Dry Weight

Fluid Overload, Assessment & Management

Suhail Ahmad
PV
ECV
Na+
Predominant
Cation

Int
ICV
K+
Predominant
Cation

Dry Weight
Majority of Patients are in Fluid Excess State

- Significant Diuresis and Weight Loss Following Renal Transplantation

% Body weight reduction after transplant


- PD
- HD

p<0.05
Dry Weight

“The reduction of BP to hypotensive levels during UF, represented the achievement of dry weight status” (w/o Anti-HTN Meds.)

- Thomson, Arch Int Med, 1967

Post-dialysis Weight at which:

• Inter-dialytic & Next Pre-dialysis BP is Normal
• No Manifestation of ECV Excess
• No Manifestation of ECV Depletion
CAUTION: The ultrafiltration rate MUST not be too fast
It may damage myocardium and cause harm
In adult patient UF should not exceed 12 -15 ml/kg/hour
70 Kg x 12 ml = 840 ml/hour (usually no more than 900 ml/hr)
Impact of Fluid Excess

- Hypertension
- CCF, Cardiomyopathy
- Associated with Inflammation
- Bowel Wall Edema → Malnutrition
  - Low Serum Albumin!
- Pulmonary Complications

Maintaining normal fluid status must be objective of dialysis treatment
- Assessing dry weight accurately
- Achieving the dry weight

Cardiovascular sequelae
Leading cause of death

The Strongest Predictor of Death
Elevated BP in dialysis patients increases risk of death.

Lowering of BP is protective, directly influencing outcome (Charra & others).

Most effective method to control BP is by reducing Na (fluid) Excess.

Normalization of fluid excess & BP must be a goal of dialytic therapy.
Elevated BP is prevalent in dialysis patients

Agarwal, Am J Kid Dis, 2003: 86% had HTN → 76% used anti-HTN & 70% had sub-optimal BP

Normalizing fluid excess is most effective in controlling BP:

• Reduce IDWG – Na intake.
• Remove extra Fluid/Na with dialysis
  • Appropriate use of UF during dialysis
  • Appropriate Dialysate Na
• Adequate length/Frequency/type of dialysis to ensure safe removal of fluid excess
Reducing IDWG

- Na Restriction Most Effective
- Constant Nagging About water (Fluid) Restriction (w/o Na restriction):
  - Ineffective
  - Causes Discomfort
  - Causes Unnecessary Guilt
- Emphasize Na Restriction ~2 gram/day
IDWG: Na Vs. Water Restriction
A Prospective Controlled Study

 Patients Randomized to (One Mid-week Interdialytic Period):
1. Restricted Na & UNRESTRICTED Water Intake.
2. Usual Na & Water Restriction

Rigby-Mathews, 99
**IDWG**

**Fluid Weight**
- Excessive Na/H2O Intake
  - HTN, ↑Fluid, Poor Outcome
- Excessive IDWG → Indep. Risk Factor Hypertension  

> 5.7% Body Weight, Associated with Increased RR Death.  

**Tissue Weight**
- Limited Food Intake → Limited IDWG - Harmful

IDWG < 3% BW – Higher RR of Death.  

**Appropriate Diet**
- Limited Na, (K, P) Intake
- Judicious Fluid Intake
- Enough Protein & caloric Intake
Na (Fluid) Removal by Dialysis
Dialysis Removes Na by Diffusion & Convection/UF

**Diffusion:** Movement of solute (Na) on Concentration gradient. D-Na lower than B-Na

**Convection:** Movement of solute (Na) on Pressure gradient. D-P Lower than B-P

<table>
<thead>
<tr>
<th>BLOOD</th>
<th>DIALYSATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Na</td>
<td>Na</td>
</tr>
</tbody>
</table>
Evolution of HD Technique

- In 1960s:
  - Dialysate Na <130; Low Na Diet; Longer Dialysis \(\rightarrow\) Good BP Control

- In 70s-80s (till now):
  - High Efficiency Shorter HD: Hypotension
  - Increase in Dialysate Na \(\sim 135\) \(\rightarrow\) Less Dialytic Complications
    - BUT More HTN
    - Increase in mortality (? Na)
  - Standard dialysate Na \(\rightarrow\) 140
Dialytic Na Removal Challenges

• Despite Na gradient difference and significant weight loss (UF)
• Often patients are left in positive Na balance at the end of the treatment?

Gibbs-Donnan Effect
Sodium balance with dialysis (Flanigan, 1998)

• Av. predial. Na →137.7, D-Na ~142, Av. weight loss 2.2 Kg
• Calculated Na balance +85 mEq (Na retained, despite 2.2 Liters UF)
• Several studies have shown the limitation of dialysis for Na removal by diffusion + convection (particularly with standard dialysate of 140 Na)
Diffusion –
Gradient between B-Na and D-Na

Diffusible Na, that is not:
electrochemically attached to protein, and other non-diffusible anions
These ‘attachments’ are dependent on pH and concentrations of anions.

Diffusible Na -
Lower than total serum Na
Indirectly proportional to albumin
Clinical Example:
Total serum Na = 140
Dialysate Na = 137
Expected gradient +3
However,
Diffusible Na = \(135\) mEq/L
Gradient = -2

**Convection** – Gradient independent
However ultrafiltrate will only remove Na not ‘attracted’ to anions
Or, the ultrafiltrate is relatively hyponatremic to serum:
UF- Na < Serum- Na,
In previous example \(\rightarrow\) UF Na = 135 mEq/L UF
Limitation of Diffusion & Convection

• Concentration gradient between plasma & dialysate determines diffusion
  – The concentration gradient between free Na on both sides of membrane
  – However, because of Gibbs Donnan effect, the free serum Na is lower than measured concentration
  – Thus diffusion is either limited or is in wrong direction, dialysate to blood.

• Convection:
  – Because of Gibbs Donnan effect the UF is hyponatremic, amount of Na removed / liter is lower, limiting total Na removal.
Effect of Dialyzer Membrane and Rapid UF

1. Gradient is from D to Blood
2. UF Na is lower, UF is hyponatremic

Both of these make Na removal challenging

It is important that dialysate Na must not be high.

Effect of Dialysate Na →
Dialysate Na
(Levin N et al Blood Purif 19:217,2001)

- Data Extracted from 58 Stable HD Pts. Over 9-16 Months
- 98% Had Average Predialysis Plasma Na Below Dialysate Na (143 mEq/l)
- Significant Correlation Between:
  - Na Gradient & Interdialytic Weight Gain
  - Na Gradient & Predialysis MAP

Larger the Difference Between, Dialysate Na and Plasma Na the Larger the ECV Expansion & HTN

<table>
<thead>
<tr>
<th>Davenport, Neph Clin Pract, 2006: Dialysis units survey:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialysate Na - 136.8</td>
</tr>
<tr>
<td>D-Na 140</td>
</tr>
<tr>
<td>Larger IDWG</td>
</tr>
<tr>
<td>Higher Pre- &amp; Post- BP</td>
</tr>
<tr>
<td>More anti-HTN Meds.</td>
</tr>
</tbody>
</table>
Implications of current trends toward prescribing high dialysate sodium in hemodialysis.

Santos S F F, Peixoto A J CJASN 2008;3:522-530
Sodium Modeling

- Data is accumulating that it leads to positive Na balance and hypertension
- Increased Na is harmful
- Very selective and limited/No use of Na modeling
  - Use UF modeling, lower temperature, reducing IDWG, increasing dialysis time etc.
Reaching Dry Weight

Major Barriers:

- Inaccurate Assessment of Dry Weight
- Intra-dialytic Hypotension
- Poor Understanding of IDWG
- Poor Cardio-vascular Status
  - Older Patients with Multi-system Problems
  - Diabetics with Poor Vascular & Autonomic Response
Assessment of Dry Weight

- Clinically:
  - BP
  - JVP
  - Pulmonary Exam
  - Edema / anasarca

- Use of devices and Lab Tests:
  - ANP
  - Others, Bio-impedance
Signs of ECV Excess
1. Increased BP
2. ↑ Central Venous Pressure (JVP)
3. Edema & Anasraca
4. Fluid in Lungs (Pulm.Edema)
5. Increased Trans-cellular space (Ascitis, Pl. Effusion etc.)
ECV Determination

- Only accurate laboratory method is radio-labelled determination of ECV/plasma/water
- Bio-impedence determination provides information about ECW, ICW & nutrition
  - However its accuracy is controversial
  - Requires equipment and trained staff
- Careful clinical examination is most practical and useful method
Reaching Dry Weight

Major Barriers:

- Inaccurate Assessment of Dry Weight
- Intra-dialytic Hypotension
- Poor Understanding of IDWG
- Poor Cardio-vascular Status
  - Older Patients with Multi-system Problems
  - Diabetics with Poor Vascular & Autonomic Response
Preventing Hypotension

1. UFR Vs. Re-equilibration Rate
Intra-Cellular
Interstitial

Na excess – ECV Excess

Free Water Excess

Intra-Cellular
Interstitial

PV

Movement of Fluid Between Plasma & Interstitium Occurs at the Capillary Level Governed by Starlings Forces

\[ J_f = K_f (P_{cap} + Onc_{Int}) - (Onc_C + P_{Int}) \]

Arteriole
Capillary
Pcap
Venule
OncC

Ahmad
Intra-Cellular Interstitial PV

**Fluid Compartments**

UFR Slower Than Refill Rate
No PV
No Hypotension

UFR Faster Than Refill Rate
PV Depletion
Hypotension

Normal RER
15-18 ml/kg/hr
Recomm. UFR <13ml/kg/hr

Ahmad
Dialysis Treatment

- Long Enough To Remove IDWG
  - Weight = 60 Kg, Re-equilib. rate = 15 ml/Kg/hr.
  - Dialysis Time = 3 Hours, IDWG = 4 Kg
  - UFR = 4lit./3 hr or 1300 ml/hr
  - Re-equilb. Rate = 15 x 60 or 900 ml/hr - Hypotension

- Dialysis Time > 4 Hours

- More Frequent Dialysis
  - >2 hrs  6 times/wk.
Preventing Hypotension

2. Effect of Osmolarity
Osmolarity

Hemodialysis

Osmolar Drop → Shrinks ECV (PV) More Than caused by UF

Hypotension

Separate the Osmolar Drop From UF

Normal Response to Blood Loss

In Uremia Response to UF

HR

SVR

BP is Maintained

Hypotension

HR

SVR
Convective Vs. Diffusive Dialysis

Osmolarity

Hemodialysis

Convective D
Better Hemodynamics
UF Profiling

High UFR in the beginning followed by a gradual reduction in UFR
Blood Volume Response to UF Modelling

STEPPED UF

INTERMITTENT UF

Lopot et al, Int J Artif Org 20:91,'97

Stiller et al, Trans Am Soc Artif Int Org 35:S532,'89
UF Profiling

- Reported to Decrease Hypotensive Episodes
- Appears to Be More Effective Than Na Profiling
- Increase in IDWG not reported
- More Studies Needed:
  - Type of Profile
  - Long Term Effects
Controlling Na Fluid Excess

- Limit IDWG by adjusting Na intake
- Dialysis must be long enough to remove fluid excess safely (UFR <13 ml/Kg/hr)
- The dialysate Na must be low enough to aid diffusive loss more importantly prevent positive Na balance.
  - Balance between dialytic symptoms and Na removal
- Use convective dialysis to prevent hypotension
No Device Measures Absolute BV
- Optical Absorption (Crit-Line, Hemoscan): Influenced by Hb, O2 Saturation, Light Scattering by Cells.
- Sound Speed (BVM-Fres.): Measures Relative BV, Influenced by Protein Conc., & Temperature.

Effect on patient outcome remains controversial.
- Randomized Study: Use of BVM did not reduce mortality or hospitalization (higher with BVM)
  (Reddon et al, JASN 2005)
- Multi center quality improvement project – 50% reduction in hospitalization with BV monitoring by Crit-Line
<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical Markers, ANP, cGMP</td>
<td>Easy to use, Sensitive to Volume Overload</td>
<td>Heart failure, Valve Disease, Not useful in Volume depletion, Normal values?</td>
</tr>
<tr>
<td>Vena Cave Diameter</td>
<td>Available, Reflects Vascular Volume &amp; UF Volume</td>
<td>Overestimates Volume Decrease, Inter-operator Errors, Very Variable</td>
</tr>
<tr>
<td>Bioimpedence</td>
<td>Easy to Use</td>
<td>Underestimates UF, Underestimates Trunk Volume, Confounded by Temp., Ion, Recumbancy</td>
</tr>
<tr>
<td>Blood Volume Monitoring</td>
<td>Ease of Use, May prevent Hypotension</td>
<td>Measures Relative Volume Only, Affected by other variables, Interpatient variability</td>
</tr>
</tbody>
</table>
Blood Volume Monitoring

Non-dialyzable substances such as RBC and Protein concentration Can be monitored in the art. blood line.

As plasma water is ultrafiltered, the Increase in concentration of these particles Will be proportional to the decrease in Plasma water.

The slope of the curve will reflect Ultrafiltration Vs Re-equilibration

The BV monitor can non-invasively and continuously measure percentage change in BV. The Crit-Line measures HCT, oxygen saturation, and calculates hemoglobin.
BVM advantages & limitations

- BVM only monitor the percentage change in blood volume during dialysis.
- Device is helpful in preventing too fast UF leading to hypotension and cardiac issues.
- Device seems to be helpful in convincing patients to allow adequate UF.

Limitations:
- The effect of change in RBC volume with a decrease in osmolarity can influence the results.
- **It does not provide any information about ECV status, only a % change in blood volume**
- Effect on patient outcome is controversial.
Intradialytic Hypotension (Prevention)

- Slower UF, UF Modeling?
- Increased Dialysate Na, Na Modeling. Risk of +Ve Na Balance
- Remove BP Meds. (Use Short Acting)
- Lower Dialysate Temperature
- Dialysate Buffer, Avoid Acetate
- Avoid Large Meals During HD
- Prevent Arrhythmia, Improve Cardiac Fx
- SUF; UF modeling
- Avoid Low Dialysate Ca
- Treat Lower Hct.
Anti-hypertensive Medications

- Normal response to UF is to ↑ SVR & HR
  - BP = CO x SVR → BP is maintained
  - BP medications work by:
    - Reducing SVR; Reducing CO; or Both
- BP medication interfere with normal response to UF, thus reaching DW
BP control in ESRD

• Most effective method to control BP is by normalizing fluid (Na/ECV) excess.
• Use of BP medication, w/o controlling ECV excess, may have adverse effect on outcome (Charra, Scribner)
• Interferes with UF, achieving dry weight & eu- volumia
  – May affect CV responses to dialytic process
  – May cause arrhythmia & intra-dialytic symptoms
• No strong evidence that BP medication improve hard outcome
However,

• Home BP is more predictive of outcome than dialytic BP
• During the inter-dialytic period BP may increase to hypertensive levels and BP medications may help?
• In non-ESRD, BP medications have been shown to:
  – Improve cardiac remodeling – ACEI/ARB (CCB)
  – Improve outcome after coronary events (B-blockers)
  – Improve CCF (MRA, B-blockers, ACEI/ARB)
  – Remodel arterial wall thickening (ACEI)
Review of literature


• Meta-analysis of 8 RCT in 2009 showed:
• Decrease in BP associated with:
  – significant reduction in CV events, mortality & all cause mortality
• No beneficial effects of ACEI,ARB, CCB and B-blocker independent of BP lowering effect
• No agent had superiority over others
BP Medications: ACEI & ARB

• ACEI are dialyzed ARBs are not
• ACEI increase cytokines more than ARB (Ahmad et al)
  – More risk of allergic reactions, angioedema with ACEI
• Both are associated with risk of hyperkalemia
• Supporting evidence for benefit is not as strong as in non ESRD population
• My bias is to use ARB (if you have to)
<table>
<thead>
<tr>
<th>Class/Agent</th>
<th>Dialyzed</th>
<th>Dosages</th>
<th>Class/Agent</th>
<th>Dialyzed</th>
<th>Dosages</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCBs</td>
<td>No</td>
<td>30-60 mg bid</td>
<td>Beta blockers</td>
<td>Yes/No</td>
<td>40-160 mg bid</td>
</tr>
<tr>
<td>Nifedipine</td>
<td>No</td>
<td>30-60 mg bid</td>
<td>Propranolol</td>
<td>No</td>
<td>40-160 mg bid</td>
</tr>
<tr>
<td>Amlodipine</td>
<td>No</td>
<td>2.5-10 mg qd</td>
<td>Metoprolol</td>
<td>&gt;75%</td>
<td>50-200 mg bid</td>
</tr>
<tr>
<td>Felodipine</td>
<td>No</td>
<td>2.5-10 mg qd</td>
<td>Nadolol</td>
<td>50%</td>
<td>40-240 mg daily</td>
</tr>
<tr>
<td>Non-dihydropiridines - Not used</td>
<td></td>
<td></td>
<td>Atenelol</td>
<td>50-75%</td>
<td>25-100 mg 24-48 hrs</td>
</tr>
<tr>
<td>( Except in Tachycardia )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACEI</td>
<td>Yes (except Fosinopril)</td>
<td></td>
<td>Cravedilol</td>
<td>No</td>
<td>3.125-25 mg bid</td>
</tr>
<tr>
<td>Fosinopril</td>
<td>No</td>
<td>10-80 mg daily</td>
<td>Labetalol</td>
<td>No</td>
<td>50-600 mg bid</td>
</tr>
<tr>
<td>Ramipril</td>
<td>20-30%</td>
<td>2.5-10 mg daily</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benazepril</td>
<td>20-50%</td>
<td>5-40 mg daily</td>
<td>Diuretics:</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Enalapril</td>
<td>35-50%</td>
<td>2.5-10 mg bid</td>
<td>Furosemide</td>
<td>No</td>
<td>40-160 mg bid</td>
</tr>
<tr>
<td>ARBs</td>
<td>No</td>
<td></td>
<td>Ethacrynic Acid</td>
<td>No</td>
<td>50-200 mg bid</td>
</tr>
<tr>
<td>Losartan</td>
<td>No</td>
<td>25 - 50 mg bid</td>
<td>Torsemide</td>
<td>No</td>
<td>10-80 mg daily</td>
</tr>
<tr>
<td>Valsartan</td>
<td>No</td>
<td>40-160 mg bid</td>
<td>Bumetanide</td>
<td>No</td>
<td>0.5-2 mg bid</td>
</tr>
<tr>
<td>Candesartan</td>
<td>No</td>
<td>4-32 mg daily</td>
<td>Spirinolactone</td>
<td>No</td>
<td>25-100 mg daily</td>
</tr>
<tr>
<td>Telmisartan</td>
<td>No</td>
<td>40-80 mg daily</td>
<td>Eplerenone</td>
<td>No</td>
<td>50-100 mg daily</td>
</tr>
<tr>
<td>Olmesartan</td>
<td>No</td>
<td>10-40 mg daily</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Short Acting</td>
<td>Clonidine</td>
<td>5%</td>
<td>0.1-0.4 tid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long Acting</td>
<td>Hydralazine</td>
<td>No</td>
<td>10-100mg tid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minoxidil</td>
<td>Yes</td>
<td>2.5-30 mg daily</td>
<td></td>
</tr>
</tbody>
</table>
General Guideline

- Use Short-acting Anti-hypertensive
- Maintain accurate record of BP Meds
- Reduce and Stop BP Meds. As Dry Weight is Reached

Re-establish Dry Weight:
- Nutritional Status Improves
- Concurrent Illness → Malnutrition
- After Hospitalization
- Social Status Change
Starting Dialysis (BP elevated on fosenopril 40, amlod 10, atenelol 50)

- Slow UF
- Post-dial Weight reduction

Change meds:
- enalapril 20 bid
- nifedipine 30 bid
- metoprolol 25 bid

As BP decreases, Hold /reduce dose
On dialysis days (HD)

Pre-dial BP decreases (155/95) or intradialytic hypotension

- Continue UF & Wt reduction
- Start reducing & d/c meds:
  1. metoprolol
  2. nifedipine
  3. enalapril

Pre-dialysis BP <140/<90
- No BP medication
- No signs of ECV excess

DRY WEIGHT
Volume Control

- Must Be A Part of Adequacy of Dialysis Assessment
- More Attention Must be Paid to:
  - Dry Weight Determination
  - IDWG
  - BP
- Improve Patient & Staff Education