# Peripheral Blood Hematocrit Is a Poor Surrogate for Red Blood Cell Volume in Patients with Volume Excess or Depletion

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## BACKGROUND

➢Anemia ( Hg <11) is associated with poor prognosis in acutely and chronically ill patients – particularly in those with volume excess or depletion. Conversely Hg above 13 portends greater morbidity and mortality. (Choir and Create studies)

➢While peripheral hematocrit (pHct) may provide a good estimate of red blood cell volume (RBCV) in euvolemic patients, discordance between pHct and RBCV has been reported in critical care, hematology and congestive heart failure (CHF) settings.

➢Dialysis often produces large variations in pHct; 4 hours of ultrafiltration may increase pHct by >5% points.

➢We considered whether volume status may be important in assessments of RBCV in clinical situations in which achievement of adequate perfusion and tissue oxygenation dictate management.

➢To examine whether pHct is a suitable proxy for RBCV, we performed a retrospective analysis on a large population of patients with a wide variety of medical conditions.

## DEFINITIONS

➢ TBV = PV + RBCV (where PV= plasma volume)

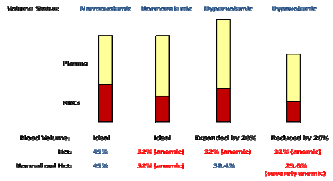
➢ pHct (% packed red cell volume)= [RBCV/(RBCV + PV)]x100

➢Normalized Hct (nHct)= pHct (TBV/Ideal TBV)

➢Blood Volume Analysis (BVA): FDA approved, radioisotopic method of determining PV, RBCV and TBV. Observed results are compared with ideal volumes which are predicted based on patient gender, height, and weight.

## CENTRAL QUESTION

Figure 1. Is pHct a good surrogate for RBCV?




## OBJECTIVE

To examine whether the peripheral blood Hct is a suitable proxy for RBCV in patients with a variety of volume states.

## METHODS

➢Design: Blood volume analyses (BVA) of inpatients and outpatients at two large tertiary care hospitals were retrospectively reviewed.

➢Inclusion criteria: 940 consecutive patients with a wide variety of illnesses were referred to nuclear medicine for radioisotopic blood volume analysis. Patient characteristics are described in Table 1.

➢Exclusion criteria: Pregnant or nursing; allergic to iodine

➢Blood Volume Analysis: Peripheral Hct was assessed from baseline blood sample. BVAs were performed using the BVA-100 (Daxor Corporation, New York, NY). 1 mL of $^{131}$I-labeled albumin (<25 uCi) was injected IV. 5mL blood samples, collected at 12, 18, 24, 30, and 36 min post-injection, were assayed for radioactivity in duplicate and the results plotted (minimum three sample points, standard deviation SD <2.9%). Plasma volume (PV) was derived by extrapolating to time zero. BVA presents RBCV, PV, TBV and nHct as absolute values and as deviation (mL and %) from ideals, based on patient gender, height and weight.

➢Interpretation of Results: Blood volume status is classified based on the severity of blood volume derangements as follows:

-Hypovolemic: Measured BV shows >8% deficit relative to ideal BV
-Normovolemic: Measured BV shows ≤8% deviation relative to ideal BV
-Hypervolemic: Measured BV shows >8% excess relative to ideal BV

➢Data Analysis: Regression analysis was used in correlation studies. Bland-Altman analysis examined the mean difference between normalized and peripheral Hct methods.

## SUBJECTS

**Table 1:** Patient Characteristics (n=940)

| | |
|---|---|
| Gender | 459 F, 481 M |
| Mean Age, years (range) | 65.2 (17-95) |
| Mean BMI kg/m$^2$ (range) | 30.6 (14.3-80.3) |

**Table 2**: Volume Status of Patients (n=940)

| | Number (%) |
|---|---|
| Hypovolemic (TBV>8% Below Ideal TBV) | 208 (22.1%) |
| Normovolemic (TBV=Ideal TBV +/- 8%) | 372 (39.6%) |
| Hypervolemic (TBV>8% Above Ideal TBV) | 360 (38.3%) |

## RESULTS

**Table 3:** Sample Patient Data

| Patient # | Age (yr) / Gender | Volume Status (BVA) | pHct | nHct | % Dev from ITBV | % Dev from IRBCV | % Dev from IPV |
|---|---|---|---|---|---|---|---|
| 1 | 80/M | Hypervolemic | 31.5 | 46.1 | 46.3 | 2.5 | 76.1 |
| 2 | 86/F | Hypervolemic | 32.9 | 42.0 | 27.7 | 5.0 | 40.5 |
| 3 | 77/F | Normovolemic | 33.3 | 33.8 | 1.7 | -15.5 | 11.3 |
| 4 | 82/M | Hypovolemic | 31.8 | 25.3 | -20.5 | -43.9 | -4.5 |
| 5 | 77/F | Hypovolemic | 32.0 | 22.5 | -29.5 | -43.7 | -21.6 |

ITBV: Ideal Total Blood Volume (Normal ±8%); IRBCV: Ideal Red Blood Cell Volume (Normal ±10%); IPV: Ideal Plasma Volume (Normal ±8%)

## RESULTS

**Fig. 2. Normalized Hct – Available Only from Blood Volume Analysis – Correlates Better with True RBCV than does Peripheral Hct**

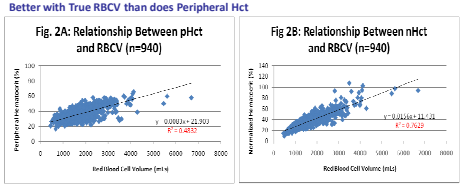



**Fig. 3. Bland-Altman Analysis Examines Difference Between Peripheral and Normalized Hct Methods as a Function of Volume Status**

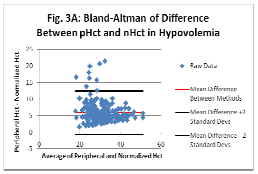
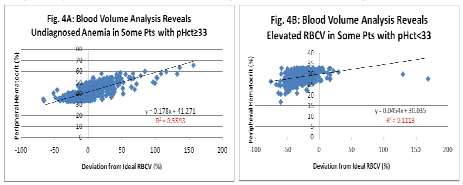



**Fig. 4. Peripheral Hct Both Underestimates (Fig. 4A) and Overestimates (Fig. 4B) True Anemia**



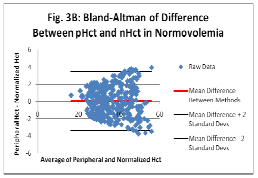
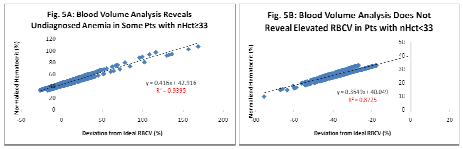
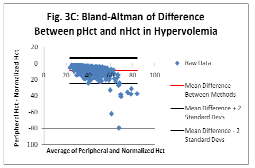




**Fig. 5. Normalized Hct is a Better Proxy than pHct for Reductions in RBCV**




## CONCLUSIONS

➢Evaluation of anemia is inextricably linked to volume status

➢Peripheral blood Hct (pHct) provides a good estimate of RBCV in normovolemic patients, but not in hypo- or hypervolemic patients.

- pHct underestimates RBCV in states of fluid excess (dilutional anemia) and overestimates RBCV when PV is low (hemoconcentration).

➢The normalized Hct (nHct) provided by blood volume analysis offers dramatically improved correlation with true RBCV in hyper- and hypovolemic patients because it corrects for abnormal volume status.

➢Blood volume analysis may greatly improve anemia and volume management in a wide variety of patient types.

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