Blood Volume Analysis--
Value in Patient Care
Opportunity for Nuclear Medicine

SNM Annual Meeting 2008
SNMTS Categorical Seminar
June 14, 2008

Timothy A. Manzone, MD, JD
Associate Medical Director, Nuclear Medicine
Christiana Care Health System
Newark, Delaware

Disclosure: Dr. Manzone is on the speakers’ bureau for Daxor Corp, manufacturer of the Daxor BVA-100 blood volume analyzer.
Our Agenda:

• What is blood volume?
  – Blood and fluid balance

• How is blood volume assessed?
  – Clinical assessment
  – Nuclear medicine techniques
    • $^{51}$Cr RBC’s
    • $^{125}$I HSA

• New nuclear medicine BVA technique
  – How do you do it?
  – How does it work?

• Expanding clinical indications for BVA
How much blood does a human adult have?

Answer: About 5-6 quarts
What is Blood?

**What is Blood?**

**Plasma Composition**
- Plasma proteins 7%
- Other solutes 1%
- Water 92%
- Transports organic and inorganic molecules, formed elements, and heat

**Formed Elements**
- Platelets 0.1%
- White blood cells 1%
- Red blood cells 99.9%

**Other Solute**
- Electrolytes
- Organic nutrients
- Organic wastes

**Plasma Proteins**
- Albumins (50%)
- Globulins (35%)
- Fibrinogen (4%)
- Regulatory proteins (<1%)

**Platelets**

**White Blood Cells**
- Neutrophils (50–70%)
- Eosinophils (2–4%)
- Basophils (<1%)
- Lymphocytes (20–30%)
- Monocytes (2–8%)

**Red Blood Cells**

Sample of whole blood

Contains plasma (46–63%) and formed elements (37–54%).
Blood volumes & Hematocrit

HEMATOCRIT = 45%

PLASMA VOLUME
10 ml
91% Water
7% Blood proteins (albumin, fibrinogen globulin)
2% Nutrients (amino acids, sugars, lipids)
Hormones (insulin, erythropoietin, etc.)
Electrolytes (Na, K, Ca, PO₄, etc.)

CELLS (~45% of total blood volume)

Buffy Coat
White blood cells
Platelets

Red Blood Cells (RBCs)
About 5,000,000/mm³ blood

RED CELL VOLUME
5 ml
# Blood Volume Changes in Disease

## Normal Total Blood Volume

<table>
<thead>
<tr>
<th>Total Blood Volume</th>
<th>Plasma Volume</th>
<th>Red Cell Volume</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normovolemic</td>
</tr>
<tr>
<td>Normal</td>
<td>↓</td>
<td>↑</td>
<td>Polycythemia Vera</td>
</tr>
<tr>
<td>Normal</td>
<td>↑</td>
<td>↓</td>
<td>Anemia with homeostatic plasma expansion. <em>(Only situation where Hct properly reflects anemia severity.)</em></td>
</tr>
</tbody>
</table>
# Blood Volume Changes in Disease

## Increased Total Blood Volume

<table>
<thead>
<tr>
<th>Total Blood Volume</th>
<th>Plasma Volume</th>
<th>Red Cell Volume</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>Congestive Heart Failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>COPD, Exercise</td>
</tr>
<tr>
<td>↑</td>
<td>↑</td>
<td>Normal</td>
<td>Congestive Heart Failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polycythemia Vera</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>COPD on diuretics</td>
</tr>
<tr>
<td>↑</td>
<td>↑↑</td>
<td>↓</td>
<td>Congestive Heart Failure, esp. with bleeding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Therapeutic hemodilution prior to surgery</td>
</tr>
<tr>
<td>↑</td>
<td>↓</td>
<td>↑↑</td>
<td>COPD with extreme overdiuresis</td>
</tr>
</tbody>
</table>

Normal Congestive Heart Failure, esp. with bleeding Therapeutic hemodilution prior to surgery

COPD with extreme overdiuresis
## Blood Volumes Changes in Disease

### Decreased Total Blood Volume

<table>
<thead>
<tr>
<th>Total Blood Volume</th>
<th>Plasma Volume</th>
<th>Red Cell Volume</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>Early hemorrhage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Post-op “Hidden Anemia”— red blood cell depletion with incomplete plasma expansion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>Dehydration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vasoconstrictive hypertension</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td></td>
<td>Anemia with incomplete compensatory plasma expansion</td>
</tr>
</tbody>
</table>
Fluid balance is dynamic …especially in illness

- NPO
- Anorexia
- IV fluids
- Transfusions

<table>
<thead>
<tr>
<th>Fluid Intake</th>
<th>(ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingested water</td>
<td>1300</td>
</tr>
<tr>
<td>Ingested food</td>
<td>1000</td>
</tr>
<tr>
<td>Metabolic oxidation</td>
<td>300</td>
</tr>
<tr>
<td>Total</td>
<td>2600</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fluid Output</th>
<th>(ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kidneys</td>
<td>1500</td>
</tr>
<tr>
<td>Skin</td>
<td></td>
</tr>
<tr>
<td>Insensible loss</td>
<td>200–400</td>
</tr>
<tr>
<td>Sensible loss</td>
<td>300–500</td>
</tr>
<tr>
<td>Lungs</td>
<td>400</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>2500–2900</td>
</tr>
</tbody>
</table>

- Bleeding
- Diarrhea
- Fever
- Renal Failure
- Dialysis
- Surgery (!)
- Ventilator
A 2\textsuperscript{nd} fluid circulation—

Vascular $\rightarrow$ Interstitial $\rightarrow$ Lymphatic

At arterial end of capillary: predominant movement of fluid is from bloodstream into interstitial spaces.

At venous end of capillary: predominant movement of fluid is from interstitial spaces into bloodstream.

Excess fluid and escaped protein drain into lymphatic vessels.
How do physicians evaluate volume status?
Overheard in the hospital concerning volume status

"I know his lungs are pretty clear, but still I think he's a bit wet—Let's give one more dose of Lasix"

"Yes, her hematocrit is only 24, but don't forget, she has been getting lots of fluids. It's probably dilutional."

"He has still only put out 15cc of urine. He could be pre-renal….Let's give him another fluid challenge."

"We have to get her hydrated up before we go to the OR…but watch out she doesn't go into failure."

"I don't think he really has polycythemia; His hematocrit is elevated because of his COPD."
Ways to assess volume status

Clinical indicators (indirect):

- Vital signs: BP, HR
- Input/Output, weights
- Jugular venous distension
- Lung sounds
- Central venous pressure
- Fluid Challenge

Direct Measurement:

• Blood Volume Analysis
Blood Volume Analysis—Nuclear Medicine Techniques
Indicator Dilution Technique

1. Inject known amount /volume of tracer

2. Wait for mixing

3. Measure tracer concentration, calculate volume

\[ C_1 \times V_1 = C_2 \times V_2 \]
Nuclear Medicine
Blood Volume Studies

• Red Cell Volume study
  – $^{51}$Cr RBC’s

• Plasma Volume study
  – $^{125}$I Human serum albumin (HSA)

• Dual-isotope, Dual-tracer
  – $^{51}$Cr RBC’s and $^{125}$I HSA
Limitations of traditional BVA

- Blood product labeling ($^{51}$Cr RBC)
- Complicated (and low-volume)
- Time-consuming!
- Single point sampling
- Is it reliable? Accurate?
- Does it give all required information?
Red Cell Volume study

CALCULATIONS:
A = hematocrit of tagged solution  
B = net whole blood standard count  
C = net plasma standard count  
D = net patient whole blood sample count  
E = patient hematocrit  
F = net patient plasma count

RED CELL VOLUME = \((B - C(1 - A))E\) \(\frac{1000}{D - F(1 - E)}\)

WHOLE BLOOD VOLUME = \(\text{red cell volume} \div \text{patient hematocrit}\)

PLASMA VOLUME = whole blood volume - red cell volume

Calculated Total Blood Volume \(\text{ cc}\)

Total Packed Red Cell Volume \(\text{ cc}\)

Hematocrit \(\%\)

6/96 eab
Limitations of traditional BVA

- Blood product labeling ($^{51}$Cr RBC)
- Complicated (and low-volume)
- Time-consuming!
- Single point sampling
- Is it reliable? Accurate?
- Does it give all required information?
Another problem--
What is “Normal” blood volume?
A way to determine

“Ideal” Blood Volume

- Ideal values based on % deviation from Ideal Weight (Metropolitan Life tables)
- Accounts for blood volume in avascular fat

Automation comes to Blood Volume Analysis
Semi-automated Blood Volume Analysis System

Daxor Blood Volume Analyzer

Nuclear Medicine technologist loads a specimen into BVA machine
Semi-automated BVA

- FDA approved in 1999
- Indicator Dilution Technique
  - $^{131}$I labeled albumin (10-30 uCi)
- Unit dose injectates & standards
  - Volumetric flow chamber (Volumex)
- Multiple samples, each counted in duplicate
- Equivalent to dual tracer “gold standard” method
- Results compared with ideal values for patient’s sex, height, weight
- Results can be available in 90 minutes

Dworkin, H., et al., Comparison of red cell and whole blood volumes as performed using both Chromium-51 tagged red cells and Iodine-125 tagged albumin versus using I-131 tagged albumin and extrapolated red cell volume. *J Nucl Med.* 46 Supp.2, 2005; (#1372)
BVA procedure

• Get height & weight, put patient supine

• Specimen collection:
  – Administer injectate
  – Wait 12 minutes for mixing
  – Do 5 blood draws at about 6 min intervals.

• Specimen processing:
  – Perform microhematocrit on samples
  – Centrifuge, then pipette 1ml plasma samples
  – Counting is automatic, takes 20-40 min

• Data QC on computer

• Print final report
How modern BVA works—
How BVA works—Comparison with “ideal” values
Final BVA Results

- **BLOOD VOLUME ANALYSIS - FINAL REPORT**
- **Patient Name:**
- **Identification Number:** 084329449
- **Height:** 67.0 Inches  **Weight:** 321.0 Pounds (Dev. from Ideal: 116.2%)
- **Comments:** V32305-84 cap 0.04  **Gender:** Male
- **Analyzed on:** 06/05/2003 at 17:42:54 by: Dr.L & JR

<table>
<thead>
<tr>
<th>Sample Time</th>
<th>Hct-A</th>
<th>Hct-B</th>
<th>Avg</th>
<th>Count-A</th>
<th>Count-B</th>
<th>AvgCnt</th>
<th>UnadjVol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>49.4</td>
<td>50.2</td>
<td>49.8</td>
<td>63</td>
<td>53</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Standard-1</td>
<td></td>
<td></td>
<td></td>
<td>20347</td>
<td>20313</td>
<td>20330</td>
<td></td>
</tr>
<tr>
<td>Pat-Samp-1</td>
<td>46.7</td>
<td>46.8</td>
<td>46.8</td>
<td>3576</td>
<td>3566</td>
<td>3571</td>
<td>9963</td>
</tr>
<tr>
<td>Pat-Samp-2</td>
<td>46.8</td>
<td>47.4</td>
<td>47.1</td>
<td>3608</td>
<td>3593</td>
<td>3601</td>
<td>9935</td>
</tr>
<tr>
<td>Pat-Samp-3</td>
<td>47.7</td>
<td>47.9</td>
<td>47.8</td>
<td>3363</td>
<td>3290</td>
<td>3326</td>
<td>10887</td>
</tr>
<tr>
<td>Pat-Samp-4</td>
<td>48.0</td>
<td>48.3</td>
<td>48.2</td>
<td>3514</td>
<td>3280</td>
<td>3397</td>
<td>10716</td>
</tr>
<tr>
<td>Pat-Samp-5</td>
<td>48.4</td>
<td>48.7</td>
<td>48.6</td>
<td>3397</td>
<td>3364</td>
<td>3380</td>
<td>10838</td>
</tr>
</tbody>
</table>

- **Room Background:** 70 counts. Sample Acquisition Time was 2.50 min.
- **Anti-Coagulation Factor:** 1.00 Isotope: I-131 Dose: 16.6 microCi
- **Blood Vol.:** 9486 ml  **Ideal Vol.:** 6736 ml  **Excess:** 2751 ml  **Devtn.:** 40.8 %
- **Red Cell Vol.:** 4074 ml  **Ideal Vol.:** 2731 ml  **Excess:** 1343 ml  **Devtn.:** 49.2 %
- **Plasma Vol.:** 5412 ml  **Ideal Vol.:** 4005 ml  **Excess:** 1407 ml  **Devtn.:** 35.1 %

**Patient Blood Volume is:** HYPEROVOLMIC  **Normalized HCT is:** 67.1%

- **Slope is:** 0.00407
- **Standard Deviation is:** 368.3 ml (3.882%)

**BV Deviation (%):** 0 to 8  >8 to 16  >16 to 24  >24 to 32  >32

- Normal  Mild  Moderate  Severe  Extreme
How are BVA studies interpreted?
## BVA Interpretation

### Patient
- Total Blood Vol. (TBV)
- Plasma Vol. (PV)
- Red Cell Vol. (RCV)

### Ideal
- TBV
- PV
- RCV

### Deviation
- ml
- %

**Normalized Hematocrit (nHct)**
(hematocrit corrected for volume status)

**“Slope”**
(rate of albumin transudation, measures capillary permeability)
BVA analysis example--Hematology
P. vera vs. Gaisbock syndrome

Plasma

Red Cells
Hematocrit

Normal
Normovolemic

Polycythemia Vera
Normovolemic

Not P. Vera
Hypovolemic

45%
55%
55%
BVA Example—P. vera?

52 year old male  275# (125kg), 6’0” (183 cm)
History: smoking, HTN, IDDM, CABG, mitral valve replacement (on coumadin but INR =1.2)
Presents with ischemic stroke.  Hematocrit = 54.4%
Problem: Smoker’s erythrocytosis, or polycythemia vera?

<table>
<thead>
<tr>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>5978</td>
<td>6522</td>
<td>-544</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>3108</td>
<td>3878</td>
<td>-770</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>2871</td>
<td>2644</td>
<td>+227</td>
</tr>
</tbody>
</table>

RBC Vol/Adjusted Desirable Weight = 34.2 ml/kg
48 year old male 207# (94kg), 5'9" (176 cm)
History: erythrocytosis  \textit{Hematocrit} = 47%
Problem: Does he have polycythemia vera?

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>6711</td>
<td>5428</td>
<td>+1283</td>
<td>+23.6</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>3924</td>
<td>3228</td>
<td>+696</td>
<td>+21.6</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>2787</td>
<td>2201</td>
<td>+586</td>
<td>+26.7</td>
</tr>
</tbody>
</table>

\textbf{RBC Vol/Adjusted Desirable Weight = 37.1 ml/kg}
BVA analysis example
Volume status—Blood loss from trauma

- **Normovolemic**
  - Normal red cell
  - 5000cc

- **Normovolemic**
  - Anemia
  - 5000cc

- **Hypovolemic**
  - Anemia
  - 3750cc

**Plasma**

**Red Cells**

**Hematocrit**

45% 30% 30%

**Loss of**

1/3 RBC’s

1/2 RBC’s

**Fluid Replacement**
BVA Example—Volume status

84 year old female 5’5” (165 cm), 128# (58 kg)
History of anemia (Hct 28), kidney disease, CHF

Problem:
Uncertain volume status

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>4097</td>
<td>4093</td>
<td>+4</td>
<td>+0.1</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>3057</td>
<td>2618</td>
<td>+439</td>
<td>+16.8</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>1040</td>
<td>1475</td>
<td>-435</td>
<td>-29.5</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 28.2%
BVA Example—Volume status

37 year old male 5’11” (180 cm), 147# (66.6 kg)
Admitted with bilateral pneumonia, hypoxia
Patient is “dry” by clinical exam on admission

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>6134</td>
<td>5099</td>
<td>+1035</td>
<td>+20.3</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>4514</td>
<td>3032</td>
<td>+1482</td>
<td>+48.9</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>1620</td>
<td>2067</td>
<td>-447</td>
<td>-21.6</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 35.3%
**BVA Example—Volume status**

61 year old female 5’3” (161 cm), 163# (74 kg)
History of pulmonary hypertension, CAD, Uncertain volume status

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>3122</td>
<td>4223</td>
<td>-1101</td>
<td>-26.1</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>2309</td>
<td>2701</td>
<td>-392</td>
<td>-14.5</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>813</td>
<td>1522</td>
<td>-709</td>
<td>-46.6</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 21.4%
Emerging clinical uses for Blood Volume Analysis
BVA and Heart Failure—
The magnitude of the problem

- Nearly five million heart failure (HF) patients in U.S.
- Almost 500,000 new diagnoses/year
- Accounts for 12 - 15 million office visits/year
- Accounts for 6.5 million hospital days/year
- Hospitalizations/year for HF nearly doubled in last 10 years
- Nearly 300,000 deaths from HF as a primary/contributory cause/year
- Most common Medicare diagnosis–related group (DRG)

Source: ACC/AHA Guidelines for the Evaluation and Management of Chronic Heart Failure in the Adult
BVA in Heart Failure

• Distinguish hypervolemic vs. hypovolemic patients.

• More accurate than clinical assessment
  – Clinical indicators may be unreliable
  – CA complicated by edema, CRF, etc

• In a study comparing BVA and clinical assessment (CA):
  – CA & BVA concordance 51%
  – CA Sensitivity for hypervolemia = 43%
  – CA Specificity for hypervolemia = 67%

BVA in Heart Failure

• Volume status as a predictor of clinical outcome in CHF

“Clinically unrecognized intravascular volume overload may contribute to worsening symptoms and disease progression in patients with chronic heart failure (CHF)”

BVA in Heart Failure

• Dilutional anemia as poor prognostic sign in HF

BVA Case Study

Patient: 86 year old female, 4'9” (146 cm), 124 lbs (56.5 kg)

History of:
Hypertension, CAD (PTCA), a-fib (pacemaker),
L. nephrectomy, anemia (Hct = 32.9%)

Problem:
Is patient being dehydrated by over-diuresis?

<table>
<thead>
<tr>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>4383</td>
<td>3431</td>
<td>+952</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>3084</td>
<td>2195</td>
<td>+889</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>1299</td>
<td>1237</td>
<td>+62</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 42.0%
BVA in Critical Care

The importance of fluid resuscitation and blood replacement in critical care settings has long been recognized:

But how can we assess volume status to guide therapy?
BVA in Critical Care

• Determine RBC and plasma volume status in critically ill patients
• Identify volume derangements despite confounding clinical findings.
• Aid in guiding:
  – Transfusion
  – Volume resuscitation
  – Dialysis
Critical/Perioperative care—

Study of SICU patients, Queen’s Hospital, Honolulu

Patients With PA Catheter
- Less Fluid - 35%
- More Fluid - 5%
- No Blood - 15%
- No Change - 45%

Changes in treatment suggested by BVA

Patients Without PA Catheter
- More Fluid - 11%
- Transfusion - 22%
- No Change - 67%

Biuk-Aghai, et. al., Blood Volume Measurement in Critically Ill Patients, Poster Presentation Society of Critical Care Medicine – Phoenix AZ January 15-17, 2005
BvA and RBC status in inpatients

Bland-Altman analysis:
Concordance of Hct and nHct

Lab Hct and RCV status

nHct and RCV status
Patient: 52 year old female 5’0” (152 cm), 137 lbs (62.1 kg)
History of: IDDM, 1° biliary cirrhosis, multiple myeloma
Presents hypotensive, febrile, clinically dehydrated after 1 week watery diarrhea.
Problem:
Creatinine increases after hydration.
What is her volume status?

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>4635</td>
<td>3712</td>
<td>+923</td>
<td>+24.9</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>3182</td>
<td>2374</td>
<td>+808</td>
<td>+34.0</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>1453</td>
<td>1338</td>
<td>+115</td>
<td>+8.6</td>
</tr>
</tbody>
</table>
BVA Case Study

61 year old female 5’5” (166 cm), 364# (165 kg)
In Medical ICU with acute renal failure.
Problem:
What is her volume status?

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>8765</td>
<td>6466</td>
<td>+2229</td>
<td>+34.5</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>6704</td>
<td>4136</td>
<td>+2568</td>
<td>+62.1</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>2061</td>
<td>2330</td>
<td>-269</td>
<td>-11.5</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 35.4%
# BVA Case Study

61 year old female 5’5” (166 cm), 364# (165 kg)  
In Medical ICU with acute renal failure.

Follow-up study after treatment:

<table>
<thead>
<tr>
<th></th>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>6632</td>
<td>6466</td>
<td>+166</td>
<td>+2.6</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>4533</td>
<td>4136</td>
<td>+397</td>
<td>+9.6</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>2100</td>
<td>2330</td>
<td>-230</td>
<td>-9.9</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 36.0%
81 year old female 5’5” (165 cm), 136# (62 kg)
Admitted with change in mental status. Hematocrit = 31%
Problem:
What is her volume status?

<table>
<thead>
<tr>
<th>Measured Volume (ml)</th>
<th>Ideal Volume (ml)</th>
<th>Excess (+) Deficit (-) (ml)</th>
<th>Deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Vol</td>
<td>2599</td>
<td>4140</td>
<td>-1541</td>
</tr>
<tr>
<td>Plasma Vol</td>
<td>1877</td>
<td>2648</td>
<td>-771</td>
</tr>
<tr>
<td>Red Cell Vol</td>
<td>722</td>
<td>1492</td>
<td>-770</td>
</tr>
</tbody>
</table>

Normalized hematocrit (nHct) 19.3%
BVA in Septic Shock / Trauma

“Slope” reflects albumin transudation from vascular compartment

Normal transudation is about 0.25% per minute.

Slope measures capillary permeability

How can we use this clinically??
BVA in Hypertension

- Most common primary diagnosis in US.
- 35 million office visits/year
- **Two** mechanisms, with different treatments:
  - Expanded Blood Volume
  - Vasoconstriction

- Blood Volume Analysis
  - determines etiology, aids treatment planning
  - helps avoid overdiuresis
  - avoid hypotensive crisis when altering vasodilator therapy
Syncope

- Accounts for 3-5% of ER visits and 1-6% of hospital admissions
- Etiology remains unclear in 24-37% of cases even after workup.
- Positive tilt table test shows an imbalance:

- Which of the two factors is responsible for the symptoms?
- How can an abnormal tilt-table study be followed up?

Cleveland Clinic:
“Evaluation of syncope patients should include a blood volume measurement to help define the cause of syncope as elicited by a tilt table test.”
Indications for Blood Volume Analysis

- Polycythemia
- Congestive Heart Failure
- Hypertension
- Chronic Hypotension
- Orthostatic Hypotension
- Shock
- Syncope
- Chronic Fatigue Syndrome
Indications for Blood Volume Analysis

- Nephrology—Renal Failure/Dialysis
- Pre and Post Surgical Volume Status
- Blood Transfusion/Donation Assessment
- Pre-Op Hemodilution
- Pre-Op screening for hypovolemia
- Acute Blood Loss
Blood Volume Analysis 2008

- Blood—Components, hematocrit
- Fluid compartments and balance
- Traditional Nuclear Medicine methods:
  - $^{51}$Cr RBC Red cell volume study
  - $^{125}$I or $^{131}$I HSA Plasma volume study
- Modern semi-automated BVA study
  - How study is performed
  - How it works
  - How it is interpreted
- Clinical applications for BVA
Blood Volume Analysis--Value in Patient Care
Opportunity for Nuclear Medicine