrected for factors that shift the oxyhaemoglobin dissociation curve. Functional SaO_2 is a derived value from the measured partial pressure of oxygen, and is calculated from the oxyhaemoglobin dissociation curve. Therefore, any conclusions derived from this study is restricted to comparisons between functional SaO_2 and SpO_2 . The other reason for discrepancy could be attributed to the fact that SpO_2 has been calibrated with different groups of normal individuals and skin pigmentation has not been taken into ac-

count for this calibration. Ideally, one should have different calibrations depending on the skin pigmentation. The other possible reason for the discrepancy may be technical which would be difficult to distinguish in our study.

In conclusion, pulse oximetry is generally reliable as an estimate of SaO_2 . However, in hypoxic conditions, jaundiced patients and heavily pigmented patients, one has to be aware of the possibility that there may be differences in SpO_2 when compared to SaO_2 . Systolic blood and haemoglobin levels were not important in affecting this difference.

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Determination of hCG in urine for early pregnancy detection



SENSITIVITY: ≥ 25 mIU/ml hCG

SPECIFICITY: No cross reactivity with:

- 300 mIU/ml luteinizing hormone (hLH)
- 1000 mIU/ml follicle stimulating hormone (hFSH)
- 1000 mIU/ml thyroid stimulating hormone (hTSH)

ASSAY TIME: Five (5) minutes

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