Relationship between Hematocrit and CO₂ Contents in Whole Blood and True Plasma

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Abstract The amount of CO₂ liberated out of the red cell was measured by decreasing P_{CO_2} in human blood with different fractional hematocrits of about 0.24, 0.45, and 0.75, respectively, in order to elucidate whether it depends on the hematocrit and the intracellular pH. From a venous P_{CO_2} level the P_{CO_2} of the sample blood was lowered to 12 Torr. P_{CO_2} , CO₂ content, pH, Cl⁻, and Na⁺ were measured in whole blood and true plasma before and after the reduction of P_{CO_2} . Change in water concentration in plasma was calculated from change in plasma Na⁺ concentration. The bicarbonate shift well counterbalanced to the Cl⁻ shift. As the hematocrit was decreased, the amount of CO₂ released per mol of hemoglobin increased, while the change in intracellular bound CO₂ concentration decreased. That is, the intracellular bound CO₂ became higher in the lower hematocrit blood than in the higher hematocrit one. This fact suggested that the intracellular pH became higher as the hematocrit was lowered, and thus the amount of alkali bound with hemoglobin or the CO₂ release was enhanced. The Donnan ratio of the bound CO₂ at 12 Torr was independent of the hematocrit, though the pH was inversely related to the hematocrit.

Key Words: CO₂ content in blood, CO₂ content in plasma, hematocrit, bicarbonate shift, chloride shift.

For measuring the diffusion rate of CO₂ into and out of the red cell, it is absolutely necessary to obtain quantitative relations between the hematocrit and the CO₂ contents in the red cell and surrounding medium. The CO₂ content in the plasma depends not only on the buffer action of plasma protein, but also on the buffer action of hemoglobin, and therefore, on the extent of chloride and bicarbonate shifts across the red cell membrane. VAN SLYKE *et al.* (1923) measured the

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amount of alkali bound with hemoglobin, (BP)c and found that it linearly increased with pH. Since the Donnan ratio should be independent of the hematocrit the ratio of bicarbonate content change in plasma to that in red cells increases with a decrease of the hematocrit. Thus, the bicarbonate shift per mol of hemoglobin is expected to increase as the hematocrit is decreased. Furthermore, the intracellular pH would be increased in parallel with the released bicarbonate quantity, $\Delta(\text{BP})_c$.

When a blood sample is put in contact with a low P_{CO_2} gas mixture, CO_2 molecules diffuse out of the red cell into a gas phase, reducing the bicarbonate concentration within the red cell. And bicarbonate shift occurs from the plasma into the red cell according to its concentration gradient in exchange for Cl^- ion. As long as the bicarbonate shift proceeds, hydrogen ions are liberated from hemoglobin and pH turns alkaline. The more the bicarbonate shift and the CO_2 release, the higher will be the intracellular pH at the final equilibrium state. In the lower hematocrit blood, the change in (BP)c may certainly be greater than in the higher hematocrit one, but it can not exceed the extent defined by the buffer value and the intracellular pH change. From the Henderson-Hasselbalch equation it is realized that at a constant P_{CO_2} the higher pH is attained by a higher HCO_3^- concentration. Namely, in order to secure the pH at a higher alkaline level at a constant P_{CO_2} , the bicarbonate concentration must be higher. Thus, it seems quite possible that the magnitude of the change in (BP)c caused by changing P_{CO_2} is inversely related to that in bicarbonate concentration inside the red cell.

In order to confirm the validity of the above hypothesis, the changes in CO_2 contents and pH's of the whole blood and true plasma with a fall in P_{CO_2} were measured at three different fractional hematocrits of about 0.24, 0.45, and 0.74, respectively. As a substitute for the change in intracellular bicarbonate, the change in bound CO_2 in the red cell, $\Delta(\overline{\text{CO}_2})_c$, was measured. The (BP)c change, $\Delta(\text{BP})_c$, was evaluated by the change in bound CO_2 of the whole blood minus that of the separated plasma. From the measured data it was clarified that the released CO_2 per mol of hemoglobin increased as the hematocrit was decreased, whereas the change in bound CO_2 concentration in the red cell was smaller in the samples with lower hematocrit. In other words, the contribution of the bicarbonate shift to the total CO_2 release out of the red cell became greater as the hematocrit was decreased. We also found that plasma pH increased as the hematocrit was decreased, but the Donnan ratio for the bound CO_2 showed no significant dependency on the hematocrit.

SYMBOLS AND NOTATIONS

(BP)c: buffer base of hemoglobin (mmol/liter blood)

$\Delta(\text{BP})_c$: change in buffer base of hemoglobin (mmol/liter blood)

$\Delta(\text{BP})_p$: change in buffer base of plasma protein (mmol/liter plasma)

- Cb_0 : CO₂ content in blood at venous P_{CO_2} (mmol/liter blood)
 Cb_1 : CO₂ content in blood after equilibration (mmol/liter blood)
 Cp_0 : CO₂ content in plasma at venous P_{CO_2} (mmol/liter plasma)
 Cp_1 : CO₂ content in plasma after equilibration (mmol/liter plasma)
 Cl_0^- : Cl⁻ concentration in plasma at venous P_{CO_2} (mmol/liter plasma)
 Cl_1^- : Cl⁻ concentration in plasma after equilibration (mmol/liter plasma)
 $(CO_2)c$: intracellular bound CO₂ (mmol/liter RBC)
 $\Delta(CO_2)c$: change in intracellular bound CO₂ (mmol/liter RBC)
 Intra $\Delta(CO_2)c = \Delta(CO_2)c \cdot Ht_1$ (mmol/liter blood)
 $(CO_2)p$: bound CO₂ content in plasma (mmol/liter plasma)
 $\Delta(CO_2)p$: change in bound CO₂ in the plasma due to the bicarbonate shift (mmol/liter plasma)
 Extra $\Delta HCO_3^- = \Delta(CO_2)p \cdot (1 - Ht_1)$ (mmol/liter blood)
 $\Delta(BP)c^*$: change in buffer base of hemoglobin per mmol Hb (mmol/mmol Hb)
 $\Delta(CO_2)c^*$: change in intracellular bound CO₂ per mmol Hb (mmol/mmol Hb)
 Ht_0 : fractional hematocrit at venous P_{CO_2}
 Ht_1 : fractional hematocrit after equilibration
 $\Delta Ht = Ht_0 - Ht_1$
 Na_0^+ : Na⁺ concentration in plasma at venous P_{CO_2} (mmol/liter plasma)
 Na_1^+ : Na⁺ concentration in plasma after equilibration (mmol/liter plasma)
 P : P_{CO_2} (Torr)
 αc : CO₂ solubility in the red cell (mmol/(liter RBC · Torr))
 αp : CO₂ solubility in plasma (mmol/(liter plasma · Torr))

METHODS

Blood samples (*ca.* 15 ml) obtained from 8 male laboratory personnel, 27 to 59 years of age, were used for the analyses. Immediately after the sampling, P_{CO_2} , pH, C_{CO_2} , Hb concentration, and hematocrit were measured in the whole blood at the venous P_{CO_2} level. The P_{CO_2} and pH were measured by I-L-Meter, type 227, and the CO₂ content was measured by a Natelson's analyzer (NATELSON, 1951), where the correction was made according to TAZAWA *et al.* (1983). The hemoglobin concentration was measured by the cyan-methemoglobin method (Coulter, S-Jr), and expressed on a heme basis. In parallel with the above analyses the same sample of 1 ml was spun down anaerobically at 640 *g* for about 10 min at 37°C to obtain the true plasma. Then, the true plasma was analyzed for P_{CO_2} , pH, C_{CO_2} , Na⁺, and Cl⁻. Na⁺ and Cl⁻ ions were measured by using ion-electrode (Stat/Ion, Technicon, U. S. A.). The P_{CO_2} of the true plasma measured after the centrifugation was about 2 Torr lower than that of the whole blood. In contrast, the pH of the true plasma was about 0.014 higher than that

of the whole blood, on an average.

The rest of the sample was subdivided into the three groups of 1, 3, and 9 ml, which were referred to as A, B, and C, respectively. The sample of the group C was transferred from the syringe to a test tube with paraffin oil of about 3 cm in height. Then, the true plasma was separated from the blood with the same conditions as mentioned above. After the centrifugation 3 ml of the plasma was removed from the test tube: 1 ml of which was added to the blood of group A in order to obtain a sample of about 0.25 in hematocrit. The rest of 2 ml was used as the separated plasma. The rest of the C group was used as the sample with hematocrit of 0.75, and the A and B groups had hematocrits of about 0.25 and 0.45. Above all, through the above procedures the samples with fractional hematocrits of 0, about 0.25, 0.45, and 0.75 were prepared.

These samples were tonometered by a tonometer (I-L-Meter, 237) at P_{CO_2} of 12 Torr and P_{O_2} of 175 Torr for 10 to 15 min. After the equilibration, C_{CO_2} , pH, and hematocrit were measured in a portion of each sample. The rest of each sample was set for centrifugation to obtain true plasma, in which C_{CO_2} , pH, Cl^- , and Na^+ were measured. The hematocrits of the venous blood and the samples with three different hematocrits after tonometry were measured by a centrifugation method. The hematocrits of the samples before tonometry were estimated from Na^+ concentrations in the plasma before and after the tonometry. The details of the latter method will be described later. All the analyses were made in duplicate, and the algebraic mean was adopted as the measured value.

Calculation of the analyzed data. Bound CO_2 concentration in plasma, $(\overline{\text{CO}_2})_p$ was calculated from the CO_2 content in the true plasma, C_p by subtracting from it the physically dissolved CO_2 as follows:

$$(\overline{\text{CO}_2})_p = C_p - \alpha_p \cdot P \text{ (mmol/liter plasma),} \quad (1)$$

where α_p is the CO_2 solubility in the plasma, *i. e.* 0.0308 mmol/(liter · Torr). Similarly, the bound CO_2 in the red cell was evaluated as,

$$(\overline{\text{CO}_2})_c = (C_b - (1 - \text{Ht})C_p) / \text{Ht} - \alpha_c \cdot P \text{ (mmol/liter RBC),} \quad (2)$$

where C_b is the CO_2 content in whole blood, Ht is the fractional hematocrit and α_c , the CO_2 solubility in the red cell, 0.026 mmol/liter RBC (VAN SLYKE *et al.*, 1928; BARTELS *et al.*, 1959).

When the P_{CO_2} decreases, the hematocrit becomes smaller, because the water shift occurs from the red cell to plasma together with the Cl^- ion. Therefore, in order to calculate the amount of bicarbonate and Cl^- shifts it is necessary to calculate the hematocrit before and after tonometry. Since the Na^+ ion was not thought to shift across the red cell membrane, the change in hematocrit was evaluated by use of Na^+ concentrations in plasma before and after tonometry, Na^+_0 and Na^+_1 , as follows:

$$\Delta \text{Ht} = (1 - \text{Ht}_1) (\text{Na}^+_0 - \text{Na}^+_1) / \text{Na}^+_0, \quad (3)$$

where Ht_1 is the measured hematocrit after tonometry. Using ΔHt value of Eq. (3) the amount of Cl^- shift was calculated as,

$$\Delta Cl^- = (Cl_1^- - Cl_0^- \cdot Na_1^+/Na_0^+) (1 - Ht_1) \text{ (mmol/liter blood)}. \quad (4)$$

The change in bound CO₂ concentration in plasma, due to the bicarbonate shift (mmol/liter plasma), was given by,

$$\Delta(\overline{CO_2})_p = (C_{p0} \cdot Na_1^+/Na_0^+ - C_{p1}) - \alpha p(P_0 \cdot Na_1^+/Na_0^+ - P_1) - \Delta(BP)_p, \quad (5)$$

where P_0 and P_1 are P_{CO_2} 's of venous and tonometered bloods, and $\Delta(BP)_p$ is the change in HCO_3^- concentration due to the buffer action of plasma protein. The $\Delta(BP)_p$ was calculated from a buffer value of the separated plasma by referring to the pH difference between venous and tonometered bloods. The change in bound CO₂, $\Delta(\overline{CO_2})_c$, in the red cell (mmol/liter RBC) was given as usual by,

$$\Delta(\overline{CO_2})_c = (Cb_0 - (1 - Ht_0)C_{p0})/Ht_0 - (Cb_1 - (1 - Ht_1)C_{p1})/Ht_1 - \alpha c(P_0 - P_1), \quad (6)$$

where Cb_0 and Cb_1 are the CO₂ contents in the whole blood of the venous and tonometered bloods.

The amount of bicarbonate shift (mmol/liter blood), extra ΔHCO_3^- , was given from Eq. (5) by,

$$\text{Extra } \Delta HCO_3^- = \Delta(\overline{CO_2})_p \cdot (1 - Ht_1). \quad (7)$$

The change in intracellular bound CO₂ per liter blood, intra $\Delta(\overline{CO_2})_c$ (mmol/liter blood), was given from Eq. (6) by,

$$\text{Intra } \Delta(\overline{CO_2})_c = \Delta(\overline{CO_2})_c \cdot Ht_1. \quad (8)$$

Thus, since the change in carbamate was thought to be very small as referred to the data of FERGUSON and ROUGHTON (1934) and STADIE and O'BRIEN (1937), the total bicarbonate change due to the hemoglobin buffer, $\Delta(BP)_c$ (mmol/liter blood) was given from Eqs. (7) and (8) by,

$$\Delta(BP)_c = \Delta(\overline{CO_2})_p \cdot (1 - Ht_1) + \Delta(\overline{CO_2})_c \cdot Ht_1. \quad (9)$$

The ratio of the HCO_3^- shift into RBC to $\Delta(BP)_c$, λ , was given from Eqs. (7) and (9) by,

$$\lambda = \Delta(\overline{CO_2})_p \cdot (1 - Ht_1) / \Delta(BP)_c. \quad (10)$$

The change in hemoglobin buffer base per mmol of Hb, $\Delta(BP)_c^*$, was evaluated by dividing $\Delta(BP)_c$ of Eq. (9) by molar concentration of hemoglobin (as heme) in blood as follows:

$$\Delta(BP)_c^* = \frac{\Delta(BP)_c \text{ (mmol/liter blood)}}{(\text{Hb g/liter blood}) \times 0.062}, \quad (11)$$

where 0.062 is a factor to convert the concentration of hemoglobin in g/liter to mmol/liter. The change in intracellular bound CO₂ per mmol of Hb, $\Delta(\overline{CO_2})_c^*$,

was obtained by dividing the intra $\Delta(\overline{\text{CO}_2})_c$ of Eq. (8) by molar Hb concentration.

RESULTS

In Table 1 the summarized data in the 8 subjects are shown. The average venous P_{CO_2} was 57.1 Torr and its S. D. was 4.6 Torr. In order to prevent the

Table 1. Summarized data on the relations between the hematocrit, and CO_2 contents in whole blood and red cell and plasma compartments, pH, and Cl^- and Na^+ concentrations.

P_{CO_2} (mmHg)	Ht	Cbco_2 (mmol/ liter blood)	$(\overline{\text{CO}_2})_p$ (mmol/ liter plasma)	$(\overline{\text{CO}_2})_c$ (mmol/ liter RBC)	$\frac{(\overline{\text{CO}_2})_c}{(\overline{\text{CO}_2})_p}$	pH	Cl^- (mmol/ liter plasma)	Na^+ (mmol/ liter plasma)
57.1 ± 4.6	0.457 ± 0.037	25.24 ± 1.60	28.49 ± 1.89	18.23 ± 2.02	0.64 ± 0.04	7.329 ± 0.024	103 $\pm$ 2	141 $\pm$ 2
	0.236 ± 0.011	17.70 ± 1.28	19.16 ± 1.32	11.39 ± 1.08	0.60 ± 0.04	7.801 ± 0.035	107 $\pm$ 2	138 $\pm$ 1
12	0.450 ± 0.039	12.48 ± 0.66	15.06 ± 0.94	8.48 ± 0.70	0.57 ± 0.06	7.686 ± 0.043	110 $\pm$ 2	137 $\pm$ 2
	0.748 ± 0.039	8.31 ± 0.49	10.80 ± 0.84	7.02 ± 0.41	0.63 ± 0.04	7.491 ± 0.045	112 $\pm$ 2	136 $\pm$ 2

Fig. 1. The relation between the ratio, $(\overline{\text{CO}_2})_c/(\overline{\text{CO}_2})_p$ and the pH in plasma. $(\overline{\text{CO}_2})_c$ is the bound CO_2 content in the red cell in terms of mmol/liter RBC, and $(\overline{\text{CO}_2})_p$ is the same in plasma in terms of mmol/liter plasma. The broken line was obtained from the data of DILL *et al.* (1937) by dividing the Donnan ratio by the ratio of water concentration in the plasma to that in the red cell, 1.29.

sample from hemolysis the equilibration procedure of oxygenating the venous blood was omitted. Thus, a problem was expected to arise that the Donnan ratio for the bound CO₂, $(\overline{\text{CO}_2})_c/(\overline{\text{CO}_2})_p$, was to some extent higher in the venous blood than in the oxygenated blood by the released quantity of carbamate. However, it was not significantly higher in reference to the data on the oxygenated blood of TAZAWA *et al.* (1983). In general, Donnan's ratio is inversely related to pH. Since the pH values in the tonometered blood were higher in the lower hematocrit group than in the higher hematocrit group, the Donnan ratio for the $\overline{\text{CO}_2}$ was expected to be lower in the lower hematocrit group. However, such a tendency was not observed among the three groups at 12 Torr P_{CO_2} . The individual ratios of $(\overline{\text{CO}_2})_c/(\overline{\text{CO}_2})_p$ plotted against pH are shown in Fig. 1. The broken line shows the average values recalculated from the data on the Donnan' ratio of DILL *et al.* (1937) by dividing it by the water concentration ratio of plasma to the red cell obtained by SIGGAARD-ANDERSEN (1974), that is, 1.29. In a hematocrit range higher than 0.45 the $(\overline{\text{CO}_2})_c/(\overline{\text{CO}_2})_p$ certainly decreases as pH increases. However, when the hematocrit was about 0.24, the ratio increased somewhat, indicating that the decrease of the intracellular bound CO₂ became smaller as the hematocrit was decreased.

The Na⁺ concentration was higher at the venous P_{CO_2} level than at 12 Torr, and the lower hematocrit had a higher Na⁺ concentration at $P_{\text{CO}_2}=12$ Torr. As shown in Table 1, with reducing P_{CO_2} to 12 Torr, the hematocrit of the original venous blood decreased from 0.457 to 0.450. When the change in hematocrit was

Fig. 2. Relation between the Cl⁻ and HCO₃⁻-shifts, observed when P_{CO_2} was reduced from the venous level to 12 Torr.

Fig. 3. Relations between the changes in hemoglobin buffer base, $\Delta(\text{BP})_c^*$ and in intracellular bound CO_2 , $\Delta(\text{CO}_2)_c^*$ and the hematocrit.

calculated by using Na^+ concentration from Eq. (3), on the other hand, the decrease was about 0.015 in fraction. According to the data of TAZAWA *et al.* (1983), it was about 0.014, when the hematocrit was determined by a centrifugation method. Taking into account a great error in the hematocrit measurement, the difference between the above two hematocrit values, 0.008 seems to be insignificant.

Between the Cl^- shift calculated from Eq. (4) and the bicarbonate shift calculated from Eq. (7) a close correlation was observed as shown in Fig. 2. The correlation coefficient was 0.75 and the regression line was given by,

$$\Delta\text{Cl}^- = 1.19 \times \Delta\text{HCO}_3^- - 1.13 \text{ (mmol/liter blood)}. \quad (12)$$

The relationships between the hematocrit and $\Delta(\text{CO}_2)_c^*$ and $\Delta(\text{BP})_c^*$ (mmol/mmol Hb) are shown in Fig. 3. The $\Delta(\text{CO}_2)_c^*$ values increased convexly with the increase of hematocrit, suggesting that the intracellular bound CO_2 , $(\text{CO}_2)_c^*$, decreased, as the hematocrit was increased. At the same P_{CO_2} level, the higher the bicarbonate content, the higher the pH value, as expected from the Henderson-Hasselbalch equation. Therefore, the intracellular pH is expected to be higher in lower hematocrit samples. Unlike $\Delta(\text{CO}_2)_c^*$, $\Delta(\text{BP})_c^*$ increased roughly linearly as the hematocrit was decreased, where the correlation coefficient was 0.82 and the regression line was given by,

$$\Delta(\text{BP})_c^* = 1.47 - 0.87 \times \text{Ht (mmol/mmol Hb)}. \quad (13)$$

The pH in the plasma (pH_p) was linearly but inversely related to the hematocrit, as shown in Fig. 4. The regression line thereof was given by,

Fig. 4. pH in the plasma plotted against the hematocrit measured at $P_{CO_2}=12$ Torr.

Fig. 5. Relation between the ratio of the bicarbonate shift to the released bound CO₂ from hemoglobin (λ) and the hematocrit.

$$\text{pH}_p = 7.95 - 0.61 \times \text{Ht}, \quad (14)$$

where the correlation coefficient was 0.97.

In Fig. 5 are shown the λ ratios of Eq. (10) plotted against the hematocrit, where the λ decreased linearly as the hematocrit was increased, and its regression line was given by,

$$\lambda = 0.926 - 0.81 \times \text{Ht}, \quad (15)$$

are the correlation coefficient was 0.993.

DISCUSSION

The Donnan's ratios of H^+ , HCO_3^- , Cl^- , and the bound CO_2 have so far been believed to be inversely related to pH (HENDERSON, 1928; FITZSIMONS and SENDROY, 1961; GARBY and MELDON, 1977). However, the data of Table 1 shows that the ratio of $(\text{CO}_2)_c/(\text{CO}_2)_p$ was not lower in a low hematocrit group than in high groups, though the pH in the low hematocrit group was higher than in the high hematocrit group, as shown in Fig. 4. The average $(\text{CO}_2)_c/(\text{CO}_2)_p$ ratio of the low hematocrit group was 0.60 and higher than that of the normal hematocrit group, 0.57, though there is no statistical significance between them. The broken line of Fig. 1 was obtained from Dill's data, which coincided fairly well with the ratios in the normal hematocrit group. Their ratios are a little higher than those measured in the normal blood by other authors (VAN SLYKE *et al.*, 1925; HASTINGS *et al.*, 1928; FITZSIMONS and SENDROY, 1961; TAZAWA *et al.*, 1983). Nevertheless, most of the

Fig. 6. Relationship between the bound CO_2 and pH in the plasma.

plotted points, measured in the samples with hematocrit=0.24, deviated to the higher side of Dill's value, suggesting that the Donnan ratio for the bound CO₂ receives somewhat the influence of the hematocrit.

In blood with normal hematocrit, the extracellular pH increases as the P_{CO_2} and therefore the bound CO₂ decrease, where the lower the bound CO₂ content, the higher the pH becomes. However, when the P_{CO_2} is decreased to a certain level in samples with varying hematocrits, the rise of the extracellular pH becomes greater as the hematocrit is decreased. That is, when the hematocrit is varied, the pH becomes higher in parallel with the bound CO₂ concentration. Figure 6 shows the distribution of $(\overline{\text{CO}_2})_p$ against pH, at 12 Torr P_{CO_2} , where both the pH and bound CO₂ were higher in the lower hematocrit than in the high hematocrit. Such a relation as above seems to hold not only in plasma, but also in the red cell. From the relations between $\Delta(\text{BP})c^*$, $\Delta(\overline{\text{CO}_2})c^*$, and the hematocrit, as shown in Fig. 3, it is easily seen that the increase in CO₂ release out of the red cell, that is, the increase of $(\text{BP})c^*$ results from the increase of pH_c . Since the intracellular bound CO₂ content is higher at the venous P_{CO_2} level than at 12 Torr, it is realized from Fig. 3 that the bound CO₂ is higher in the low hematocrit than in the high hematocrit. Therefore, the higher pH_c would be caused by the higher bound CO₂ content within the red cell. This experimental evidence may sound paradoxical, because an increase of CO₂ release out of the red cell usually results in a decrease of the bound CO₂. However, this paradoxical relation is very important for determining the equilibrium point of P_{CO_2} , pH, and CO₂ content. When the intracellular pH increases due to the outward CO₂ diffusion, the dehydration reaction of bicarbonate proceeds, increasing $(\text{BP})c$ and inducing the inward bicarbonate shift from the plasma. As long as the dehydration proceeds, the amount of the bicarbonate shift and $(\text{BP})c$ continue to increase in exact proportion to the increase of the intracellular pH. Therefore, the larger the amount of bicarbonate shift, the higher the final $(\text{BP})c$ and pH_c levels. The high pH_c in turn arises with the high $(\overline{\text{CO}_2})c^*$, therefore, the difference between the initial and final $(\overline{\text{CO}_2})c^*$ becomes smaller as the hematocrit is reduced. Therefore, the magnitude of the $\Delta(\text{BP})c^*$ will become inversely related to that of $\Delta(\overline{\text{CO}_2})c^*$, as shown in Fig. 3. This fact seems the basic principle to define the final point of the CO₂ release out of the red cell, the details of which will be described in the following paper (MOCHIZUKI *et al.*, 1983).

As shown in Fig. 5, the bicarbonate shift ratio certainly increases as the hematocrit is decreased. However, the net amount of the bicarbonate shift, that is, the amount of shifting HCO_3^- ions per unit volume of blood, extra ΔHCO_3^- of Eq. (7), tends to decrease with hematocrit, showing a maximum at the normal hematocrit value. In other words, to keep the CO₂ transport at a high level, the normal hematocrit seems the most efficient and advantageous.

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