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Discrepancy between SpO_2 and SaO_2 in a patient with severe anemia

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Introduction

Pulse oximetry is routinely used to detect hypoxia during anesthesia, because oxygen saturation on pulse oximetry (SpO_2) is correlated with direct arterial blood oxygen saturation (SaO_2) [1]. However, this instrument may occasionally demonstrate some abnormalities. The main factors leading to abnormalities are peripheral vasoconstriction [2–4], hypotension [4], hypothermia, nail polish [5], methemoglobinemia [6], anemia [7,8] and other factors.

We present a patient with hypotension and severe anemia who demonstrated SpO_2 values that were much lower than the SaO_2 values, despite the presence of a clear waveform on the plethysmograph.

Case report

A previously healthy 27-year-old woman was injured in a car accident. On arrival at our emergency unit, she did not respond when her name was called. Light reflex was negative. Heart rate was 63 beats·min^{-1} and respiratory rate was 8 breaths·min^{-1}. Blood pressure was 114/55 mmHg. SpO_2 was 99%. Hemoglobin (Hb) concentration was 12.9 g·dl^{-1}. Radiography showed a normal chest. Computerized tomography demonstrated acute subdural hematoma, dislocation of the right hip joint, and a fractured mandible. The patient underwent a craniotomy to evacuate the hematoma. At the induction of anesthesia, the pupils were anisocoric. Light reflex was negative and decerebrated posture was observed. Anesthesia was induced and maintained using fentanyl, nitrous oxide, and sevoflurane. Vecuronium was used to provide muscle relaxation. After the induction of anesthesia, rectal temperature was 34.2°C and SpO_2 was 100% (M1025B; Hewlett Packard Andover, MA, USA). Laboratory data were as follows: FiO_2, 0.4; Hb, 11.3 g·dl^{-1}; pH, 7.40; PCO_2, 36.7 mmHg; PO_2, 245.5 mmHg; and SaO_2, 99.8% (ABL 300; Radiometer Copenhagen, Denmark).

After the dura was opened, blood pressure decreased to 40/30 mmHg, and SpO_2 could not be detected. There was no clear bleeding observed in the operating field. Laboratory data were as follows: FiO_2, 1.0; Hb, 4.4 g·dl^{-1}; pH, 7.41; PCO_2, 25.0 mmHg; PO_2, 555.3 mmHg; and SaO_2, 100%. Phenylephrine was administered, and crystalloid and colloid solutions were infused quickly until blood transfusion was prepared. SpO_2 values decreased gradually to the lowest reading of 76%. When SpO_2 values were low with a clear plethysmograph waveform (Figs. 1 and 2), laboratory data were as follows: FiO_2, 1.0; Hb, 2.0 g·dl^{-1}; pH, 7.28; PCO_2, 37.6 mmHg; PO_2, 584.8 mmHg; and SaO_2, 100%. Significant hemorrhage, causing hemoglobin to drop from 11.3 to 2.0 g·dl^{-1}, was suspected to be due to retroperitoneal hemorrhage. After surgery the patient did not regain consciousness. There was no spontaneous respiration, no corneal reflex, and no eyelash reflex. The patient died on the ninth postoperative day.

Discussion

In the present patient, the lowest reading on the pulse oximeter was 76% with a clear plethysmograph waveform, despite full SaO_2 saturation. Factors that may have led to underestimation of the SpO_2 values in the present patient are considered to be as follows.

First, low SpO_2 values may be due to nail polish, methemoglobinemia, or vasoconstriction. However, the

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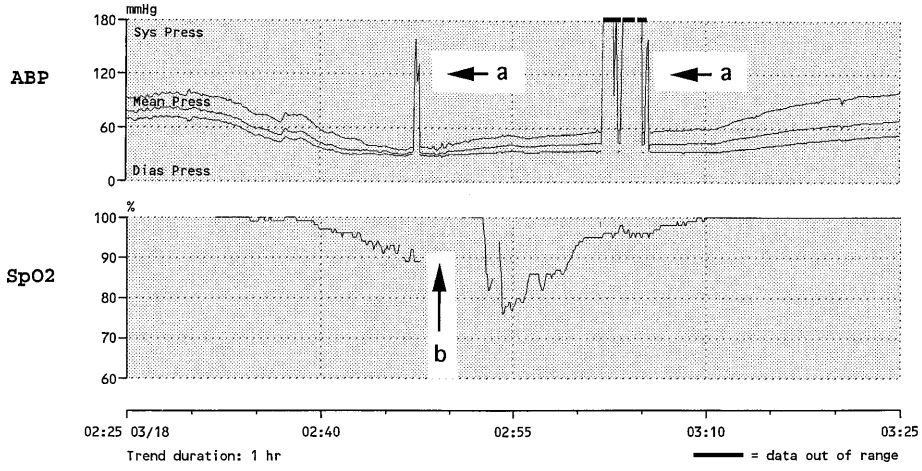

Fig. 1. Trends of arterial blood pressure and oxygen saturation on pulse oximetry (SpO_2) values in a patient with severe anemia. *a* Flush with heparinized saline; *b* Check of pulse oxymeter finger probe. Findings seemed to be consistent between the decreased blood pressure and decreased SpO_2 values. When SpO_2 values quickly increased, phenylephrine was administered, and crystalloid, hydroxyethyl starch, and plasma protein fraction were infused quickly. *ABP*, Arterial blood pressure; *Sys press*, systolic pressure; *Dias press*, diastolic pressure

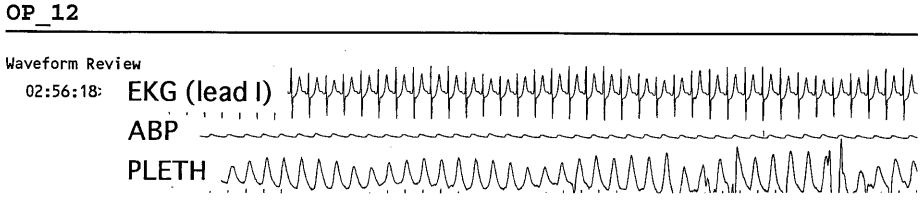

Fig. 2. Wave form of electrocardiogram (*EKG*; lead I), arterial blood pressure (*ABP*), and plethysmograph (*PLETH*). When SpO_2 values were low, a large wave form was observed on the plethysmograph. *OP-12*, Operation room No. 12

fingernails of this patient were not covered with nail polish, and the methemoglobin value was 0.5%, which is within normal limits, and the oximeter showed a clear waveform with normal heart rate, despite a body temperature of 34.1°C and hypotension. Thus, the low SpO_2 values were not due to nail polish, methemoglobinemia, or vasoconstriction.

Second, low SpO_2 values may be due to severe anemia. Severinghaus and Koh [9] reported that SpO_2 error due to anemia was zero at 97% SaO_2, but became evident when SaO_2 fell below 75%. Lee et al. [8] observed the effects of anemia on pulse oximetry and continuous mixed venous hemoglobin saturation monitoring in dogs, and found that the accuracy of a pulse oximeter was relatively independent of hematocrit until values fell below 14% . The accuracy deteriorated significantly when the hematocrit decreased to 10% or less [8]. In the present patient, Hb was $2.0\,g\cdot dl^{-1}$ when SpO_2 values were low with a clear plethysmograph waveform, and this value is nearly equal to a hematocrit of 6%. Thus, the low SpO_2 values might have been due to severe anemia.

The mechanism involved in the low SpO_2 with severe anemia may be considered to be venous pulsation. Many of the low SpO_2 values presented by pulse oximetry during low perfusion states are associated with signals from venous blood, which can generally be in the 75% to 80% range. In the present patient, because the lowest SpO_2 value was 76%, the SpO_2 value would be due to venous blood. Kim et al. [10] reported that the venous blood in the skin is composed of two fractions: the shunted arterial blood, which is highly saturated and pulsatile, and the true venous blood, which is drained from the capillaries after tissue perfusion and is, therefore, desaturated and nonpulsatile. If the proportion of shunted arterial blood greatly exceeds that of the true venous blood, the SpO_2 value should be close to a true SaO_2 [10]. If arteriovenous (AV) shunting is severely restricted by increased sympathetic tone, the increased proportion of true venous blood should result in a false low value of SpO_2 [10]. In the present patient, we rapidly infused relatively large volumes of crystalloid and colloid solutions while preparing a transfusion because the blood pressure decreased, and then volume replacement caused severe hemodilutional anemia. In severe hemodilutional anemia, because the blood viscosity decreases markedly, arterial pulses may easily pass the capillary beds or AV anastomoses, despite increased sympathetic tone. Thus, venous pulsation might be generated by the transmission of arterial pulses, resulting in clear pulsation on the plethysmograph and measurement of the venous SpO_2 value.

In conclusion, under conditions of severe hemodilutional anemia, a clear plethysmograph waveform and low SpO_2 might be observed, despite full SaO_2 saturation.

References

1. Bowes WA 3rd, Corke BC, Hulka J (1989) Pulse oximetry: a review of the theory, accuracy, and clinical applications. Obstet Gynecol 74:541–546
2. Langton JA, Lassey D, Hanning CD (1990) Comparison of four pulse oximeters: effects of venous occlusion and cold-induced peripheral vasoconstriction. Br J Anaesth 65:245–247
3. Wilkins CJ, Moores M, Hanning CD (1989) Comparison of pulse oximeters: effects of vasoconstriction and venous engorgement. Br J Anaesth 62:439–444
4. Severinghaus JW, Spellman MJ Jr (1990) Pulse oximeter failure thresholds in hypotension and vasoconstriction. Anesthesiology 73:532–537
5. Cote CJ, Goldstein EA, Fuchsman WH, Hoaglin DC (1988) The effect of nail polish on pulse oximetry. Anesth Analg 67:683–686
6. Chisholm DG, Stuart H (1994) Congenital methaemoglobinaemia detected by preoperative pulse oximetry. Can J Anaesth 41:519–522
7. Ramsing T, Rosenberg J (1992) Pulse oximetry in severe anaemia. Intensive Care Med 18:125–126
8. Lee S, Tremper KK, Barker SJ (1991) Effects of anemia on pulse oximetry and continuous mixed venous hemoglobin saturation monitoring in dogs. Anesthesiology 75:118–122
9. Severinghaus JW, Koh SO (1990) Effect of anemia on pulse oximeter accuracy at low saturation. J Clin Monit 6:85–88
10. Kim JM, Arakawa K, Benson KT, Fox DK (1986) Pulse oximetry and circulatory kinetics associated with pulse volume amplitude measured by photoelectric plethysmography. Anesth Analg 65:1333–1339