Can Hemoglobin-Hematocrit Relationship Be Used to Assess Hydration Status?

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ABSTRACT

There is an opinion that if the hematocrit is lower than multiplied hemoglobin (Hct< 3 x Hb), the patient is overhydrated, and if it is higher (Hct> 3 x Hb), the patient is dehydrated. This practice is flawed. Hemoglobin-hematocrit relationship is not affected by a patient's hydration status, and thus its alteration cannot be used to assess it. The relationship can only be altered if the red blood cells (RBCs) are abnormal, or look altered because of technical factors.Instead of multiplying hemoglobin value and comparing it to the hematocrit, a quicker way to assess is to evaluate the mean corpuscular hemoglobin concentration (MCHC). Clinicians can still predict hydration status by comparing the hematocrit to its baseline value or the laboratory's reference range, by physical examination, or use other laboratory tests such as urine specific gravity and osmolality.

Keywords: Hematocrit, hemoglobin, hydration

ABSTRAK

Ada pendapat bahwa jika nilai hematokrit lebih rendah dari nilai kadar hemoglobin dikalikan tiga maka pasien mengalami kelebihan cairan, dan jika lebih tinggi maka pasien mengalami dehidrasi. Praktik penilaian seperti ini tidak benar. Hubungan hemoglobin-hematokrit tidak dipengaruhi oleh status hidrasi pasien, dan oleh karena itu tidak dapat digunakan untuk menilainya. Hubungan tersebut hanya bisa diubah jika eritrosit tidak normal, atau terlihat seakan-akan berubah karena faktor teknis. Cara yang lebih cepat adalah menilai *mean corpuscular hemoglobin concentration* (MCHC). Klinisi masih bisa menilai status hidrasi dengan membandingkan hematokrit dengan nilai basalnya atau nilai rujukan laboratorium, dengan pemeriksaan fisik, atau melakukan pemeriksaan laboratorium lain seperti berat jenis urin dan osmolalitas. **Hubertus Hosti Hayuanta. Dapatkah Rasio Hemoglobin-Hematokrit Digunakan untuk Menilai Status Hidrasi?**

Kata kunci: Hematokrit, hemoglobin, hidrasi

Introduction

The human body regulates water very tightly because all of its functions depend heavily on the presence of fluid and its movement. Over- and dehydration can lead to various complications, from merely headaches to therapeutic failure, seizures, coma, and death.

There is a practice to assess hydration status through hemoglobin-hematocrit relationship. The hematocrit must always be three times the value of hemoglobin (Hct = 3 x Hb). If it is lower (Hct< 3 x Hb), the patient is overhydrated, and if it is higher (Hct> 3 x Hb), the patient is dehydrated.

No peer-reviewed literatures have ever been published regarding the practice, except for a few training materials. In a survey conducted by the author in 2015 to 157 medical doctors - 51% medical residents and 49% general practitioners graduated from various universities in Indonesia, 79.6% have heard about the practice, 72.4% of them used it in their clinical practice. Most were taught by medical specialists (52.4%) and consultants (33.9%) during their residencies (62.1% in discussions, 30.6% during rounds). But, is the practice reasonable?

This review discuss the hemoglobin-hematocrit relationship, the practice and its value, and alternatives to determine hydration status.

The Logic Behind the Practice

The practice relies on some basic understanding: hemoglobin value is the **absolute** number of hemoglobin stored in red blood cells (RBCs), hematocrit is the percentage of RBC volume to the blood sample volume,and 'real' hematocrit is always three times the hemoglobin value.

Therefore, if the hematocritis lower than the 'real' value (3 x Hb), there must be fluid excess that reduces the RBC volume percentage. And if the hematocrit is higher, there must be fluid loss that increases the RBC volume percentage. For example, if a patient has a hemoglobin value of 12.0, he should have a hematocrit of 36%. If he is overhydrated, his hemoglobin will still be 12.0, but his hematocrit will be less than 36%. And if he is dehydrated, his hemoglobin will also be 12.0, but his hematocrit will rise above 36%.

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What are Hemoglobin Value and Hematocrit Actually?

We must first consider the actual definition of hemoglobin value and hematocrit. Hemoglobin is a kind of protein contained in RBCs that is responsible for delivery of oxygen to the tissues.[1] Hemoglobin value is expressed in grams per deciliter (g/dL).[1,2] This is usually measured with spectrophotometer techniques.[2] The reference range is 14 to 18 g/dL for men, and 12 to 16 g/dL for women.[1]

Hematocrit is the proportion of the volume of a blood that is occupied by RBCs.[2] It is expressed in percentage (%) and can be determined manually or automatically.[1] In the manual method, the blood sample is centrifuged at a specific speed and time in a standardized glass tube. Hematocrit is then determined by visually comparing the height of RBC column and the height of total sample.[2] In automatic method, the machine counts the RBCs, measures the mean corpuscular volume (MCV), and then calculates the hematocrit using both variables. The reference range is approximately 40 to 54% for men, and 36 to 48% for women.[1]

Mean corpuscular volume, on the other hand, is the average volume of the RBC. It is expressed in femtoliters (fL) and it is one of the red cell indices. The other two are mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC). Mean corpuscular hemoglobin is the average hemoglobin content per RBC, measured in picograms (pg), while MCHC is the average hemoglobin concentration per RBC, measured in grams per deciliter (g/dL).[2] The reference range for MCV, MCH, and MCHC are, respectively 80 to 94 fL, 27 to 31 pg, and 32 to 36 g/dL.[3]

Is the Practice Reasonable?

The answer for the question is simply, no. The reason can be described by reviewing the basic understanding of hemoglobin value. In the practice, hemoglobin value is considered as an **absolute** number while actually it is not. It is a value of **concentration**, just like hematocrit.[2,4] The difference is that hemoglobin value is measured in mass per volume (g/dL), while hematocrit is volume per volume (%).

Thus, keeping in mind that both are values of concentration, hydration status affects hemoglobin and hematocrit equally. A patient with excessive fluid in his/her blood will have both hematocrit and hemoglobin values reduced, while a patient with fluid loss will have both hematocrit and hemoblogin values elevated. Hematocrit will always be three times the hemoglobin value, regardless patient's hydration status.

For example, if a patient has a hemoglobin value of 12.0 g/dL, he should have a 36% hematocrit. If he is overhydrated, his hematocrit will decrease, also his hemoglobin. And, if he is dehydrated, his hematocrit will increase, also his hemoglobin [Figure 1]. There will never be a change in hematocrit without the hemoglobin value following suit.

Hence, the only way to assess a patient's hydration status using hematocrit is not by comparing it with hemoglobin value, but with its own baseline value (the patient's usual hematocrit) or the laboratory's reference range. It is important to note that clinicians should only use laboratory's own reference range, not from other laboratories or a textbook. Reference range is heavily determined by the laboratory's measurement method, measurement device, and the reference range that is very lab-specific.

Other ways to assess a patient's hydration status that do not involve hematocrit include evaluating the patient's vital signs, looking for signs of dehydration (dryness) or overhydration (rales), measuring the patient's fluid input and output, or ordering other laboratory tests such as urine specific gravity or urine osmolality, even though its accuracy to diagnose dehydration only revolves around 60%.[5]

Clinical Factors that Do Influence Hemoglobin-Hematocrit Relationship

Even though the hemoglobin-hematocrit relationship is not changed by hydration, we do find that sometimes hematocrit is

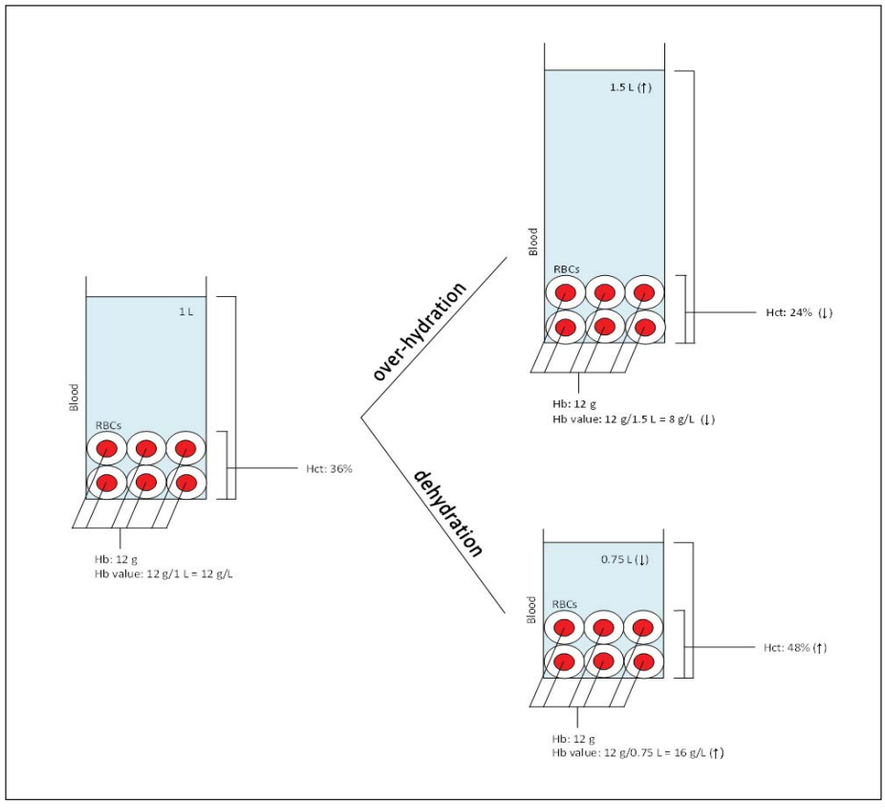

Figure 1. Hemoglobin-hematocrit change in different hydration state.
A change in hematocrit is always followed by a change in hemoglobin value in the same direction. RBCs, red blood cells; Hb, hemoglobin; Hct, hematocrit.

not three times the value of hemoglobin. This is because some conditions that affect it. The relationship is based on normal RBCs. Should there be a change in the normal hemoglobin or the RBC volume, reflected in MCHC, the relationship is surely changed.[4,6] Several conditions that may present with abnormal MCHC include iron deficiency anemia, anemia of chronic disease, sideroblastic anemia, thalassemia (low MCHC), hereditary spherocytosis (high MCHC), and variant hemoglobins (low or high MCHC). For example, a patient with hereditary spherocytosis will have an altered hemoglobin-hematocrit relationship. A spherocyte is an RBC with small volume and normal hemoglobin content.[7] A patient with spherocytosis will show low MCV, high MCH, and consequently, high MCHC, and the hematocrit will always be less than three times the hemoglobin value (Hct< 3 x Hb) [Figure 2].

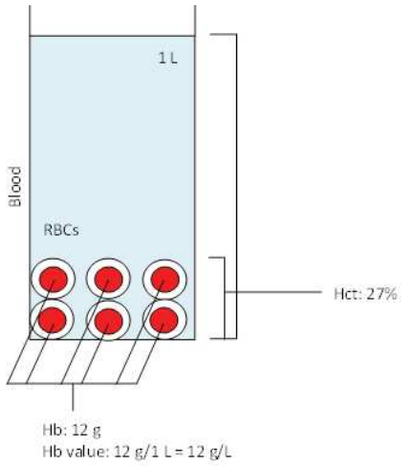

Figure 2. Hereditary spherocytosis with **high** MCHC. The hematocrit will be less than three times the value of hemoglobin. The values of 12 g/dL and 27% used in this figure are for illustration purpose only.

Another example is a patient with microcytic hypochromic RBCs. An RBC has reduced volume and much reduced hemoglobin content, reflected by some widening of the RBC's central pallor. A patient with microcytic hypochromic RBC will show low MCV, even lower MCH, and consequently, low MCHC, consequerntly the hematocrit will always be more than three times the hemoglobin value (Hct >3 x Hb) [Figure 3].[8]

The last example is a patient with macrocytic anemia. An RBC in macrocytic anemia has increased volume and equally increased hemoglobin content.[9] A patient with macrocytic anemia will show high MCV, high MCH, and normal MCHC; and the hematocrit will be three times the hemoglobin value (Hct = 3 x Hb) [Figure 4].

The hemoglobin-hematocrit relationship is true only if the hemoglobin concentration per RBC, or MCHC, is within the normal range. When the MCHC is not normal, the relationship no longer applies because MCHC basically describes the hemoglobin-hematocrit relationship itself, although on a cellular level and not on a total sample level. So rather than multiplying the hemoglobin value and comparing it to hematocrit, it may be better to just look at the MCHC, especially if we consider that MCHC has its own study-generated-reference range to compare to.

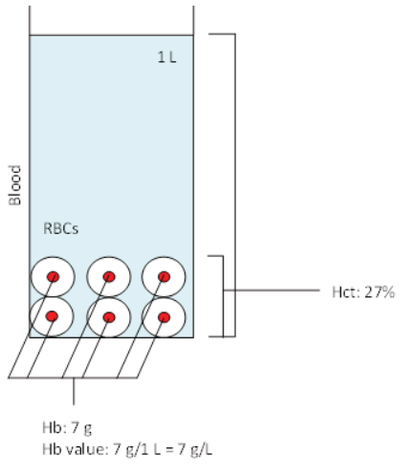

Figure 3. Microcytic hypochromic RBCs with **low** MCHC. The hematocrit will be more than three times the value of hemoglobin.[8]The values of 7 g/dL and 27% used in this figure are for illustration purpose only.

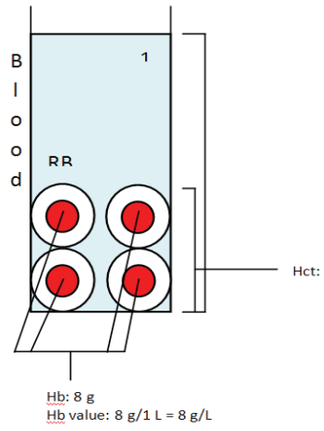

Figure 4. Macrocytic RBCs with **normal** MCHC. The hematocrit will be three times the value of hemoglobin. The values of 8 g/dL and 24% used in this figure are for illustration purpose only.

So, when a clinician or, especially, a clinical pathologist spot a discrepancy between the hemoglobin value and the hematocrit, or an abnormal MCHC, a blood film should be made and investigated for any RBC morphological abnormalities. If the RBCs show nothing abnormal, the hemoglobin-hematocrit disagreement may be caused by the technical factors.

Technical Factors that Do Influence Hemoglobin-Hematocrit Relationship

These factors are needed to be considered when a sample shows normal RBCs in blood film examination but shows discrepancy in the hemoglobin-hematocrit relationship. They originate from physiological phenomenon, incorrect procedures, or inherent errors of measurement devices used. RBCs in room temperature between 6 to 24 hours will swell, causing increased hematocrit without an elevation in hemoglobin value.[10] Inadequate homogenization prior to testing can also falsely increase or decrease the hematocrit.[8] A blood sample with too much EDTA will have its hematocrit decreased without subsequent elevation in hemoglobin value due to RBC shrinkage.[8,10]

Moreover, test methods are also sources of variations. As already explained, hematocrit is measured in two ways, manually and automatically. In the manual method, hematocrit may falsely increased or decreased if a result is incorrectly visually inspected [Figure 5]. This method is also affected when the patient has anemia, spherocytosis, or thalassemia in a different manner than what is already explained in the clinical factors. In such a patient, the RBC layer will trap more plasma when the sample is centrifuged, creating a hematocrit that is falsely higher than what is obtained from an automated machine.

Lastly, there is also a matter of inaccuracy and imprecision of measurement in both

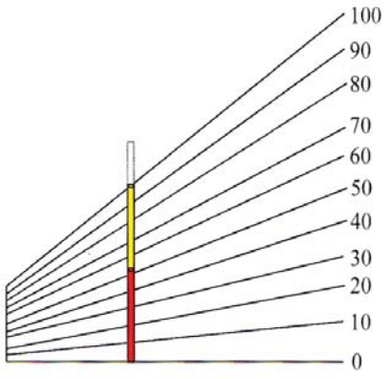

Figure 5. Microhematocrit reader chart.[11]
Mistakes may be made in determining the hematocrit visually.

methods. This is especially true in the automated method because hematocrit is derived from two other measurements (MCV and RBC count), further increasing its imprecision and inaccuracy. For example, some hematology analyzers have a hematocrit and hemoglobin coefficient of variance of 3%.[12] Assuming there isn't any inaccuracy, a sample with 12 g/dL hemoglobin and 36% hematocrit may be read as having a hemoglobin value of 11.6 g/dL (12 – 3/100*12) and a hematocrit of 37.1% (36 + 3/100*36), the patient will look like having microcytic hypochromic RBC (37.1 > 3 x 11.6) while he/she actually doesn't.

Summary
Hemoglobin-hematocrit relationship is not affected by a patient's hydration status, and thus its alteration cannot be used to assess it. The relationship can only be altered if the RBCs are abnormal, or because of technical factors. Instead of multiplying the hemoglobin value and comparing it to the hematocrit, a quicker way to assess the relationship is evaluating the MCHC. Clinicians can still predict a patient's hydration status by comparing the hematocrit to its baseline value or the laboratory's reference range, by performing a physical examination, or by using other laboratory tests such as urine specific gravity and osmolality.

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