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Pulse oximetry in severe anaemia

Th. Ramsing and J. Rosenberg

Department of Surgical Gastroenterology 235, Hvidovre University Hospital, Hvidovre, Denmark

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Abstract. Measurement of arterial oxygen saturation by pulse oximetry was performed in two patients with acute and chronic anaemia (haemoglobin concentrations: 2.9 mmol/l (4.7 g/dl) and 1.9 mmol/l (3.0 g/dl), respectively) using a Radiometer OXI and a Nellcor N-200 pulse oximeter. The two oximeters read alternating different values in the two patients. In conclusion, pulse oximeters are able to give a value for oxygen saturation even at extreme anaemia, and when a high value is given, it possibly reflects arterial oxygen saturation. The value of pulse oximetry in severe anaemia is discussed.

Key words: Pulse oximetry – Anaemia – Oxygen – Postoperative – Surgery – Hypoxaemia – Hypoxia

Measurements of arterial oxygen saturation (SaO_2) by pulse oximetry (SpO_2) [1, 2] in patients with severe anaemia (haemoglobin concentration (Hb) < 5.0 mmol/l) has not previously been reported. We present pulse oximetry measurements in two patients with severe anaemia in order to discuss the utility of pulse oximetry in this clinical situation. Pulse oximetry data is presented as bias ($SaO_2 - SpO_2$).

Case 1

Acute anaemia

A 78-year-old male (Jehovah's Witness) presented with a bleeding duodenal ulcer. At the time of hospitalization the Hb was 8.1 mmol/l. The patient refused to receive blood transfusion during the course. After 24 h the patient lost a further 1500 ml of blood and surgery was performed because of haemodynamic instability. Immediately after the operation the patient developed respiratory failure and was ventilated with 100% oxygen in the intensive care unit for two days. He died on the seventh post-operative day with intractable shock. The oxygen saturation was measured 24 h after operation with a Nellcor N-200 (software version 2.7) and a Radiometer OXI pulse oximeter, and arterial blood samples were drawn simultaneously for measurement in an ABL300 (Radiometer A/S, Copenhagen), showing $SaO_2 = 99.3\%$. The patient was not in shock during measurements.

Hb was then 2.9 mmol/l (4.7 g/dl). N-200 bias was -0.3% SO_2, and OXI bias was -4.0% SO_2. The heart rate was 114 min^{-1} on both ECG and the two pulse oximeters.

Case 2

Chronic anaemia

A 74-year-old female suffering from disseminated cancer presented with severe anaemia requiring transfusion every week. At hospitalization two weeks earlier, the patient's Hb was 2.8 mmol/l, and she received 1.75 l of SAG-M (leucocyte-free red blood cell suspension) blood. Before the transfusion was given, the patient was monitored with the two pulse oximeters and an arterial blood sample was drawn showing estimated $SaO_2 = 97.5\%$ (ABL300). The patient was not in shock during measurements.

When performing the actual measurements her Hb was 1.9 mmol/l (3.0 g/dl) and haematocrit was 0.09. N-200 bias was -3.5% SO_2 and OXI bias was $+0.5\%$ SO_2. The heart rate was 100 min^{-1} on both ECG and the two pulse oximeters.

Discussion

Pulse oximetry utilizes the fact that oxygenated and reduced haemoglobin absorb light differently at different wavelengths. Contrary to traditional oximetry, pulse oximeters are able to separate the absorption of light by the pulsating blood from the absorption by the surrounding tissue and thereby estimate the arterial oxygen saturation. In the evaluation of pulse oximeters, the control arterial blood measurements should be performed using a multi-wavelength haemoximeter that measures the actual percentage of oxygenated blood, instead of a blood gas analyzer that calculates the oxygen saturation from the oxygen tension, pH, temperature and a standard 2.3-DPG-concentration in the machine's algorithm. Our institution did not have a multi-wavelength haemoximeter at the time of the study, thus the given values for SaO_2 come from a blood gas analyzer (ABL300, Radiometer A/S, Copenhagen).

Lee and colleagues studied the accuracy of pulse oximetry (Nellcor N-100) in anaemic dogs and found that

bias was -1.35% SO_2 at haematocrit below 0.25 and 5.40% at haematocrit below 0.10 [3]. Severinghaus & Koh found in a study in healthy volunteers of 43 pulse oximeters from 12 different manufacturers, that bias in oxygen saturation at induced hypoxaemia (SaO_2 approximately 55%) was inversely correlated with the haemoglobin concentration in the blood [4]. They found pulse oximetry bias to be 0% SO_2 at Hb above 14 g/dl (8.7 mmol/l), increasing to 14% SO_2 at Hb 8–9 g/dl (5.0–5.6 mmol/l) [4]. Bias in the anaemic patients (Hb = 5.0 mmol/l) was dependent of the oxygen saturation (from 0.13% SO_2 at $SaO_2 = 98.5\%$ to -9.95% SO_2 at $SaO_2 = 53.6\%$) [4]. Kolesar and colleagues studied the effect of different haemoglobin concentrations on the accuracy of pulse oximetry in an experimental in vitro study [5]. They found significant errors in the pulse oximetry measurements at both high and low Hb levels but the exact mechanism is still unknown. In the present study the difference between the values given by the two machines may partly be explained by differences in their built-in calibration algorithms, where the N-200 calibrates to functional saturation and the OXI to fractional saturation (difference between functional and fractional saturation is usually about 2.5% in normal individuals).

In the present study Patient 1 had developed severe anaemia in only 24 h and the blood loss was replaced by thin fluids, whereas Patient 2 had developed severe anaemia in the course of several days. It is possible that the two patient's ability to dissociate oxygen from their haemoglobin differed, and it may be presumed that especially Patient 2 had an oxygen dissociation curve shifted to the right. This would cause the estimated oxygen saturation (ABL 300) to be higher than the measured value (haemoximeter), but we were not able to verify this.

The place of pulse oximeters in monitoring patients with severe anaemia is controversial since the transport capacity in the blood for oxygen in this situation is highly dependent on the dissolved blood gas more than on oxygen saturation, since even fully saturated blood may be inadequate to ensure a significant blood oxygen concentration, ensuring sufficient tissue oxygen supply. Nevertheless, pulse oximeters may be used for continuous assurance that the arterial oxygen saturation is close to 100%. The accuracy of pulse oximetry in severe anaemia is still not fully elucidated. The present study found pulse oximetry oxygen saturation to differ by no more than 4% from the blood analyses, which we consider to be acceptable in the clinical setting as long as the problems of transport capacity are kept in mind.

In conclusion, pulse oximeters are able to give a value for oxygen saturation at extreme anaemia, and when a high value is given, it possibly reflects arterial oxygen saturation. Anaemia and hypoxaemia are both factors causing pulse oximetry bias, although the underlying mechanisms is still unknown. Until further data is available we recommend intermittent measurement of oxygen saturation and oxygen tension by blood samples during pulse oximetry monitoring in patients with severe anaemia. As in severe hypoxaemia, pulse oximetry may be used for continuous monitoring of the oxygen status, although the exact values for oxygen saturation may be slightly erroneous.

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J. Rosenberg, MD
Surgical Department 235
Hvidovre University Hospital
DK-2650 Hvidovre
Denmark