# LETTER TO THE EDITOR

**Open Access** 

# A proposal for a new temperaturecorrected formula for the oxygen content of blood



Kiichi Hirota<sup>1\*</sup>, Miyahiko Murata<sup>2</sup> and Koh Shingu<sup>3</sup>

To the Editor.

Oxygen (O<sub>2</sub>) is essential for normal aerobic metabolism in mammals. O<sub>2</sub> delivery is the process of transport of oxygenated blood from the alveolar capillaries to the tissues and is dependent on two factors: arterial O2 content (CaO<sub>2</sub>) and cardiac output. The carriage in the blood occurs as O2 bound to hemoglobin and O2 dissolved in the plasma and is expressed as the sum of these components with the following equation:  $CaO_2 = 1.39 \times Hb (g/dl) \times$  $SaO_2 + 0.0031 \times PaO_2$  (mmHg) (1).  $CaO_2$  is the milliliters of O2 per 100 mL of blood, SaO2 is the fraction of hemoglobin (Hb) that is saturated with O2, the O2-combining capacity of Hb is 1.39 mL of O2 per gram of Hb, Hb is grams of Hb per 100 mL of blood, PaO<sub>2</sub> is the O<sub>2</sub> tension, and solubility of O2 in plasma is 0.003 mL of O2 per 100 mL plasma for each mm Hg of PaO<sub>2</sub> [1, 2]. The pressure is 1 atm (101.325 kPa). However, the temperature is not clearly specified. In fact, the coefficient of 1.39 in the previous item of the equation was obtained under the standard condition of 0 °C (273 K). It is obtained as 22.4 (volume of 1 mol of gas at 273 K) × 4 (molecular number bound to 1 molecule of hemoglobin)/64,458 (molecular weight of hemoglobin)/1000 (correction coefficient) [3, 4]. In the case of 37 °C (310 K), the coefficient should be 1.58 due to Boyle-Charles law or combined gas law (273 + 37)/  $273 \times 1.39$ . On the contrary, the coefficient 0.0031 from the last item of the equation is derived from evidence on O<sub>2</sub> solubility at 37 °C (310 K). It is obtained as 0.0239 (Bunsen absorption coefficient  $\alpha$  of oxygen at 37 °C)  $\times$ 100/760 [5]. These items from the same equation are derived at different temperatures. Although equation (1) is established and is described in almost all published textbooks, the equation should be revised so that it is more clinically relevant. In lieu of equation (1), we propose a new temperature correction formula:  $CaO_2$  (ml/dl) = 1.58 × Hb (g/dl) ×  $SaO_2$  + 0.0031 ×  $PaO_2$  (mmHg) at 37 °C and 1 atm. Lack of experimental results is one of limitations of our proposal, and we need to confirm them in clinical settings.

#### Acknowledgements

Not applicable

#### Authors' contributions

K.H, M.M, and K.S. conceived and designed the study. Y.F performed the analysis. K.H, M.M, and K.S. wrote the paper. All authors read and approved the final manuscript.

#### Funding

The authors received no financial support for publication of this article.

#### Availability of data and materials

Not applicable

### Ethics approval and consent to participate

Not applicable

#### Consent for publication

Not applicable

## Competing interests

The authors declare that they have no competing interests.

#### Author details

<sup>1</sup>Department of Human Stress Response Science, Institute of Biomedical Science, Kansai Medical University, Hirakata, Osaka 573-1010, Japan. <sup>2</sup>Department of Medical Care and Welfare Engineering, School of Industrial and Welfare Engineering, Tokai University, Kumamoto, Kumamoto 862-8652, Japan. <sup>3</sup>Department of Anesthesiology, Osaka Red Cross Hospital, Osaka, Osaka 543-8555, Japan.

Received: 26 May 2020 Accepted: 4 August 2020 Published online: 12 August 2020

#### References

 West JB. Gas transport by the blood. In: West JB, Luks AM, editors. West's Respiratory Physiology: The Essentials 10th Ed. Baltiore: Lippincott Williams & Wilkins; 2015. p. 75–92.

<sup>&</sup>lt;sup>1</sup>Department of Human Stress Response Science, Institute of Biomedical Science, Kansai Medical University, Hirakata, Osaka 573-1010, Japan Full list of author information is available at the end of the article



© The Author(s). 2020 **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

<sup>\*</sup> Correspondence: hif1@mac.com; khirota-kyt@umin.ac.jp

Hirota et al. JA Clinical Reports (2020) 6:62 Page 2 of 2

- Severinghaus JW. Oxyhemoglobin dissociation curve correction for temperature and pH variation in human blood. J Appl Physiol. 1958;12:485–6.
- Sendroy J, Dilton RT, Van Slyke DD. Studies of gas and electrolyte equilibria in the blood: XIX. The solubility and physical state of uncombined oxygen in blood. J Biol Chem. 1934;105:597–632.
- Pittman RN. Chapter 4 Oxygen transport In: Regulation of tissue oxygenation. San Rafael: Morgan & Claypool Life Sciences; 2011. https:// www.ncbi.nlm.nih.gov/books/NBK54103/ Accessed 2 August 2010.
- Forstner H, Gnaiger E. Calculation of equilibrium oxygen concentration. In: Gnaiger E, Forstner H, editors. Polarographic oxygen sensor: aquatic and physiological applications. Berlin: Springer-Verlag; 1983. p. 321–33.

### **Publisher's Note**

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

# Submit your manuscript to a SpringerOpen journal and benefit from:

- ► Convenient online submission
- ► Rigorous peer review
- ▶ Open access: articles freely available online
- ► High visibility within the field
- ► Retaining the copyright to your article

Submit your next manuscript at ▶ springeropen.com