"Normalized Hematocrit" from Blood Volume Analysis Offers Enhanced Accuracy over Peripheral Hematocrit in Red Blood Cell Volume

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BACKGROUND / OBJECTIVES
- Assessment of red blood cell volume (RBCV) is fundamental in clinical medicine, and is particularly important in the evaluation of anemia.
- Peripheral hematocrit (pHct) (% packed red cell volume) is commonly used as an indicator of RBCV. pHct is a good indicator of RBCV in normovolemic patients, but pHct may be unreliable when volume status is abnormal and pHct is confounded by diurnal variation or hemocentration (Fig. 1). Abnormal volume status is common in critical illness, kidney disease, and heart failure.

DEFINITIONS
- Blood Volume Analysis (BVA) is an FDA approved, radiolabeled tracer indicator dilution method of determining RBCV, Plasma Volume (PV), and Total Blood Volume (TBV).
- Total Blood Volume (TBV) = PV + RBCV
- Peripheral hematocrit (pHct) (% packed red cell volume) = (RBCV/(RBCV + PV)) x 100
- Normalized hematocrit (nHct) = pHct/(TBV/ideal TBV)

METHODS
- Study Design: Retrospective review of inpatient BVA studies at a large tertiary care hospital.
- Peripheral Hematocrit (pHct) was assessed by Coulter counter in the hospital clinical lab. pHct was used as the method of reporting RBCV unless otherwise noted.
- Blood Volume Analysis: BVA was performed using the BVA-100 (Baxter Corporation, New York, NY). 1 mL of 1% labeled albumin (≤50 CG) was injected IV. 5 mL blood samples, collected at 12, 18, 24, 30, and 36 min post-injection, were assayed for radioactivity in duplicate and the results plotted (semi-log, minimum 3 sample points, standard deviation 0.3). Plasma volume (PV) was determined by extrapolating to time zero. RBCV and TBV were calculated using patient pHct. BVA provides RBCV, PV, and TBV as absolute values and as deviation (ML and %) from ideal values and also provides nHct. Patient volume status was classified as follows:
  - Hypovolemic: Measured TBV is <8% below ideal TBV
  - Normovolemic (Euvolemic):  Measured TBV is within 8% of ideal TBV
  - Hypervolemic: Measured TBV is >12% above ideal TBV
- Results: 837 consecutive inpatients with a wide variety of illnesses were referred for initial BVA studies between 12/1/04 and 4/30/08. These studies were reviewed from the BVA-100 database for analysis.
- Data Collection: Bland-Altman analysis was used to examine the correlation between pHct and nHct. Regression analysis was used to examine the correlation between pHct, nHct, and true red cell volume status.

RESULTS

Fig. 1 The problem with peripheral hematocrit (pHct)

<table>
<thead>
<tr>
<th>Volume Status</th>
<th>Normovolemic</th>
<th>Normovolemic</th>
<th>Hypervolemic</th>
<th>Hypervolemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma RBCs</td>
<td>Ideal</td>
<td>Expanded 2%</td>
<td>Reduced 2%</td>
<td></td>
</tr>
<tr>
<td>Total Blood Volume (TBV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral Hct (pHct)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 1 Patient Characteristics

<table>
<thead>
<tr>
<th>Trait of patients</th>
<th>n=627</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>female</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>60 (E/C-70)</td>
</tr>
</tbody>
</table>

Fig. 2 Patient Volume Status

<table>
<thead>
<tr>
<th>Total volume status</th>
<th>All patients (n=627)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normovolemic</td>
<td>(36%)</td>
</tr>
<tr>
<td>Hypovolemic</td>
<td>(25%)</td>
</tr>
<tr>
<td>Hypervolemic</td>
<td>(40%)</td>
</tr>
</tbody>
</table>

Fig. 3 Concordance of pHct & nHct in NORMAL Volume status (n=227)

A) Concordance of pHct & nHct in NORMAL Volume status (n=227)

B) Concordance of pHct & nHct in ABNORMAL Volume status (n=400)

Fig. 5 pHct and nHct as indicators of red blood cell volume status

CONCLUSIONS

- Abnormal volume status (hypervolemia or hypovolemia) is very common in the inpatient population.
- Peripheral Hct (pHct) may be a very unreliable indicator of RBCV in hypervolemic or hypovolemic patients.
- Peripheral Hct underestimates RBCV in states of fluid excess (dilutional anemia) and overestimates RBCV when PV is low (hemococoncentration).
- Reliable assessment of RBCV status requires knowledge of volume status; blood volume analysis provides this information.
- Normalized Hct (nHct) from blood volume analysis offers improved assessment of true RBCV in hyper- and hypovolemic patients because it is corrected for abnormal volume status.

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