The “Downside” of Hemodialysis’ Hemodynamic Challenges

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Nephrologist, SPH
Common Intradialytic Complications

- **HYPOTENSION**
  - Arrhythmia
  - Hypoxemia
  - Muscle cramps

- Anaphylactic reactions
- Dialysis Disequilibrium
  - Nausea, vomiting
  - Headache
- Hypertension
Overview

• Definition and prevalence
• Pathophysiology
• Treatment strategies
• Interactive case reviews
Definition

• Many different definitions in the literature
  – SBP <100 mm Hg or BP drop >20 mm Hg with concomitant symptoms
    • Dizziness, blurred vision, cramps, fatigue
  – Rapid changes in BP
    • Fall of >40 mm Hg systolic or >20 mm Hg diastolic within 15 min. period regardless of symptoms or whether requires nursing interventions
Prevalence

• May complicate 10-30% of all HD treatments
• Affects 20-50% of HD pts.
• Frequency has not decreased despite improved technology such as ultrafiltration controllers
• High risk patient population
Consequences

• **Clinical Sequelae**
  – Neurologic - seizures, stroke
  – Cardiac - angina, MI, arrhythmias
  – Mesenteric ischemia
  – Vascular access closure
  – Decreased adequacy of dialysis treatment
  – Prevents achievement of goal weight

• Increased morbidity and mortality related to patient population comorbidities
“Unphysiology” of Hemodialysis

• Major reason for side effects is severe fluctuations in various ions and water which may be detrimental to cells of the body
  – Intermittent short dialysis procedure
  – Vigor or efficiency of each individual dialysis
  – Patient non-compliance with fluid, protein, electrolytes
Multifactorial Causes

- **Patient Related factors**
  - Limited cardiac reserve – systolic and diastolic dysfunction
  - Arterial tone and venous capacitance
  - Autonomic dysfunction (neuropathy)

- **Dialysis Related Factors**
  - Ultrafiltration, amount and rate
  - Decline in plasma osmolality
  - Warm dialysate temperature
  - Dialysate electrolytes, sodium, calcium, magnesium
  - Dialysate buffer, acetate vs. bicarbonate
  - Membrane interactions

- **Other**
  - Antihypertensives and negative inotropes
Determinants of Systemic BP

Systemic BP

Cardiac Output
- Heart rate
- Stroke Volume

Peripheral Vascular Resistance

Plasma Volume

Myocardial contractility
Compensatory Mechanisms

- Plasma Refilling
- Venous Capacity
- Arteriolar Resistance
- Cardiac
Plasma Volume

• Approximately 3 L
• Entire plasma volume removed during typical dialysis session
• Blood volume drops by 5-20% because:
  – Plasma refilling from:
    • Intracellular and interstitial fluid compartments
    • Splanchnic and cutaneous circulation
  – UF leads to:
    • Increase in plasma oncotic pressure
    • Drop in capillary hydrostatic pressure
    • Both mobilize fluid from extravascular space
• Plasma volume falls depending on:
  – relative UF rate
  – plasma refilling rate
Plasma Refilling Rate

• Direct relationship with size of interstitial compartment
• Still very variable between patients of similar interstitial compartment size
• Higher risk of hypotension if low proteins or high ureas (oncotic & osmotic forces)
• Hypotensive episodes are common when extra/intravascular fluid shift occurs at a rate of <4 ml/mm Hg/min.
• Also dependent on sodium
Poor Plasma Refilling

- Inadequate arteriolar and venous vasoconstriction leading to venous pooling
  - Autonomic neuropathy
    - Ineffective sympathetic nervous system
  - Factors leading to vasodilatation
    - Need to dissipate heat
    - Medications
    - Buffers
    - Ischemia creating adenosine
  - Eating on dialysis
    - Increases splanchnic blood flow
    - Increases production of gastric fluids
Compensatory Mechanisms

- Plasma Refilling
- Venous Capacity
- Arteriolar Resistance
- Cardiac
Venous Compliance

• Crucial for adjustments to changes in intravascular volume
• Provides capacitance of circulation
  – Venous systems holds 60-80% of blood volume
• Reduced in hypertensive HD patients
  – Cannot be normalized with medications
  – Suggests structural abnormalities
    • Increased media of venous wall
Arterial Compliance

- Arterial stiffness and loss of arterial compliance
  - Arteriosclerosis
    - Gross intimal fibrosis and medial calcification
    - Lipid deposits are infrequent
    - Caused by uremia
- Correlates with development of LVH
Autonomic Neuropathy

- Occurs in >50% of dialysis patients
- Afferent limb defect of baroreceptor function
  - Situated at carotid sinus
  - Minimized reflex increase in catecholamine release
- Downregulation of alpha-adrenergic receptors
  - Diminished response to endogenous catecholamines
- Paradoxical reflex- Bezold-Jarisch reflex
  - Decreased sympathetic and parasympathetic activity
  - Cardioinhibitory- sinus bradycardia and lower BP
Compensatory Mechanisms

- Plasma Refilling
- Venous Capacity
- Arteriolar Resistance
- Cardiac
Cardiac Function

• Diastolic Dysfunction or LVH
  – Inability for ventricle to relax during diastole resulting in reduced stroke volume

• Systolic Dysfunction
  – Diminished cardiac reserve in situation of hemodynamic challenge
LV Diastolic Volume

Fig. 1. Compliance characteristics of the left ventricle during diastolic filling. In end-stage renal disease a leftward shift of the pressure–volume relationship is common, such that myocardial compliance is decreased. Reproduced from [8], with permission.

Physiologic Factors in Intradialytic Hypotension

- Venous Compliance
- Hypertension
- Arterial Compliance
- Venous Return
- LVH
- Plasma Volume
- Diastolic Filling
- Cardiac Output
- Failure of Reflex Vasoconstriction

HYPOTENSION
Treatment Strategies
Dry Weight

- Requires frequent assessment
  - If patients are eating well, they can develop more tissue mass or vice versa
  - Clinical examination lacks sensitivity and specificity
- Encourage patient compliance with fluid and sodium intake
  - High dietary sodium increases thirst
  - Adjustment of dialysate sodium to prevent thirst and thus high interdialytic weight gain
  - Need to balance with attempts to prevent intradialytic hypotension
Methods to Assess Volume Status

• IVC diameter
• Bioimpedance } Not practical to use on daily basis
• Continuous Blood Volume Monitoring
  – Small decrease in BV could suggest fluid overload
    • Dry weight could be adjusted lower
  – Achieve patient-specific ideal curve of blood volume decline
    • Can reduce hypotensive episodes by 30%
Ultrafiltration

• Isolated UF
  – Reduces efficient dialysis time
  – Can be considered if total time on dialysis is increased
  – May not be better than just increasing total time

• UF modeling
  – Allows for plasma refilling when at risk for hypotension
  – Can profile in concert with sodium
    • Hemocontrol Biofeedback System (Hospal, Italy)
      – Automatically decreases UF rates or increase dialysate conductivity if Blood volume falls below predefined level
Blood Volume monitoring and manual feedback

$\Delta BV\%$

Stop Uf

Stop Uf

Stop Uf

UFR ml/min

0 10 20

60 120 180 240

minutes
Blood Volume Monitoring “Crit Monitor”

- Stable hemoglobin 110-120
  - Anemia, decreased oxygen delivery, ischemia
  - Transfusions reduced hypotension by 50% when Hb < 60

- Crash Crit
  - Hematocrit at which UF rate exceeds plasma refilling rate causing hypotension
  - Real-time surveillance of blood volume changes
CRASH CRIT Observed

![Graph showing hematocrit over time with CRASH CRIT threshold and UF on/off indicators.](image)

- CRASH CRIT THRESHOLD
- UF Off (Crash)
- UF Off (Crash)
- UF Off (Crash)
- UF On
- UF On

UFR = 1828 ml/hr

Time (hours)

DE210793
Individualize Treatment

- RBV\text{\textsubscript{critical}}
- Symptomatic hypotension when blood volume below 50 ml/kg
- Discover individual limit and develop algorithm to predict point of risk

# Characteristics of Hypotension-Prone HD Patients

Table 1. Concomitant diseases in the study population

<table>
<thead>
<tr>
<th>Condition</th>
<th>Prevalence (% of all patients)</th>
<th>Prevalence (% of female patients)</th>
<th>Prevalence (% of male patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>64.4</td>
<td>75.0</td>
<td>47.8</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>44.1</td>
<td>55.6</td>
<td>26.1</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>28.8</td>
<td>25.0</td>
<td>34.8</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>27.1</td>
<td>27.8</td>
<td>26.1</td>
</tr>
<tr>
<td>Peripheral arterial occlusive disease</td>
<td>25.4</td>
<td>30.6</td>
<td>17.4</td>
</tr>
<tr>
<td>Autonomous neuropathy</td>
<td>18.6</td>
<td>22.2</td>
<td>13.0</td>
</tr>
<tr>
<td>Cardiac arrhythmia</td>
<td>15.3</td>
<td>13.9</td>
<td>17.4</td>
</tr>
<tr>
<td>Chronic hypotension</td>
<td>5.1</td>
<td>0.0</td>
<td>13.0</td>
</tr>
</tbody>
</table>

Characteristics of Hypotension-Prone HD Patients

Table 2. Patient characteristics according to gender and diabetes mellitus

<table>
<thead>
<tr>
<th></th>
<th>All patients</th>
<th>Female patients</th>
<th>Male patients</th>
<th>$P$ (gender)</th>
<th>Patients with DM</th>
<th>Patients without DM</th>
<th>$P$ (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution (%)</td>
<td>100</td>
<td>62</td>
<td>38</td>
<td></td>
<td>57</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>$66 \pm 11$</td>
<td>$65 \pm 11$</td>
<td>$68 \pm 11$</td>
<td>0.34</td>
<td>$64 \pm 8$</td>
<td>$68 \pm 12$</td>
<td>0.11</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>$73 \pm 16$</td>
<td>$71 \pm 15$</td>
<td>$78 \pm 15$</td>
<td>0.11</td>
<td>$77 \pm 3$</td>
<td>$71 \pm 3$</td>
<td>0.05</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>$26.6 \pm 4.9$</td>
<td>$26.8 \pm 5.2$</td>
<td>$26.2 \pm 4.6$</td>
<td>0.70</td>
<td>$28.1 \pm 3.9$</td>
<td>$25.4 \pm 5.3$</td>
<td>0.04</td>
</tr>
<tr>
<td>UFV (% of weight)</td>
<td>$3.7 \pm 1.4$</td>
<td>$3.6 \pm 1.3$</td>
<td>$3.9 \pm 1.5$</td>
<td>0.47</td>
<td>$3.8 \pm 1.3$</td>
<td>$3.7 \pm 1.5$</td>
<td>0.15</td>
</tr>
<tr>
<td>sBP (mmHg)</td>
<td>$147 \pm 25$</td>
<td>$152 \pm 24$</td>
<td>$136 \pm 24$</td>
<td>0.01</td>
<td>$155 \pm 28$</td>
<td>$140 \pm 22$</td>
<td>0.03</td>
</tr>
<tr>
<td>dBP (mmHg)</td>
<td>$82 \pm 18$</td>
<td>$84 \pm 19$</td>
<td>$78 \pm 17$</td>
<td>0.23</td>
<td>$85 \pm 19$</td>
<td>$78 \pm 17$</td>
<td>0.12</td>
</tr>
<tr>
<td>RBV$_{crit}$ (%)</td>
<td>$88.7 \pm 6.2$</td>
<td>$88.8 \pm 5.9$</td>
<td>$88.6 \pm 6.9$</td>
<td>0.77</td>
<td>$88.7 \pm 6.2$</td>
<td>$88.8 \pm 6.4$</td>
<td>0.50</td>
</tr>
<tr>
<td>IME per HD session</td>
<td>$1.1 \pm 0.7$</td>
<td>$1.1 \pm 0.8$</td>
<td>$1.0 \pm 0.7$</td>
<td>0.50</td>
<td>$1.2 \pm 0.8$</td>
<td>$0.9 \pm 0.7$</td>
<td>0.06</td>
</tr>
</tbody>
</table>

sBP, dBP, systolic, diastolic blood pressure at start of treatment; UFV, ultrafiltration volume (relative to dry weight). All values are given as mean ± SD.
## Intradialytic Morbid Events

**Table 3.** Summary of 760 reported symptoms during 537 intradialytic morbid events

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Frequency</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>508</td>
<td>66.8</td>
</tr>
<tr>
<td>Cramps</td>
<td>99</td>
<td>13.0</td>
</tr>
<tr>
<td>Dizziness</td>
<td>36</td>
<td>4.7</td>
</tr>
<tr>
<td>Nausea</td>
<td>23</td>
<td>3.0</td>
</tr>
<tr>
<td>Headache</td>
<td>15</td>
<td>2.0</td>
</tr>
<tr>
<td>Vomiting</td>
<td>13</td>
<td>1.7</td>
</tr>
<tr>
<td>Others</td>
<td>66</td>
<td>8.7</td>
</tr>
<tr>
<td>Total</td>
<td>760</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Table 4.** HD sessions with no, one and multiple intradialytic morbid events (IME)

<table>
<thead>
<tr>
<th>No. of HD sessions</th>
<th>No. of IME per session</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>265</td>
<td>0</td>
<td>45.3</td>
</tr>
<tr>
<td>183</td>
<td>1</td>
<td>31.3</td>
</tr>
<tr>
<td>79</td>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>41</td>
<td>3</td>
<td>7.0</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Intradialytic Morbid Events

Fig. 1. Distribution of intradialytic morbid events (IME) over the HD session. Each bar represents the percentage of IME in the indicated 5% of the delivered treatment time.
Critical Relative Blood Volume

$RBV_{\text{critical}}$

Critical Relative Blood Volume $\text{RBV}_{\text{critical}}$

Table 5. Cumulative patient distribution of the individual $\text{RBV}_{\text{crit}}$

<table>
<thead>
<tr>
<th>$\text{RBV}_{\text{crit}}$</th>
<th>No. of patients</th>
<th>No. of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 80$</td>
<td>3</td>
<td>5.0</td>
</tr>
<tr>
<td>$\leq 85$</td>
<td>19</td>
<td>31.7</td>
</tr>
<tr>
<td>$\leq 90$</td>
<td>30</td>
<td>50.0</td>
</tr>
<tr>
<td>$\leq 95$</td>
<td>51</td>
<td>85.0</td>
</tr>
<tr>
<td>$\leq 100$</td>
<td>57*</td>
<td>95.0*</td>
</tr>
</tbody>
</table>

*One patient with $\text{RBV}_{\text{crit}} > 100\%$, and two patients without $\text{RBV}_{\text{crit}}$ during the observation period.

Table 6. Cumulative intra-individual variability of $\text{RBV}_{\text{crit}}$

<table>
<thead>
<tr>
<th>SD</th>
<th>No. of patients</th>
<th>Sum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq \pm 1%$</td>
<td>4</td>
<td>6.7</td>
</tr>
<tr>
<td>$\leq \pm 2%$</td>
<td>12</td>
<td>20.0</td>
</tr>
<tr>
<td>$\leq \pm 3%$</td>
<td>24</td>
<td>40.0</td>
</tr>
<tr>
<td>$\leq \pm 4%$</td>
<td>35</td>
<td>58.3</td>
</tr>
<tr>
<td>$\leq \pm 5%$</td>
<td>46</td>
<td>76.6</td>
</tr>
<tr>
<td>$\leq \pm 6%$</td>
<td>47</td>
<td>78.3</td>
</tr>
<tr>
<td>All patients</td>
<td>60</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Mean $\pm$ SD: $3.6 \pm 2.1\%$.
Algorithm

\[
RBV_{\text{crit}} = 97.8 - 0.08 \text{ dBP} - 1.4 \frac{V_{\text{UF}}}{\text{Wt}} + 0.05 \text{ Age} + 1.5 \text{ Arrh} + 0.2 \text{ CHF}
\]
Sodium

- Low dialysate Na assoc. with hypotension
- Low dialysate Na reduces serum Na
  - Drives ECF water into cells
  - Reduction in plasma volume
- Higher serum sodium may have direct vasoconstrictor effect (vasopressin effect)
  - Trial of Na ramping so that by end of HD treatment, patient has not gained sodium
  - Individualize dialysate Na (predialysis sodium)
    - Osmolality set point
Individualized Dialysate Sodium Prescription

- Reduction in interdialytic weight gain
  - Reduction in UF
- Reduction in interdialytic thirst
- Improvement in predialysis BP in hypertensive patients
- Adjustment in sodium prescription based on predialysis values may be used safely
  - Limitation of study – patients prone to hypotension may not tolerate

UF and Sodium Profiling

**Figure 1.** Treatment protocols. (A) Conventional hemodialysis (HD; control; dialysate sodium 138 mEq/L). (B) Sodium balance-positive step-down sodium profiling HD (PS; time-averaged mean of dialysate sodium 143 mEq/L). (C) Sodium balance–neutral step-down sodium profiling HD (NS; 138 mEq/L). (D) Sodium balance–neutral alternating type sodium profiling HD (NA; 138 mEq/L). (E) Conventional HD + step-down ultrafiltration profile (UFP; UFP only; 138 mEq/L). (F) PS + step-down UFP (PS+U; 143 mEq/L). (G) NS + step-down UFP (NS+U; 138 mEq/L). (H) NA + alternating type UFP (NA + U; 138 mEq/L). Dotted line, time-averaged mean of dialysate sodium or UF rate during the session.

UF and Sodium Profiling

UF and Sodium Profiling

Cool Dialysate

- Subnormal core temperature in 20% of dialysis population
- 34-35 C dialysate
  - Increases peripheral vasoconstriction
  - Increase cardiac inotropy
  - Increase in catecholamines
  - Risk of increasing myocardial oxygen demand in patients with CAD and precipitate angina
- Cool HD room
- Post dialysis hypotension is not more common
- “Isothermic” dialysis
Fig 6. Changes over time in (A) systolic (ΔSBP) and diastolic blood pressure (ΔDBP) and (B) heart rate (ΔHR) during the two treatments. Values given as mean ± SEM. *P < 0.05. (-•-) Thermoneutral HD; (−−−) isothermic HD.
Midodrine

- Pro-drug of alpha-1-adrenergic receptor agonist, desglymidodrine
- Induces constriction of both arterial and venous capacitance vessels
- Peak levels achieved in 1 h; $T^{1/2}=3$ h
- Few side effects
- Safe in patients with CAD
Systematic Review

- 9 studies
- Exclusion criteria
  - Patients on antihypertensive agents
  - Active Medical Conditions
  - Vascular Access Dysfunction
  - Dialysis with a catheter
  - Pericardial Effusions
  - Impaired LV documented on echo
  - Diabetes

Systematic Review

- Dosing ranged from 2.5 –10 mg given 15-30 min. prior to onset of dialysis treatment
- Six out of 10 reported improved symptoms
- Conclusion
  - Midodrine can blunt the drop in BP during HD
  - Limitation was poor quality of studies
    - Only 2 were crossover in design; no RCTs
    - Small groups of patients
    - Does not answer whether there is any added advantage over cool dialysate
      - No discernible difference between the two strategies

Approach to Midodrine Therapy

- Initiate therapy 30 minutes before HD at dose of 2.5 – 5mg and titrate upwards
  - Maximum daily dose of 30 mg
- May give a second dose if there is mid-dialysis or post dialysis hypotension
  - Give dose midway during HD treatment
- Avoid during active coronary ischemia
Sertraline

- Serotonin re-uptake inhibitor
- Preserves central sympathetic activity through inhibition of excessive serotonin in CNS
- Allows alpha-1-adrenergic receptor mediated venous and arteriolar constriction
  - Theoretical
Sertraline

• Would it improve BP in patients already receiving other treatments?
  – Cool dialysate, midodrine, sodium profiling
• 18 patients in crossover design
• Measured CO, CBV, PVR with US dilution
  – Not statistically different with or without sertraline 50 mg/day

Brewster UC et al. Nephrology 2003; 8: 296-301.
Caffeine

• Adenosine is an antagonist of norepinephrine
  – Release following hypotension which may cause ischemia
    • Breakdown from ATP
• Caffeine 250 mg (4 cups of coffee) given 2 hrs. into dialysis
  – Reduction in sudden hypotension
  – No difference in common gradual hypotension
Carnitine

- Co-factor to move fatty acids into mitochondria of cells
- Deficiency may cause asthenia, hypotension, cardiomyopathy
- Dose of 20 mg/kg IV at end of HD
- Hypotension reduced by 44% to 18%
- Not readily available and expensive
- Oral doses of 1 g for muscle cramps
Composition of Dialysate

- **Low calcium baths**
  - Lowers cardiac contractility
  - 2.5 vs. 3.5 baths
  - Risk of hypercalcemia with higher baths
  - No benefit in those with EF<40%

- **High Mg baths**
  - Causes vasodilation; used for treatment of eclampsia

- **Mg 0.25 baths** in combination with low Ca 1.25
  - Mg 0.75 preserved BP if using Ca 1.25 but not 1.75

- **Bicarbonate baths**
  - Dialysate bath of 32 vs. 26
Intravenous Fluids

• Normal Saline
• Albumin
  – 5% albumin no more effective than NS
  – More expensive
• Mannitol
• Hypertonic saline
  – 5 ml boluses, 3 doses 10 minutes apart
  – Potentially can cause hypernatremia
• Hypertonic glucose
Salty Broth

- Slower method of providing saline
- Requires absorption from gut
- Only should be offered if lines have been removed
Avoid Medications

- Long acting CCBs or ACEI vs. short-acting
- May hold meds on day of HD
- Trial and error
- Verapamil may be helpful for diastolic dysfunction
  - Relaxation of stiff left ventricle allowing for proper filling during diastole
  - Preserved stroke volume
Dialyzer membranes

- Biocompatible theoretically better for hemodynamic stability
- Long term benefits
  - Long term survival
  - Fewer infections
  - Fewer hospitalizations
Underlying Disease

- Dialysis related Amyloidosis
  - Hypotension during dialysis and interdialytic period
  - Postural Hypotension
  - Amyloid infiltration of blood vessels or sympathetic nerve endings
- Adrenal Insufficiency
- Pericardial Effusion
Exercise

• Improves quality of life by increasing stamina
• Increases Hgb, normalizes lipid patterns
• Increases cardiovascular stability
Blood Flow

- Increasing BFR increases dialysis of small solutes
- Extracellular fluid osmolality falls
- Shift of intravascular fluid to intracellular
- Reducing BFR will reduce efficiency of HD
Daily and Extended HD

- Perform HD over a longer duration
- Add extra HD days
- Extended HD can increase arterial baroreflex sensitivity and compliance
  - Normalizes BP, reduces LVH
# Nocturnal HD

**Table 1.** Dialysis dose, hemodynamics, baroreflex sensitivity for heart rate, and medication requirements before and after 2 months of nocturnal hemodialysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Conventional hemodialysis</th>
<th>2 months of nocturnal hemodialysis</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kt/V per session</td>
<td>1.2 ± 0.05</td>
<td>2.1 ± 0.1</td>
<td>0.008</td>
</tr>
<tr>
<td>Phosphate mmol/L</td>
<td>2.01 ± 0.3</td>
<td>1.29 ± 0.11</td>
<td>0.04</td>
</tr>
<tr>
<td>Systolic blood pressure mm Hg</td>
<td>143 ± 4</td>
<td>120 ± 6</td>
<td>0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure mm Hg</td>
<td>86 ± 5</td>
<td>70 ± 5</td>
<td>0.02</td>
</tr>
<tr>
<td>Pulse pressure mm Hg</td>
<td>56 ± 3</td>
<td>49 ± 2</td>
<td>0.05</td>
</tr>
<tr>
<td>Heart rate min⁻¹</td>
<td>76 ± 7</td>
<td>77 ± 1</td>
<td>0.93</td>
</tr>
<tr>
<td>Stroke volume mL</td>
<td>55 ± 7</td>
<td>66 ± 9</td>
<td>0.07</td>
</tr>
<tr>
<td>Weight kg</td>
<td>64.1 ± 11.9</td>
<td>64.2 ± 11.7</td>
<td>0.70</td>
</tr>
<tr>
<td>Stroke volume/pulse pressure mL/mm Hg</td>
<td>0.98 ± 0.13</td>
<td>1.43 ± 0.2</td>
<td>0.019</td>
</tr>
<tr>
<td>Baroreflex sensitivity msec/mm Hg</td>
<td>4.76 ± 1.1</td>
<td>6.91 ± 1.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Medications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angiotensin-converting enzyme inhibitors number</td>
<td>5</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Angiotensin receptor blocker number</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>β blocker number</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>α blocker number</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Calcium channel blocker number</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Other vasodilators number</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*N = 10. Values are presented as mean ± SEM or number, as indicated.*
Intradialytic Hypotension in ICU Patients with ARF

- CRRT (Prisma)
- SLEDD, SCUF
- Can use similar treatment strategies when performing intermittent HD
  - Sodium and UF profiling
  - Give Albumin to increase plasma oncotic pressure to help with vascular refilling
  - Cool dialysate temperature
  - IV vasoconstrictors, inotropes
  - Consider dialysate calcium, magnesium
Case Reviews
S.V.

- 38 F
- Long CKD history
  - ESRD from HSP/IgAN 1976
  - 3 failed transplants, last Apr 2002
    - Restarted on HD in Jan 2003
- Precipitous BP drop in first 1-2 hrs of HD
  - Similar complication during prior HD history
  - Associated with headache and tachycardia
  - Receives Cafergot and Midodrine
Patient Data

• GW 42.2 kg
  – Average wt. gain 1.5-2 kg which is 3.5-4.7% of GW

• Dialysis – L upper arm AV graft
  – F70, BPS 300, Dialysate flow 750, dialysate temp 35.5 C
  – Na 138-132, K 1.0, Ca 1.25, Mg .3

• Predialysis Bloodwork
  – Hb 122, Na 136, K 5.5, HCO₃ 31, albumin 40

• Medications
  – Usual CKD meds – EPO, Ca, IV iron
  – Not on antihypertensives

• Echo in November 2003
  – Normal global LV and RV function
  – LVMI normal (no LVH)
## Typical Dialysis

<table>
<thead>
<tr>
<th>Time</th>
<th>0740</th>
<th>0900</th>
<th>1000</th>
<th>1040</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR (per min.)</strong></td>
<td>106</td>
<td>85</td>
<td>-</td>
<td>91</td>
</tr>
<tr>
<td><strong>Blood Volume Changes (%)</strong></td>
<td>0</td>
<td>-7.0</td>
<td>-11.8</td>
<td>-</td>
</tr>
<tr>
<td><strong>BP (mm Hg)</strong></td>
<td>163/78</td>
<td>145/94</td>
<td>100/70</td>
<td>96/65</td>
</tr>
<tr>
<td><strong>Fluid Removal (L)</strong></td>
<td>0</td>
<td>0.94 (2.2%)</td>
<td>1.64 (3.9%)</td>
<td>1.86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>0730</th>
<th>0850</th>
<th>0940</th>
<th>1030</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR (per min.)</strong></td>
<td>112</td>
<td>93</td>
<td>89</td>
<td>92</td>
</tr>
<tr>
<td><strong>Blood Volume Changes (%)</strong></td>
<td>0</td>
<td>-5.7</td>
<td>-9.5</td>
<td>-11.7</td>
</tr>
<tr>
<td><strong>BP (mm Hg)</strong></td>
<td>116/67</td>
<td>126/80</td>
<td>118/76</td>
<td>135/80</td>
</tr>
<tr>
<td><strong>Fluid Removal (L)</strong></td>
<td>0</td>
<td>.81 (1.9%)</td>
<td>1.37 (3.2%)</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Write the Dialysis Orders

- Dialysis time - increase to 4 hrs
- Filter, BPS, dialysate flow – no effect
- Dialysis solution
  - Na ramped already
  - Ca 1.5, Mg 0.75, lower HCO₃ bath
  - Temp – could decrease lower at time of risk
- NPO
- Adjust GW
- Medications – Midodrine at 90 min – 2 hrs
T.S.

- 79 M, DM2
- Cardio- & cerebro-vascular history
  - 1994 CVA
  - 1997 Complete heart block, pacemaker
  - 2000 CABG
  - Dyslipidemia, HTN
- Precipitous drop in first 1-2 hrs of HD and hypotensive at end of HD
  - Receiving Midodrine 5 mg pre-HD and at 2 hrs
Patient Data

- GW 82.3 kg
  - Average wt. gain 2.5-3 kg which is 3.0-3.6% of GW
- Dialysis- LIJ Permacath
  - F160, BPS 270, Dialysate flow 500, dialysate temp 36 C
  - Na 150-140, K 2.0, Ca 1.25, Mg .3
- Predialysis Bloodwork
  - Hb 112, Na 141, K 4.1, HCO₃ 23, albumin 34
- Medications
  - Ramipril, Metoprolol – held prior to HD
  - Insulin, Plavix, Lipitor, Gabapentin, Darbepoetin, Tums
- Echo
  - Increased LV wall thickness to upper range of normal
  - Normal LV and RV systolic function
## Typical Dialysis

<table>
<thead>
<tr>
<th>Time</th>
<th>1220</th>
<th>1400</th>
<th>1500</th>
<th>1550</th>
<th>1620</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fluid Removal (L)</strong></td>
<td>0</td>
<td>.91 (1.1%)</td>
<td>1.62 (2.0%)</td>
<td>2.16 (2.6%)</td>
<td>2.52 (3.1%)</td>
</tr>
<tr>
<td><strong>Blood Volume Changes (%)</strong></td>
<td>0</td>
<td>-3.1</td>
<td>-4.3</td>
<td>-6.6</td>
<td>-</td>
</tr>
<tr>
<td><strong>BP (mm Hg)</strong></td>
<td>157/57</td>
<td>96/59</td>
<td>175/75</td>
<td>168/66</td>
<td>110/44</td>
</tr>
<tr>
<td><strong>HR (per min.)</strong></td>
<td>72</td>
<td>83</td>
<td>80</td>
<td>81</td>
<td>70</td>
</tr>
</tbody>
</table>
Write the Dialysis Orders

• Dialysis time – could increase to 4.5-5 hrs
• Dialysis solution
  – Na ramped already
  – Adjust lower to avoid excessive Na gain which could be contributing to interdialytic fluid gain
  – Ca 1.5, Mg 0.75
  – Temp – could decrease lower at time of risk
• NPO
• Medications
  – Midodrine increased to 10 mg pre-HD
  – Give Midodrine 60 min. before end
  – Try Verapamil as antihypertensive
Y.C.

- 74 F DM2
- Schizophrenia, HTN, dyslipidemia, PUD, hypothyroid
- No cardiac history
- Chronic diarrhea
- Hypotensive at mid-run and end of HD
- Twice per week HD
Patient Data

• GW 50.5 kg
  – Average wt. gain 3-4 kg which is 6-8% of GW

• Dialysis- L upper arm AVF
  – F160, BPS 300, Dialysate flow 500, dialysate temp 36 C
  – Na 140, K 3.0, Ca 1.25, Mg .3

• Predialysis Bloodwork
  – Hb 96, Na 132, K 4.1, HCO₃ 21, albumin 32

• Medications
  – Metoprolol, NTG patch – held prior to HD
  – Glyburide, Pariet, Levothyroxine, Psych meds, EPO, IV iron, Ca, 1-alpha

• Echo – normal LV wall thickness, LVEF 65%
# Typical Dialysis

<table>
<thead>
<tr>
<th>Time</th>
<th>0830</th>
<th>0900</th>
<th>1000</th>
<th>1002</th>
<th>1050</th>
<th>1115</th>
<th>1230</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Removal (L)</td>
<td>0</td>
<td>.67 (1.3%)</td>
<td>1.85 (3.7%)</td>
<td>2.0 (4%)</td>
<td>2.31 (4.5%)</td>
<td>-</td>
<td>3.1 (6.1%)</td>
</tr>
<tr>
<td>Blood Volume Changes (%)</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BP (mm Hg)</td>
<td>159/81</td>
<td>129/68</td>
<td>79/60</td>
<td>106/58</td>
<td>138/66</td>
<td>131/66</td>
<td>140/69</td>
</tr>
<tr>
<td>HR (per min.)</td>
<td>56</td>
<td>55</td>
<td>60</td>
<td>56</td>
<td>57</td>
<td>62</td>
<td>65</td>
</tr>
</tbody>
</table>

NS 200 mL
Minimum UF
Write the Dialysis Orders

- Dialysis frequency – increase to 3 times per week
- Dialysis solution
  - Na ramping, maybe 138-132
  - Ca 1.5, Mg 0.75
  - Temp – could decrease lower at time of risk
- Adjust GW, has there been a gain in tissue weight
  - Chronic volume depletion with diarrhea?
- NPO
- Medications - Midodrine 5mg pre-HD
  - Discontinue unnecessary meds that could exacerbate hypotension
  - Increase EPO, ensure adequate iron stores
Summary
High Risk Patients

- Elderly
- Established cardiac disease
  - Including LVH
- Diabetic autonomic neuropathy
- Premature vasculopathy
  - Diabetics
  - Hypertensives
  - Smokers
- Excessive interdialytic weight gain
  - >3% of total body weight
Pathways to Hypotension

Buffer

Biocompatibility

Temperature

Electrolytes

Water Quality

Blood Volume

Medications

Hypotension

Vascular Compliance

Fluid Status

Heart

Sympathetic Response
## Contributing Factors in Hemodialysis-Related Hypotension

<table>
<thead>
<tr>
<th>Dialysis Factors</th>
<th>Dialysate Factors</th>
<th>Patient Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fluid removal</td>
<td>Sodium</td>
<td>Cardiac function</td>
</tr>
<tr>
<td>Rate of fluid removal</td>
<td>Temperature</td>
<td>Plasma refilling rate</td>
</tr>
<tr>
<td>Rate of solute removal</td>
<td>Calcium</td>
<td>Autonomic function</td>
</tr>
<tr>
<td>Fall in plasma osmolality</td>
<td>Magnesium</td>
<td>Initial plasma volume</td>
</tr>
<tr>
<td>Membrane-blood interaction</td>
<td>Glucose</td>
<td>Anemia</td>
</tr>
<tr>
<td>Hypoxemia</td>
<td>Potassium</td>
<td>Drug Therapy</td>
</tr>
<tr>
<td>Catecholamine depletion</td>
<td>Acetate</td>
<td>Eating</td>
</tr>
<tr>
<td>Fluctuating UF rate</td>
<td>pH</td>
<td>Cytokine/NO levels</td>
</tr>
</tbody>
</table>
Simple Steps

- Frequent goal weight assessment
- Encourage patient compliance with sodium and fluid
- Avoid eating on HD
- May avoid antihypertensives on HD days
- Correct anemia
- Supplemental O₂ to improve myocardial performance
- Position patient supine
Manual or Biofeedback Systems

- RBV
  - UF profiling
- Dialysate conductivity
  - Sodium Profiling
- Isothermic dialysis
  - Cool dialysate
Medications

• Midodrine
• Sertraline
• Caffeine
• Carnitine?
Dialysate Composition

- Calcium 1.5 or 1.75 bath
- Mg 0.75 bath
- Lower Bicarbonate bath
Thank You

"I was told to keep my presentation interesting. How do you program a projector to explode?"
Three Priority Actions From Workshop

1.
2.
3.