# TENTATIVE RECOMMENDATION ON TERMINOLOGY AND DEFINITIONS IN RESPIRATORY PHYSIOLOGY: RÉSUMÉ OF THE ISOTT CONSENSUS SESSION 1992

Rolf Zander and Fritz Mertzlufft

Institute of Physiology and Pathophysiology
Johannes Gutenberg-University Mainz, D-6500 Mainz, and
Clinic of Anaesthesiology and Intensive Care Medicine
University of Homburg, D-6650 Homburg-Saar, Germany

## GENERAL REMARKS ON SYMBOLS

1. The use of small letters for the symbols "p" (partial pressure), "s" (saturation) and "c" (concentration) (e.g. $pO_2$, $sO_2$, $cO_2$) follows recommendations of the IFCC and IUPAC [4]. This supports the use of contemporary word processing systems and mostly eliminates the need to use subscripts (except for chemical valencies: e.g. $O_2$, $CO_2$, $H_2CO_3$ etc.). The potential risk of misinterpretations and double meanings is reduced also (e.g. "$cO_2$" [oxygen concentration] v.s. "$CO_2$" [carbon dioxide] and "$sO_2$" [oxygen saturation] v.s. "$SO_2$" [sulfur dioxide]).

2. The symbol shall include the site of measurement or description, e.g. $paO_2$ (arterial $O_2$ partial pressure), $s\bar{v}O_2$ (mixed venous oxygen saturation), or $avDO_2$ (arterio-venous oxygen difference). This removes in an intelligible manner the confusion of symbols (e.g. $paO_2$: $PaO_2$, $p_aO_2$, $Pa_{O_2}$, $P_{aO_2}$ etc.). One wishes to question the rationale of a statement such as "writing $S_{aO_2}$ , $S_{O_2}(a)$, $S_{O_2}(ab)$ or the like, is a matter of taste" [10], because perfect confusion may be the result, here concerning the arterial $O_2$ saturation ($saO_2$).

3. It is a convention in chemistry to refer to radicals or compounds containing oxygen with the term "oxi" rather than "oxy" (e.g. carbon monoxide (CO), carbon dioxide ($CO_2$), oxidized Hb (MetHb) etc.). On the other hand, methods and terms referring to molecular oxygen (oxygenium) should be written with "y" and not with "i" (e.g. oxymetry, pulse oxymetry, oxygenation, Hb with reversibly bound $O_2$ (Oxy-Hb, $O_2Hb$) and deoxygenated Hb (Deoxy-Hb, Hb), etc.).

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4. Even if a new in vivo method differs considerably from the established in vitro method (e.g. in vivo (transcutaneously) measurement of arterial $O_2$ saturation or $O_2$ partial pressure) this does not justify the use of different notations or symbols. Use of the symbol $ptcO_2$ should be avoided for transcutaneously determined "$paO_2$": If the method is able to measure the arterial $pO_2$ then the symbol $paO_2$ should be used. If this is not the case, however, i.e. if indeed the cutaneous $pO_2$ is determined, then the symbol $pctO_2$ is appropriate. The use of $Sp_{O_2}$ [2,7] or $S_{pO_2}$ [5] or $S_{O_2}(po)$ [10] for arterial $O_2$ saturation, measured by pulse oxymetry, could erroneously suggest the measurement of an essentially different quantity [10].

5. The number of symbols employed for a given measured value should be kept as small as possible. For this reason the suggestions of Payne and Severinghaus [5] should not be followed, since a total of six different symbols is recommended for the $O_2$ saturation. Consequences are a worldwide confusion: within only one article [2] arterial oxygen saturation is referred to as $Sp_{O_2}$ (pulse oxymeter reading), $FSa_{O_2}$ (functional saturation), $Sa_{O_2}$ (fractional saturation), $O_2Hb$ % (fractional saturation). Within the same volume of a journal [2,7] $Sa_{O_2}$ is used for fractional oxygen saturation [2] as well as for functional oxygen saturation [7]. Obviously, the notation "fraction" becomes more and more attractive: Besides the widely accepted "fraction" in respiratory physiology (e.g. $FIO_2$, inspired oxygen fraction), the oxyhemoglobin fraction $F_{HbO_2}$ was proposed [10] for the $So_2$(frac) [5] or the fractional saturation $Sa_{O_2}$ [2]. But, on the other hand, the symbol F was then introduced as $FSa_{O_2}$ for the functional (not the fractional) saturation and used besides the common $FIO_2$ [2], the inspired oxygen fraction.

6. Symbols used for any notations should be as simple as possible. Neither the use of $NSo_2$ to describe the noninvasive technique [1] for the measurement of oxygen saturation, nor that of $Sp_{O_2}$ [2] for pulse oxymetry should be accepted.

7. The symbol for a measured value must be independent of the method (cf. comment 5), and certainly independent of the manufacturer. Recent recommendations to the contrary, e.g. to use the symbol $S_{hp}O_2$ for the value given by an oxymeter from Hewlett Packard [5], or that of Barker et al [2] to use the symbol $Sx_{O_2}$ for the value given by an Oximetrix system, are unacceptable.

**In conclusion the following is proposed:**

- that no new definitions resulting from the limitations of a method be introduced,
- that symbols and methods are not combined per se, and
- that definitions and symbols be disassociated from any commercial use.

## SPECIAL REMARKS ON SYMBOLS AND DEFINITIONS

The special symbols concerning the parameters of oxygen are summarized in Table I. Relevant definitions dealing with oxygen transport by human blood are given in Table II.

**TABLE I. Symbols**

| Term | Unit | Symbol | Specifcation/Comment |
|---|---|---|---|
| $O_2$ partial pressure | mmHg, kPa | $pO_2$ | $pAO_2$ alveolar<br>$paO_2$ arterial blood<br>$pcO_2$ capillary blood<br>$pvO_2$ venous blood<br>$p\bar{v}O_2$ mixed venous blood<br>$pctO_2$ skin (cutaneous)<br>$ptO_2$ tissue |
| $O_2$ saturation | %* | $sO_2$ | $saO_2$ arterial blood<br>$svO_2$ venous blood<br>$s\bar{v}O_2$ mixed venous blood |
| Partial $O_2$ saturation | %* | $psO_2$ | $psaO_2$ arterial blood<br>$psvO_2$ venous blood<br>$ps\bar{v}O_2$ mixed venous blood |
| Hemoglobin concentration<br>(Synonym: Hb content) | g/L, g/dL,<br>mmol/L | cHb | |
| $O_2$ concentration<br>(Synonym: $O_2$ content) | mL/dL, vol%,<br>% (v/v), L/L | $cO_2$ | $caO_2$ arterial blood<br>$cvO_2$ venous blood<br>$c\bar{v}O_2$ mixed venous blood |
| Oxy-Hb concentration<br>(Synonym: Oxy-Hb fraction) | %* | $cO_2Hb$ | Identical to $sO_2$ |
| Carboxy-Hb concentration<br>(Synonym: Carboxy-Hb fraction) | %* | cCOHb | |
| Met-Hb concentration<br>(Synonym: Met-Hb fraction) | %* | cMetHb | |
| $O_2$ solubility<br>(Synonym: $O_2$ solubility coefficient) | mL/mL/atm,<br>mL/dL/mmHg | $\alpha O_2$ | |
| Arterio-venous $O_2$ difference | mmHg, %*,<br>mL/dL | $avDO_2$ | The term $avDO_2$ can only be applied to a given organ, whereas $a\bar{v}DO_2$ can also refer to the whole organism. |
| Alveolo-arterial $O_2$ difference | mmHg | $AaDO_2$ | |
| $O_2$ uptake | mL/min | $\dot{V}O_2$ | |
| $O_2$ transport<br>(Synonym: $O_2$ transport capacity;<br>$O_2$ supply; $O_2$ availability) | mL/min | $\dot{T}O_2$ | |
| $O_2$ consumption | mL/min | $\dot{Q}O_2$ | Identical to $\dot{V}O_2$ when used in conjunction with $a\bar{v}DO_2$ under steady state conditions. Use of $avDO_2$ gives the $O_2$ consumption of an organ. |

* can also be expressed as a fraction (without units)

**TABLE II. Definitions**

| Terms | Definitions | Comments |
|---|---|---|
| $O_2$ partial pressure | The pressure exerted by $O_2$ in a mixture (e.g. $CO_2$, $N_2$, $H_2O$, etc.) of gases (e.g. alveolar gas, air), in a liquid (e.g. blood, cerebrospinal fluid) or in tissue. | In the case of blood the $O_2$ partial pressure describes the pressure of both the physically dissolved and chemically bound oxygen. |
| Normoxia | Normal oxygen partial pressure at a defined location and under defined conditions. | Normoxia in the arterial blood of a patient presumes knowledge of the normal value in relation to the age, sex, relative body weight and barometric pressure. |
| Hypoxia | Decreased $O_2$ partial pressure (compared to normoxia). | The term hypoxia will continue to be used generally to describe an oxygen deficit. Greater specifity in terminology is to be preferred, however (e.g. arterial hypoxia, tissue hypoxia, etc.). |
| Hyperoxia | Increased $O_2$ partial pressure (compared to normoxia). | An increase in the inhaled oxygen concentration (normobaric) and/or the total pressure in a pressure chamber (hyperbaric) employed therapeutically. |
| $O_2$ saturation | 1. The concentration (content) of $O_2$ bound to hemoglobin in relation to the $O_2$ binding capacity (the theoretical maximum for Hb-bound $O_2$ expressed as a fraction or as a percentage: $sO_2 = (cO_2 - \text{physically dissolved } O_2)/O_2$ capacity. | The result of measuring the $O_2$ content (after deducting physically dissolved $O_2$) in relation to the $O_2$ capacity. |
| | 2. Oxyhemoglobin as a proportion of the total hemoglobin, expressed as a fraction or as a percentage, Total Hb = $O_2Hb + Hb + COHb +$ MetHb etc.: $sO_2 = cO_2Hb/(cO_2Hb + cHb + cCOHb + cMetHb)$. | The result of photometric determination with equipment using 4–7 wavelengths (Oxymeter). Not recommended [5]: Oxyhemoglobin saturation ($HbO_2$) or fractional saturation ($So_2$(frac)). |
| Partial $O_2$ saturation | The concentration of oxyhemoglobin as a fraction or percentage of the sum of the concentrations of Deoxy-Hb (Hb) plus Oxy-Hb ($O_2Hb$) alone: $psO_2 = cO_2Hb/(cO_2Hb + cHb)$. | 1. The result of photometric determination using only 2 wavelengths.<br><br>2. Obtained by calculation from the $pO_2$ and the $O_2$ binding curve under defined conditions (pH, $pCO_2$, temp., etc.). The term "partial" is used to emphasize that only a portion of the Hb ($O_2Hb$ + Hb) is taken into account resulting in limited diagnostic relevance. The term "available Hb" for the sum of Hb + $O_2Hb$ (i.e. the Hb available for $O_2$ transport) is unacceptable since the conditions of measurement are not defined: Depending upon the exposure time and magnitude of the $pO_2$ and the MetHb reductase activitiy, COHb and MetHb are converted into "available" Hb (in vivo and in vitro). The recommendation of Payne and Severinghaus [5] to saturate with a "minimum volume of oxygen" to prevent removal of COHb and MetHb is not practicable. |

**TABLE II. Definitions, continued**

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|---|---|---|
| | | Not recommended [5]: In vivo ($So_2$) or functional $O_2$ saturation ($So_2$(func)), or pulse oxymeter saturation ($SpO_2$). |
| Oxygenation | Reversible cooperative binding of oxygen to the bivalent iron of hemoglobin, whereby deoxygenated hemoglobin is converted to oxygenated hemoglobin. The splitting off of $O_2$ is referred to as deoxygenation. | Oxygenation must be distinguished from oxidation, in which an increase in the valency of iron takes place (hemiglobin formation from hemoglobin). The term "reduced Hb" [5] for deoxygenated hemoglobin should be avoided since iron is also present in divalent form ($Fe^{++}$) in the case of $O_2Hb$ [8]. The general use of the term "oxygenation" in the sense of "oxygen enrichment" should be avoided or specified. |
| Hypoxygenation | Decrease in $O_2$ saturation at a defined location and under defined conditions. | |
| Hb concentration (Hb content) Total Hb concentration (cHb) | 1. Concentration of hemoglobin in blood (e.g. g/dL). | The result of the photometric determination of Hb in blood. |
| | 2. Sum of all Hb derivatives in blood (THb = total Hb): THb = cHHb + $cO_2Hb$ + cCOHb + cMetHb. | The result of the spectrophotometric determination in a multi-wavelength oxymeter. |
| **Hemoglobin derivatives:** | | |
| Hemoglobin (Hb, HHb) | Deoxy-Hb (Hb without $O_2$). | |
| Oxyhemoglobin ($O_2Hb$) | Oxy-Hb (Hb with bound $O_2$ ). | The term "oxidized Hb" should be eliminated. |
| Carboxyhemoglobin (COHb) | Hemoglobin with reversibly bound carbon monoxide (CO). | CO is bound with a high affinity but reversibly. |
| Methemoglobin (MetHb, $Hb^+$, Hi) | Hemoglobin in an oxidized state, also known as hemiglobin, that is unavailable for $O_2$ transport. | |
| Sulfhemoglobin (SHb, SulfHb) | Hemoglobin with bound sulphur ($H_2S$ action on hemoglobin). | |
| Cyanohemiglobin (HiCN) | Hemiglobin with bound cyanide (HCN action on hemiglobin). | Only occurs in vitro. |
| OxyHb concentration ($cO_2Hb$) | Proportion of $O_2Hb$ in blood in relation to total Hb; expressed as a fraction (without dimensions) or as a percentage (%). Identical to $O_2$ saturation ($sO_2$). | The definition by Siggaard-Andersen [6] of $cO_2Hb$ as the "$HbO_2$ fraction" in relation to cHb + $cHbO_2$ (rather than to total Hb) should be rejected since the fractions of COHb, MetHb and SulfHb are related to the total Hb. The concentrations (fractions) of all Hb derivatives should be related to total Hb merely for practical reasons. |
| CarboxyHb concentration (cCOHb) | see $cO_2Hb$ | |
| MetHb concentration (cMetHb, cHi) | see $cO_2Hb$ | |
| SulfHb concentration (cSulfHb, cSHb) | see $cO_2Hb$ | |

**TABLE II. Definitions, continued**

| | | |
|---|---|---|
| $O_2$ concentration (Synonym: $O_2$ content) | The sum of the amounts of chemically bound and physically dissolved oxygen in blood. | |
| Normoxemia | The normal $O_2$ concentration in a blood sample under defined conditions. | |
| Hypoxemia | Reduced $O_2$ concentration compared to normoxemia. | The decrease in $cO_2$ is accompanied by: |
| Hypoxic hypoxemia | Hypoxemia as a result of hypoxia (decreased $pO_2$). | - decreased $pO_2$ and $sO_2$ with normal cHb, |
| Toxemic (toxic) hypoxemia | Hypoxemia as a result of a decrease in $O_2$ binding ability of Hb (e.g. by formation of COHb or MetHb)(decreased $sO_2$). | - decreased $sO_2$ with normal $pO_2$ and cHb, |
| Anemic hypoxemia | Hypoxemia as a result of anemia (decreased cHb). | - decreased cHb with normal $pO_2$ and $sO_2$. |
| Hyperoxemia | Increased $O_2$ concentration compared with normoxemia. | |
| $O_2$ solubility of the blood | Proportionality between $O_2$ partial pressure and the concentration of physically dissolved oxygen in blood; usually described by the $O_2$ solubility coeffcient. | The most widespread is the Bunsen solubility coeffcient (mL $O_2$ /mL/atm). |
| Hüfner Number (Synonym: Hüfner factor) | The maximum amount of oxygen that can be bound by 1 g of hemoglobin. | On the basis of a molecular weight of 64458 and the fact that 1 mol Hb can bind a maximum of 4 mol $O_2$ the theoretical value is 1.39 mL $O_2$/g. The fact that in practically all individuals about 3 % of the total Hb exists as COHb, MetHb or SHb should not be expressed as an "in vivo Hüfner number", but as an appropriate reduction in the $O_2$ saturation of the blood ($sO_2$ = 97 %). |
| $O_2$ capacity | The maximum amount of oxygen that can be bound by Hb in a defined blood volume; expressed as $O_2$ concentration (e.g. mL $O_2$/dl.). The $O_2$ capacity is the product of cHb and the Hüfner number. | The $O_2$ capacity is essentially a theoretical value since no experimental method is available that allows complete saturation of the total Hb with $O_2$ . Traces of COHb and MetHb will always remain which, although not interfering with the determination of the $O_2$ capacity, will be included in the measurement of Hb (as total Hb). Not to be confused with the "$O_2$ transport capacity" (see definition). |
| $O_2$ binding curve (Synonym: $O_2$ dissociation curve) | Graphical relationship (S- shaped) between the $O_2$ saturation of hemoglobin (chemically bound $O_2$) and the $O_2$ partial pressure of the blood: $sO_2$(%) as a function of $pO_2$ (mmHg), or $psO_2$ (%) as a function of $pO_2$ (mmHg). | At a $pO_2$ of over I50 mmHg, a maximum $sO_2$ can be reached of only up to 98 %, a $psO_2$ of 100 %, resp. |
| $O_2$ content curve (Synonym: $O_2$ concentration curve) | Graphical relationship (S-shaped) between the $O_2$ content (chemically bound plus physically dissolved $O_2$) and $O_2$ partial pressure of the blood: $cO_2$ (mL/dL) as a function of $pO_2$ (mmHg). | At a $pO_2$ of over 150 mmHg, the $O_2$ content curve shows a linear increase whose slope is dependent upon the $O_2$ solubility. |

**TABLE II. Definitions, continued**

| | | |
|---|---|---|
| Half-saturation pressure (p50, p0.5) | The $O_2$ partial pressure that leads to 50 % saturation of hemoglobin ($sO_2$ = 50 % or 0.5). | The p50 (p0.5) provides an approximate indicator of the status of the $O_2$ binding curve in the form of $sO_2$ (%) as a function of $pO_2$ (mmHg) or, in the presence of significant concentrations of COHb or MetHb, as $psO_2$ (%) as a function of $pO_2$ (mmHg). |
| Arterio-venous $O_2$ difference | The difference between arterial and venous ($avDO_2$) or mixed venous ($a\bar{v}DO_2$) oxygen, expressed in units of partial pressure ($pO_2$), saturation ($sO_2$) or concentration ($cO_2$) (mmHg, %, mL/dl.). | The greatest predictive value is provided by the $avDO_2$ in concentration units; this is the only parameter that yields information on the $O_2$ consumption of an organism or organ (taking into account the blood flow). |
| Alveolo-arterial $O_2$ difference | The difference between the alveolar and arterial $O_2$ partial pressures. | |
| $O_2$ uptake | The amount of $O_2$ taken up per unit time via the respiration (mL $O_2$ /min), given by the product of the ventilation and the difference between the concentrations of inhaled and exhaled $O_2$ : $\dot{V}O_2 = \dot{V} \cdot (FIO_2 - FEO_2)$. | Under steady state conditions identical to the $O_2$ consumption of the organism. |
| $O_2$ transport (Synonyms: $O_2$ transport capacity; $O_2$ supply; $O_2$ availability) | The amount of oxygen supplied to the organism via the blood flow per unit time (mL $O_2$ /min), given by the product of the cardiac output and the arterial $O_2$ concentration: $\dot{T}O_2 = C.O. \cdot caO_2$. | Not recommended: $O_2$ delivery ($DO_2$). |
| $O_2$ consumption | The amount of oxygen consumed by the whole organism per unit time (mL $O_2$ /min), given by the product of the cardiac output and the arterio-mixed venous $O_2$ difference: $\dot{Q}O_2 = C.O. \cdot a\bar{v}DO_2$. | Under steady state conditions identical to the $O_2$ uptake. |

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