Supplementary Methods

Derivation equations for acid-base calculations in blood plasma used to create summary equation too determine pH ($-\log_{10}[H^+]$) based on principles of electroneutrality.

(a) Water dissociation:

$$K'_w = [H^+] \times [OH^-] \quad \text{therefore} \quad [OH^-] = \frac{K'_w}{[H^+]} \qquad \text{(ES1)}$$

(b) Bicarbonate (HCO_3^-) formation:

$$K_c = \frac{[H^+] \times [HCO_3^-]}{pCO_2} \quad \text{therefore} \quad [HCO_3^-] = \frac{[K_c] \times [pCO_2]}{[H^+]} \qquad \text{(ES2)}$$

(c) Carbonate (CO_3^{2-}) formation:

$$K_3 = \frac{[H^+] \times [CO_3^{2-}]}{HCO_3^-} \quad \text{therefore} \quad [CO_3^{2-}] = \frac{[K_3] \times [HCO_3^-]}{[H^+]} \qquad \text{(ES3)}$$

(d) Weak acid conservation and dissociation:

$$[A_{tot}] = [HA] + [A^-] \quad \text{and} \quad K_A = \frac{[H^+] \times [A^-]}{[HA]} \qquad \text{(ES4)}$$

$$\text{therefore} \quad [A^-] = \frac{K_A \times [A_{tot}]}{K_A + [H^+]} \qquad \text{(ES5)}$$

(e) Principle of electroneutrality:

$$[SID] = [Na^+] - [Cl^-] \qquad \text{(ES6)}$$

$$[SID] + [H^+] - [HCO_3^-] - (2 \times [CO_3^{2-}]) - [OH^-] - [A^-] = 0 \qquad \text{(ES7)}$$

(f) Using equations E1-E6, equation the weak anions in E7 can be expressed in terms of $[H^+]$:

$$[SID] + [H^+] - \frac{K_c \times pCO_2}{[H^+]} - 2 \times \frac{K_c \times K_3 \times pCO_2}{[H^+]^2} - \frac{K_w}{[H^+]} - \frac{K_A \times [A_{tot}]}{K_A + [H^+]} = 0 \qquad \text{(ES8)}$$

Equilibrium constants used for the model are displayed in table 1. Using goal seeking reiteration processes, it is possible to solve this equation for $[H^+]$ for any given SID, pCO_2 and A_{tot}. Once pCO_2 and $[H^+]$, it is possible to determine bicarbonate concentration using ES2.