What does one mean by “arterial blood oxygenation?”

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Submitted 29 June 2005; accepted in final form 4 October 2005

Prakash, E. Sankaranarayanan, and Madanmohan. What does one mean by “arterial blood oxygenation?” Adv Physiol Educ 30: 46–47, 2006; doi:10.1152/advan.00039.2005.—We used the following question in a large classroom session attended by undergraduate medical students and doctors with a Bachelor of Medicine and Bachelor of Surgery (MBBS) degree (240 in all) to test for conceptual understanding as to what constitutes arterial blood oxygenation. The question read as follows: Which one of the following physiological parameters taken alone tells you that arterial blood oxygenation in a critically ill patient is satisfactory?

A. (Alveolar – arterial) O₂ gradient = 10 mmHg
B. Partial pressure of O₂ in arterial blood = 95 mmHg
C. O₂ saturation of Hb > 90%
D. Blood hemoglobin concentration = 12 g/dl

Only 25 of 240 students correctly indicated that none of the above parameters taken alone could give us this information. Once students turned in their answers, we presented five examples illustrating how none of the above answers could be used alone to assess arterial blood oxygenation. Students were then asked to provide written feedback on their understanding of this topic. The majority of students indicated that they were satisfied that they got rid of a misconception.

critical care; hypoxemia; pulmonary gas exchange; tissue oxygenation; pulse oximetry;

WE USED the following question in a large classroom session attended by undergraduate medical students who were within a few months of obtaining the Bachelor of Medicine and Bachelor of Surgery (MBBS) degree and doctors with a MBBS degree (240 in all) preparing for entrance examinations to enter postgraduate residency programs in India. The question mentioned below was used during a review class in critical care physiology after classes in cardiovascular, pulmonary, renal, and acid-base physiology. Concepts such as the alveolar gas equation, pulmonary gas exchange, oxygen content of arterial blood, whole body oxygen delivery, and oxygen extraction in tissues had been covered in the preceding 2 wk. The purpose of this question was to test for conceptual understanding as to what constitutes arterial blood oxygenation. The question read as follows:

Which one of the following physiological parameters taken alone tells you that arterial blood oxygenation in a critically ill patient is satisfactory?

A. (Alveolar – arterial) O₂ gradient = 10 mmHg

B. Partial pressure of O₂ in arterial blood = 95 mmHg
C. O₂ saturation of Hb > 90%
D. Blood Hb concentration = 12 g/dl

where Hb is hemoglobin. Seventy-one students chose option A, 56 students chose option B, 51 students chose option C, 4 students chose option D, 20 students marked more than one option but were still incorrect, and 13 students did not answer the question, i.e., they returned the answer sheet blank. Only 25 of 240 students correctly indicated by writing on the answer sheet that none of the above parameters taken alone could give us this information. The following five cases were presented with explanations as given below (as in a lecture presentation) in about 5 minutes time, and written feedback was then obtained from the participants.

To illustrate, consider the following situations.

Case 1

Consider a patient who is not getting enough oxygen to breathe or a patient with airway obstruction. The partial pressure of oxygen in alveolar gas (PₐO₂) could be 60 mmHg and the partial pressure of oxygen in arterial blood (PₐO₂) could be 50 mmHg. The alveolar – arterial O₂ gradient would be 10 mmHg. But, the patient could be hypoxic. Thus, a normal alveolar – arterial O₂ gradient only tells us that ventilation-perfusion matching is optimal and also that there is not any significant arterial desaturation as a result of an extrapulmonary right-to-left shunt.

Case 2

An anemic patient may have a PaO₂ of 95 mmHg, but what if his blood Hb concentration is only 7.5 g/dl? Then, the oxygen-carrying capacity of arterial blood is reduced to half its normal value. Thus, a normal PaO₂ should not mislead us into believing that arterial blood oxygenation is normal.

Case 3

Consider a patient who is on a ventilator and has a PaO₂ of 95 mmHg and a partial pressure of carbon dioxide in arterial blood (PaCO₂) of 30 mmHg. While a PaO₂ of 95 mmHg is normal if one is breathing room air, one should note that patients who are on ventilators are given oxygen-enriched gas mixtures. For example, if 60% oxygen is being administered, then, as per the alveolar gas equation (given in the Appendix), the expected PaO₂ would be 380 mmHg. If the actual PaO₂ were only 95 mmHg, the large alveolar – arterial oxygen gradient of 285 mmHg denotes a serious impairment in oxygen exchange due to ventilation-perfusion mismatch. Actually, a PaO₂ of 95 mmHg may occur even in the absence of Hb! In this case, if the
Pao2 were 95 mmHg, not more than 0.3 ml of oxygen would be present in 1 dl of plasma.

Case 4

An O2 saturation of Hb of 90% looks deceptively normal, but what if the blood Hb concentration is only 5 g/dl? Then, the oxygen content of arterial blood would be far too low, and the individual would definitely be hypoxic. Furthermore, pulse oximeters cannot distinguish normal Hb from carboxyhemoglobin (2, 4). The consequences of this for tissue oxygenation are even more serious because the oxygen dissociation curve is shifted to the left in the presence of carboxyhemoglobin.

Case 5

A blood Hb of 12 g/dl taken alone does not guarantee adequate oxygenation of arterial blood. What if half of the oxygen binding sites are occupied by carbon monoxide?

Clearly, none of the parameters “taken alone” (especially when their values are normal as in our question) tells us that arterial blood oxygenation is satisfactory, i.e., they all have to be considered together. Thus, the definition for arterial blood oxygenation would be that it is the volume of oxygen taken up across the lungs per minute or the volume of oxygen added to arterial blood per minute. Normally, in adult humans at rest, this is about 250 ml/min (1). One option that should have been included in our question is pulmonary blood flow or cardiac output.

Learning and revision of facts and concepts in the educational context described here occurs mainly through multiple-choice questions; it is important to acknowledge the fact that one of the authors (E. S. Prakash) does not use options such as “none of the above” or “all of the above.” Instead, students are clearly instructed at the beginning of the class to examine all options in each question and write “none of the above” or “all of the above” wherever applicable. This is to motivate students to get the maximum information by evaluating each and every option in a question. However, understandably, many students suggested (in the feedback forms) that they were misled by the question because the wording in the question strongly called for one best answer, so the misconception has definitely been overestimated. Therefore, the significance that could be attached to the reported percentages of each incorrect option chosen as an answer is also limited. When feedback was obtained, participants were asked this question, “If you got the answer wrong, are you satisfied that you got rid of a misconception?” One hundred eighty-six of the 215 students who got it wrong indicated yes; 23 students gave no indication about this, and 6 students mentioned that they were still not convinced with the explanation. It is interesting to note the students’ responses to the question of “If you had a misconception, can you describe why you may have had this conceptual difficulty?”

- “In clinical practice, the first thing we look at is the oxygen saturation of Hb.”
- “I didn’t face such a question before.”
- “Having taken your highlighting ‘taken alone’ lightly.”
- “It was not taught before.”

- “Have not thought of various possibilities when some of the parameters could appear deceptively normal.”
- “Because oxygen saturation of Hb of 90% seems like a big value.”
- “Not thought of some critical clinical condition in which Hb saturation > 90% may still be problematic.”
- “Sheer carelessness. Didn’t bother to think that there could be a better option than the ones given here.”
- “Pao2. Because that is what everyone talks about.”

Students’ “misconception” aside, note that literature is replete with statements (for example, as in Ref. 3) that arterial blood oxygenation is assessed by Pao2, and Sao2 measurements are made by pulse oximetry. Rather, the advantage of pulse oximetry is that it offers the unmatched possibility of real-time continuous noninvasive monitoring of blood oxygenation when other factors such as blood Hb levels and its functionality have already been assessed. To quote Tremper and Barker (4), “metaphorically, the pulse oximeter is a sentry standing on the edge of the cliff of desaturation. It gives no warning as we approach the edge of the cliff; it only tells us when we have fallen off.”

Although the data gathered from our students may not reliably reflect the prevalence of this misconception, we would like to suggest the use of the kind of examples mentioned here to teach what constitutes oxygenation of arterial blood. If arterial blood oxygenation is defined as the volume of oxygen added to arterial blood per minute, it is also easier to understand that tissue oxygenation is additionally influenced by tissue blood flow, the oxygen extraction ratio in each tissue, and factors that influence oxygen utilization in cells.

APPENDIX

The alveolar gas equation is used to determine the ideal oxygen tension of alveolar gas (5). Because arterial CO2 readily equilibrates with alveolar CO2, the tension of CO2 in arterial blood may be substituted for the partial pressure of CO2 in alveolar gas (Paco2).

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\text{Pao2} = (\text{Pb} - \text{P}H2O)\text{FiO2} - (\text{Paco2}/R)
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Pb is barometric pressure; P, H2O is the pressure of water vapor at body temperature, usually 47 mmHg; FiO2 is the fraction of oxygen in inspired gas; and R is the respiratory exchange ratio, i.e., the volume of CO2 per volume of oxygen exchanged per unit time. Normally, it is about 0.8.

REFERENCES


