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TITLE: DOES SKIN PIGMENTATION AFFECT THE ACCURACY OF PULSE OXIMETRY? AN IN VITRO STUDY

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Introduction Pulse oximetry combines the principles of optical plethysmography and spectrophotometry to estimate arterial oxygen saturation. The effects of venous blood, bone and soft tissue are theoretically eliminated by using only the pulsatile components of specific red and infrared wavelengths absorbed by the transilluminated tissue. Since contribution of all non pulsatile absorbers are cancelled mathematically, variables such as skin pigmentation should not affect the measurement.
In order to test this basic assumption we have performed experiments on a finger model, using blue filters to simulate the absorption characteristics of dark skin pigmentation.
Methods A model finger or manual pulse Simulator (MPS) was assembled as previously described.[1] Blood was obtained from one of the authors, and the samples of different saturations were prepared by tonometry.[2] The filter used was a 1 x 5cm strip of blue plastic film (Letraset Project-a-Film, PAF 9), which was previously found to approximate the red absorption characteristics of moderately dark skin.[3] The oxygen saturation (SpO_2) of each sample was estimated three different ways using a Nellcor (N 200) pulse oximeter. For the first estimation the MPS only was used; for the second, the MPS and one filter, and for the third, the MPS and two filters were used.A portion of the blood in the tube was then removed anaerobically, and its oxygen saturation measured with a Hemoximeter. The SpO_2 readings obtained with one or two filters were compared to the SpO_2 values obtained without filter (reference values) using linear correlation analysis. The % error (or % difference) resulting from using one or two filters was calculated from differences between the lines thus obtained and the reference line (a line passing through the points of each reference value plotted against itself).
Results When two filters were used, SpO_2 estimations could not be obtained below 45%. The slopes of the lines obtained with one or two filters were significantly different from each other and that of the reference line (Fig1). The results indicate that the presence of the blue filter, simulating dark skin pigmentation causes the pulse oximeter to overestimate the oxygen saturation of the blood (Fig 2). The magnitude of the overestimation seems to depend both on the number of filters (simulating the darkness of the skin) and on the degree of desaturation of the blood.
Discussion According to widely accepted theory, skin pigmentation has no effect on the accuracy of pulse oximetry.[4] The results of this experiment indicate, however, that skin pigmentation may affect the accuracy of pulse oximetry significantly, especially at low saturations.These results, if corraborated in vivo, may have important clinical implications.

References

1.Can J Anaesth 1990;37(4):S67
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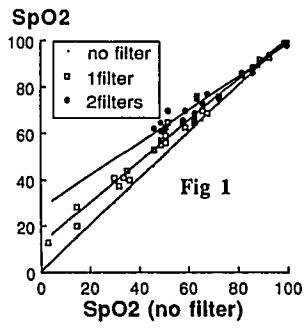

Fig 1

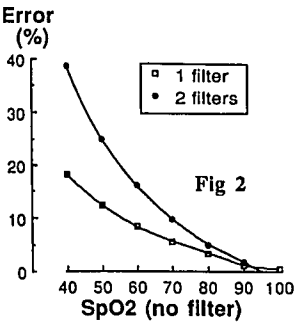

Fig 2

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TITLE: DIGITAL BLOCK FOR PULSE OXIMETRY FAILURE

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Introduction: Several authors have documented potentially disastrous arterial oxygen desaturation in the perioperative period which would otherwise go undetected without pulse oximetry. The importance of intraoperative arterial oxygen saturation monitoring has assumed such importance that the American Society of Anesthesiologists "Standards for Basic Intra-operative Monitoring" now requires use of "a quantitative method of assessing oxygenation such as pulse oximetry," and has mandated that the same standards for assessing oxygenation in the initial phases of recovery are required as of January 1, 1992.

Methods: With institutional approval, therefore, data was collected on five patients who experienced intraoperative failure of the pulse oximeter, (Nellcor Pulse Oximeter, Heywood, CA.), despite having obtained consistent sensing from a finger earlier in the operation. Following the initial pulse oximetry failure, other well described causes of loss of signal detection (other than inadequate capillary pulsations) were considered and eliminated. Each finger, toe, ear lobe and nose were then monitored without success. Attempts were made to heat these sites or to increase perfusion with local massage to restore monitoring.This occasionally yielded short term success but was not adequate for ongoing monitoring. Temperatures of the 2nd, 3rd, and 4th finger tips were then determined by an infrared surface temperature scanner (Omega Medical Corp., Clearwater, FL.). Digital nerve blocks using 2 ml of 2% lidocaine were then performed on both volar digital nerves of the middle finger at the base of the digit just distal to the interdigital web. The pulse oximeter sensor was left on this digit and removed only when finger temperatures were checked every 5 minutes for 15 minutes.

Results: In all 5 patients regular pulse oximetry detection was restored within 10 minutes. Unimpeded signal detection continued for 1.5–2 hours, becoming intermittent over the next 0.5 hour, and nonexistent thereafter. The blocked finger consistently had an increase in temperature that did not occur in the adjacent two fingers (Table).

Discussion: Pulse oximeter function requires an adequate pulsating volume of blood between the device's light source and detector for the oximeter's algorithm to compute saturation. Localized hypothermia, hypovolemia, hypotension, arterial occlusive disease, and/or vasoconstriction may diminish pulse volume sufficiently to cause loss of signal detection. Digital blocks should not detract from correcting systemic problems. Yet blocking digital sympathetic nerves locally, when safely and properly performed, should cause some local increase in capillary flow and pulse volume. This increase may be sufficient to restore adequate signal detection in a timely fashion in many patients. Our data strongly suggest that this occurred. Since monitoring saturation has become mandatory, failure of the pulse oximeter requires meaningful corrective action. We suggest that digital blocks be considered when other sites and noninvasive techniques have failed.

TABLE 1. Finger Tip Skin Temperatures

	Middle Finger (°C)		Two Adjacent Fingers (Mean °C)	
Case Number	Before Block	10 min After	Before Block	10 min After
1	23.2	28.7	23.1	23.2
2	23.5	29.4	23.5	23.4
3	24.4	27.3	24.1	24.2
4	24.3	30.0	24.4	24.6
5	22.3	25.3	22.2	22.4
Mean ± SD	23.5 ± 0.9	28.1 ± 1.9*	23.5 ± 0.9	23.6 ± 0.9

* Statistically significant difference ($P < 0.005$) paired t-test.