Dry Weight

METHODS OF MEASURING DRY WEIGHT

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Dry Weight: definition

- The weight at which the dialysis patient has *neither edema nor hypertension* with no BP medication
- Normally achieved with ultrafiltration *until* hypotensive crisis
- Iatrogenic shock:
  - Nausea
  - intradialytic hypotension
  - cramps during dialysis

Dry Weight

- Dry weight is achieved when the pt is in shock
  - Clinical definition: “challange”
- This is very uncomfortable
- There is always a risk of adverse outcome
- ...there must be a better way...
The Ideal Dry Weight

- (1) shortest post-dialysis recovery time;
- (2) least intradialytic hypotension;
- (3) longest patient survival;
- (4) fewest cardiovascular and cerebrovascular events and hospitalizations
  - Risk of myocardial stunning, risk of seizures
- (5) fewest hypovolemia-related access thromboses;
- and (6) fewest post-dialysis falls

Frequency of target weight miss by varying thresholds.

Jennifer E. Flythe et al. CJASN 2015;10:808-816
In HD patients:

- in a study of 22 patients
- underwent a **right heart catheterization** at a time when clinical dry weight was thought to be adequate
  - --> only 6 had normal filling pressures

Lack of Weight Loss in Large Fraction of Patients Admitted for Acute Heart Failure

All Enrolled Discharges from October 2001 to January 2004

Change in weight was assessed in 51,013 patient episodes (at end: 107,362)

Discharged Home (including home with additional and/or outpatient care)

Specificity and Sensitivity in Diagnosing CHF

100 patients presenting to the ER with signs or symptoms of congestive heart failure (e.g., dyspnea, edema, weight gain)

<table>
<thead>
<tr>
<th></th>
<th>Specificity</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevated Neck Veins</td>
<td>92%</td>
<td>34%</td>
</tr>
<tr>
<td>Third Heart Sound</td>
<td>90%</td>
<td>26%</td>
</tr>
<tr>
<td>Crackles in the Lungs</td>
<td>81%</td>
<td>57%</td>
</tr>
<tr>
<td>BNP (cutoff value of 100 pg/mL)</td>
<td>98%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Dao and colleagues, 49th Annual Scientific Session of the American College of Cardiology
Risk of excessive fluid volume

- Increased mortality
- Hypertension
  - Polypharmacy
  - Inadequate BP control
- Congestive Heart Failure (CHF)
Relative Hydration Status (OH% >15%)

- Bioimpedence measurements
- Hyperhydration: 15% relative to the extracellular water (ECW), which represents an excess of ECW of 2.5 L

Higher frequency of target weight misses (above and below) was incrementally associated with greater mortality.

Jennifer E. Flythe et al. CJASN 2015;10:808-816
Risk of excessive ultrafiltration (going below dry weight)

- (1) increased risk of clotted fistula,
- (2) increased rate of loss of residual renal function,
- (3) complications related to intradialytic hypotension,
- (4) frequent episodes of malaise, weakness, increase risk of falls, episodes of intradialytic hypotension,
- (5) brain hypoperfusion, with subsequent white matter degeneration
- (6) gastrointestinal ischemia leading to endotoxin exposure is also a plausible clinical consequence of overaggressive ultrafiltration

Intradialytic hypotension, in addition to requiring more nursing interventions, can be complicated by cerebral hypoperfusion, seizures, myocardial dysfunction, and mesenteric ischemia.
- KL Jablonski, M Chonchol April 2015, doi: 10.2215/CJN.03110315 CJASN May 07, 2015 vol. 10 no. 5 729-731
Methods of fluid status measurements

- 2D Echocardiography
  - IVC measurement:
    - IVC/BSA ratio
    - IVC Collapse Index
  - Sphericity index
- Biomarkers:
  - BNP
  - NT-pro-BNP
- Bioimpedance
- Continuous Hematocrit monitoring
- Relative Blood Volume Monitoring
Intravascular volume measurement: Echocardiogram

- Either by using cardiac IVC Collapse Index:
  \[ CI = \left( \frac{\text{end expiratory IVC diameter} - \text{end inspiratory IVC diameter}}{\text{end expiratory IVC diameter}} \right) \times 100 \]

- **Hypervolemia**: CI greater than 0.75
  - i.e., the collapse of IVC diameter during inspiration was less than 25% of the baseline diameter during expiration

Intravascular volume measurement: Echocardiogram

- **IVC/BSA ratio:**
  - 8.0 - 11.5 mm/m²
  - **Hypovolemia:** <8.0 mm/m²
    - Corresponds to right atrial pressure on right sided catheterization: 3.0 mmHg or less
  - **Hypervolemia:** >11.5 mm/m²
    - Corresponds to right atrial pressure on right sided catheterization: 7.0 mmHg or more

Intravascular volume measurement: Echocardiogram

- IVC U/S measurement:
  - IVC diameter can detect clinically unapparent volume depletion\(^1\)
  - interventions based on such measurements may improve hemodynamics\(^1\)

- Nonlinear regression analysis found\(^2\) that the Collapse Index strongly correlated with mean right atrial pressure:
  - \( r = 0.92, \quad p < 0.001 \) as assessed by right heart catheterization.

\(^1\)Leunissen Kmet al. *Kidney Int* 43(suppl 41):S50–S56, 1993
Intravascular volume measurement: Echocardiogram

**PROS:**
- Strong correlation with **right heart catheterization**, reflecting intravascular volume
  - Can assess both volume depletion and overload
- Noninvasive
- Valid measurement in non-dialysis patients as well

**CONS:**
- Best timing after HD not defined
- Must train skilled technicians
- Cost
- Limited availability
Intravascular volume measurement: Echocardiogram

- **Sphericity index:**
  - The rounder a heart is the more fluid it is distends it
  - The more elongated, the less fluid it holds

\[
\text{Sph. Index} = \frac{\text{EDV}}{(\text{LAD}^3 \times \pi)/6}
\]

A Kovács et al.; *J Am Soc Nephrol suppl SA-PO433 2013*
Continuous hematocrit monitoring

- **Rationale:**
  - Ultrafiltration reduces intravascular fluid volume
  - Intravascular Hct rises as fluid is removed

- **Basis of observation: intravascular refill**
  - When ultrafiltration is *suddenly stopped* the intravascular fluid refill continues and *the Hct drops* – while fluid overloaded
  - When ultrafiltration is suddenly stopped intravascular fluid refill stops and the Hct does not drop – while no longer fluid-overloaded
Continuous Hematocrit Monitoring
Continuous hematocrit monitoring: clinical practice

• Rapid refill occurs when the ECF is expanded as a result of volume overload

• Intradialytic hypotensive symptoms can be avoided with Hct monitoring

• Drawback:
  ○ Expense
  ○ Need for frequent intervention
  ○ Outcome studies did not show benefit...
## Adjusted risk ratio for hospitalization in IBVM vs conventional-care group

<table>
<thead>
<tr>
<th>Hospitalization type</th>
<th>Estimate</th>
<th>p</th>
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<tbody>
<tr>
<td>Access-related</td>
<td>1.52</td>
<td>0.04</td>
</tr>
<tr>
<td>Nonaccess-related</td>
<td>1.61</td>
<td>0.01</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>1.85</td>
<td>0.006</td>
</tr>
<tr>
<td>Other</td>
<td>1.53</td>
<td>0.02</td>
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Intravascular volume by BNP in ESRD

- BNP and pro-BNP correlated:
  - With IVC diameter index
  - Blood Volume
    - Measured with bioimpedence
    - Correlated with interdialytic hypotension
    - Measured by pulse dye-densitometry (PDD)
      - a newly developed technique for monitoring the arterial concentration of indocyanine green

1 van de Pol AC, Frenken LA et al. Hemodial Int. 2007 Jan;11(1):51-61
BNP Levels of Patients Without CHF, With Baseline LV Dysfunction, and With CHF

Mean BNP Concentration (pg/mL)

- No CHF (n = 139): 38 ± 4
- Asymptomatic LV Dysfunction (n = 14): 141 ± 31
- CHF (n = 97): 1076 ± 138

P < 0.001

Comparison of BNP levels at admission. (a) Brain natriuretic peptide (BNP) levels at admission among three groups: chronic kidney disease (CKD) + acute decompensated heart failure (ADHF) (mean ± standard deviation, 2708.6 ± 1246.9 pg/ml), CKD - ADHF (567.9 ± 491.7 pg/ml) and low-creatinine (Cr; <1.2 mg/dl)/ADHF (1418.9 ± 1126.5 pg/ml). BNP levels at admission were different among the three groups ($P = 0.000$, analysis of variance) and between each pair of groups ($P = 0.001$, $P = 0.000$ and $P = 0.001$, respectively, Tukey's post hoc test) with the highest mean value in the CKD + ADHF group. (b) BNP levels at admission of 58 dialysis-dependent patients with and without ADHF (3047.2 ± 1229.3 pg/ml vs. 632.3 ± 492.2 pg/ml, respectively, $P = 0.000$).

BNP-predicted overload correspond with bioimpedence predicted OH%

OH% vs. BNP values

\[ y = 209.83x - 1133.4 \]

\[ R = 0.6996 \]

High degree of correspondence between volume assessment methods

ROC for BNP based on OH%>15

Area under the curve: 0.885

Sensitivity vs. 1 - Specificity

BNP directed UF in Acutely Hospitalized ESRD Patients

- BNP-directed UF helps to identify patients with occult fluid overload

- BNP-directed UF helps their care:
  - Continued UF below the wrongly estimated Dry Weight
  - Reduce the # of antihypertensive meds
  - Reduce BP
  - Reduce weight

Tapolyai, Uysal, Maeweathers, et al. May/June 2009: 131-135 Congestive Heart Failure
BNP-directed UF

- BNP directed UF in a case report, shown to improve UF (15.5 L in 21 hospital days), blood pressure and polypharmacy

Tapolyai, Fülöp: April-June; 2010; 11: 00-00 JOURNAL OF VASCULAR ACCESS [ePub: 16/02/2010]
- Percentage variation of B-type natriuretic peptide (BNP) and N-terminal prohormone brain natriuretic peptide and (NTproBNP) after treatment in patients with acute decompensated heart failure from admission to discharge.
- Ntpro=-BNP is not suitable to monitor volume in ESR
Example of RPV monitoring as an indicator of dry-weight.

Rajiv Agarwal, and Matthew R. Weir CJASN 2010;5:1255-1260
Multifrequency Bioimpedance

- High frequency (high energy) electricity travels through all the tissues → it can measure Total Body Water (TBW)
- Low frequency electricity travels through the extracellular space only → it can measure Extracellular Water (only)
- All other indices are calculated
- Validation was through isotopes: D2O (heavy water), Bromide isotopes, K isotopes etc.
- Clinically utilizable instrument: Body Composition Measure (BCM)
Clinical Use of Multifrequency Bioimpedance

• It can measure both overhydration and fluid deficit:
  ○ Calculated from E/I ratio

• It can quantitate (how many liters) fluid deficit or excess
Clinical use of BCM
Achieving BCM-measured Dry Weight (absence of overhydration)

- ...little to do with residual renal function or diuretics use
- There is an inverse relationship with obesity and OH
- Conventional clinical wisdom may not always hold when fluid spaces are measured

Summary

- Dry Weight is an essential part of dialysis adequacy.
- Measuring fluid volumes and guiding dry weight targets is essential to avoid both fluid depletion and fluid overload.
- Fluid volume measurements is evidence based medicine.
- Emerging technologies will enable us to better estimate dry weight...
  - ...but will that improve outcome?