Simulation Model of Blood O2 and CO2 Content and Blood Acid-Base Chemistry

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Introduction:
Siggaard-Andersen (1960, 1962) constructed the pH-log(pCO_2) titration nomogram with Buffer base and Base excess (BB & BE) curves. Present automats used for clinical measurements work at temperature of 37°C but still commonly use the original non-corrected equations derived at 38°C. Moreover, the evaluation of the acid-base status changes which follow the plasma protein concentration disturbances is still very problematic because normal plasma protein concentrations were assumed during the nomogram construction. The next approach is the "modern" description according to *Stewart's* strong ion difference *(1983)*. Unfortunately, due to a necessity of covering of entire pathways of sodium, potassium and chlorides, this approach is not very suitable for mathematical modelling of the acid-base chemistry (ABC). *Rees and Andreassen (2005)* have recently proposed a mathematical model of the blood ABC, considering the total O_2 and CO_2 components and the reactions in the plasma and erythrocyte fractions. Their model shows the links between the Stewart's concept of strong ion difference and the more traditional formalism of Siggaard Andersen's total buffer base.

Methods:
Authors base their models on a set of independent "state variables". This set unambiguously determines the acid-base status and the O2, CO2 content of an isolated blood sample. The set is stated as follows: **Temperature** (temp), **blood haemoglobin concentration** (Hb), **plasma albumin concentration** (Alb), **total blood O_2 content** (O_2tot), **total blood CO_2 content** (CO_2tot) and so called **Base Excess standard concentration** (BEst). We define the BEst as the BE obtained under following conditions: temperature is virtually set at 37°C, oxyhaemoglobin saturation is virtually set to be 100% and the level of plasma proteins is virtually set to be normal. In accordance with this definition, the actual value of BE equals to BEst corrected to respect the actual O_2tot, saturation, temperature and plasma protein content of the given sample. The BEst value is independent of the changes in CO_2tot, O_2tot, temp, Hb or Alb! Therefore, the BEst is only function of flows in H^+/OH^- and HCO3$^-$. Other commonly measured variables, such as pH, pO_2, HCO_3^- content, oxyhaemoglobin saturation, etc. are fully dependent on the state variables and authors call them the "derived variables".

Results:
The model of the blood acid-base and blood gases chemistry has been used as a subsystem in larger models. It has also formed a base for various clinical calculations (i.e. evaluation of the rebreathing examinations etc.)., The conversion of the state variables to the required derived variables and vice versa is crucial in such clinical applications. The model and its applications are available at ***http://patf-biokyb.lf1.cuni.cz.***

Conclusions:
The models are very important as a core of educational simulators while also being a very useful tool for non-trivial clinical calculations of physiological values. However, we are still fighting with **a lack of consistent groundwork experimental data**. The model was fitted on partial experimental data from various authors, but presently available data possess many imperfections (most commonly

they don't cover areas of abnormal temperatures, abnormal concentrations of plasmatic proteins and low haemoglobin saturation). Hence, the team of authors design **a fully automated experimental apparatus** for the measurement of the acid-base and blood gases status of a blood sample under various conditions. It will enable us to obtain a unique consistent and comprehensive set of data, covering the areas of abnormal physiological values, for they commonly occur in critical care.