Innovations in Cardio/Renal Patient Care

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Deep Connections between Heart and Kidneys: CKD Patients Have Higher Rates of Heart Disease

CVD = cardiovascular disease; ASHD = atherosclerotic heart disease; AMI = acute myocardial infarction; CHF = congestive heart failure; VHD = valvular heart disease; CVA/TIA = cerebrovascular accident/transient ischemic attack; PAD = peripheral artery disease; AFIB = atrial fibrillation; SCA/VA = sudden cardiac arrest/ventricular arrhythmia.

Deep Connections between Heart and Kidneys

Majority of Patients with AHF have Renal Dysfunction (N = 118,465)

65% have at least moderate CKD

AHF = advanced heart failure; CKD = chronic kidney disease; GFR = glomerular filtration rate.
How Does the Decrease in Renal Function Impact the Heart?

How Does the Decrease in Cardiac Output Impact the Kidneys?

↓ Cardiac Output

- Activation of Ventricular & Arterial baroreceptors
- Activation of Renin-Angiotensin-Aldosterone system
- Stimulation of Sympathetic Nervous System

- Non-osmotic Vasopressin Stimulation

- ↑ Systemic and Renal Arterial Vascular Resistance
- Maintenance of Arterial Circulatory Integrity

- Renal Water Retention
- Renal Sodium Retention

↓ Renal Blood Flow

- Exhaustion of autoregulatory capacity

↓ Glomerular Filtration Rate

Sepsis, NSAIDS, Contrast

Central Venous Congestion

How Does the Decrease in Renal Function Impact the Heart?

Volume Overload in Cardiorenal Patients

A. Water and salt excess
B. Only water excess
C. Only salt excess
Volume Overload and Adverse Outcomes in non-Dialysis Dependent Chronic Kidney Disease Patients

Volume Overload and Adverse Outcomes in non-Dialysis Dependent Chronic Kidney Disease Patients

Association of Volume Overload and Mortality in Dialysis Patients is Independent of BP

Animal Model of CKD: Effect of Volume Overload on Remnant Kidney, Proteinuria and BP

Animal Model of CKD: Effect of Volume Overload on Kidney Inflammation

Animal Model of CKD: Effect of Volume Overload on Kidney Fibrosis

Hung et al. J Am Heart Ass 2015; 4:
info:doi/10.1161/JAHA.115.001918.
Impact of Strict Volume Control on Pulse Wave Velocity and Mortality

Dry Weight Concept

The lowest tolerated post-dialysis weight achieved via gradual change in post-dialysis weight at which there are minimal signs or symptoms of hypovolemia or hypervolemia.

Agarwal et al. cJASN 2010;(5):1255
Case

- 65 year old male
- Diabetes with retinopathy and neuropathy
- Ischemic cardiomyopathy with EF 30%, atrial fibrillation
- Previous smoker, left BKA
- Hypertension and ESRD
  - Initiated hemodialysis 2 months ago mainly for volume overload symptoms
    - After 10 kg ultrafiltration
    - Discontinued amlodipine
    - Reduced BB and ARB

Pre-HD
- Inter-dialytic weight gain: 3.5 kg
- Sitting BP: 180/96 mmHg
- Standing: 140/80 mmHg
- JVD 10 cmH20
- Lungs: no rales
- CVS: Regular, normal sounds, trace b/l peripheral edema

Intra-dialysis
- 30 min: UF = 500 cc, 120/86 mmHg
- 60 min: UF = 1000 cc, 96/70 mmHg with headache
Body Fluid Compartment

- Intracellular Fluid
- Interstitium
- Vascular
Pathogenesis of Hypotension in Dialysis Patients

- Aggressive Ultrafiltration
  - Reduction in intravascular volume
  - Refilling from the interstitium/sometimes ICF
  - Increased cardiac output
  - Increased SVR
  - Normal heart and normal autonomic system/baro-reflexes

\[ BP = CO \times SVR \]

Hypotension despite volume excess
Fluid Balance

Dietary Intake (Salt+water)

Output

Urine

Dialytic Ultrafiltration
Only Fluid Restriction or Salt and Fluid Restriction?

Salt intake $\rightarrow$ Osmolarity $\rightarrow$ Thirst
Where is Dietary Intake of Salt?
(Recommendation <2 gm sodium/d)

• **Breakfast**
  - 2 stripes of bacon = 400 mg
  - Half cup of yogurt = 60 mg
  - 1 egg = 60 mg
  - 1 wheat toast with unsalted butter = 100 mg
  - **620 mg**

• **Lunch = sandwich**
  - 1 slice of bread = 100-400 mg = 200-800 mg
  - Slice of cheese = 150-300 mg
  - Layer/s of meat = 200-800 mg
  - Mayo = 100 mg
  - Mustard = 100 mg
  - Bag of chips = 250-500 mg
  - **1000-2600 mg**

• **Dinner = Fajitas**
  - Fajita seasoning on chicken/beef = 240 mg + 60 mg
  - Lettuce, onion, bell pepper = 100 mg
  - Salsa = 100-300 mg
  - ½ cup beans = 550 mg
  - 2 whole wheat flour tortillas = 640 mg
  - ½ cup ice cream = 50 mg
  - **5000 mg Sodium**
Is Kidney Function Still Helpful in Dialysis Patients?

YES
### Residual Kidney Function or Urine Volume Benefits the Mortality?

<table>
<thead>
<tr>
<th>Hemodialysis (n=1254)</th>
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<tbody>
<tr>
<td><strong>GFR-24U</strong> (per mL/min/1.73m²)</td>
<td>0.98 (0.95–1.01)</td>
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<tr>
<td><strong>eGFR-urea,creat</strong> (per mL/min/1.73m²)</td>
<td>1.02 (0.98–1.05)</td>
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<tr>
<td><strong>UV</strong> (per 0.1 L/day)</td>
<td>0.97 (0.95–0.99)</td>
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<th>Peritoneal dialysis (n=692)</th>
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<td><strong>GFR-24U</strong> (per mL/min/1.73m²)</td>
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<tr>
<td><strong>eGFR-urea,creat</strong> (per mL/min/1.73m²)</td>
<td>0.93 (0.86–1.01)</td>
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<td><strong>UV</strong> (per 0.1 L/day)</td>
<td>0.94 (0.91–0.98)</td>
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<th>Dialysis vintage &lt;2 yrs (n=1259)</th>
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<tr>
<td><strong>GFR-24U</strong> (per mL/min/1.73m²)</td>
<td>0.99 (0.96–1.01)</td>
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<td><strong>eGFR-urea,creat</strong> (per mL/min/1.73m²)</td>
<td>0.98 (0.94–1.03)</td>
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<th>Dialysis vintage ≥2 yrs (n=687)</th>
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<tr>
<td><strong>GFR-24U</strong> (per mL/min/1.73m²)</td>
<td>0.94 (0.89–0.99)</td>
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<tr>
<td><strong>eGFR-urea,creat</strong> (per mL/min/1.73m²)</td>
<td>1.01 (0.91–1.12)</td>
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<tr>
<td><strong>UV</strong> (per 0.1 L/day)</td>
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Residual Kidney Function or Urine Volume Benefits the Mortality?

- Diuretics
  - Loop diuretic in high dose
  - Daily in PD
  - Off dialysis days in HD
- Angiotensin Blockers
<table>
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<tr>
<th>Outcome</th>
<th>Finding for Patients Administered v Not Administered Diuretics</th>
<th>$P$</th>
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<tr>
<td>IDWG (%)</td>
<td>Difference, $-0.4%$</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Weight change (kg)</td>
<td>Difference, $-0.2$ kg</td>
<td>0.0005</td>
</tr>
<tr>
<td>IDWG $&gt; 5.7%$</td>
<td>OR, 0.51</td>
<td>&lt;0.0001</td>
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<tr>
<td>Phosphate $&gt; 7.5$ mg/dL</td>
<td>OR, 1.05</td>
<td>0.47</td>
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<tr>
<td>Potassium $&gt; 6.0$ mEq/L</td>
<td>OR, 0.49</td>
<td>&lt;0.0001</td>
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<tr>
<td>Hypotensive episode*</td>
<td>OR, 0.55</td>
<td>0.006</td>
</tr>
<tr>
<td>RRF† one year after entering study</td>
<td>OR, 1.93</td>
<td>0.01</td>
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Fluid Balance

Dietary Intake
(Salt + water)

Output

Urine

Dialytic Ultrafiltration
Methods to Assess Volume Status

• Physical examination
  – Blood pressure but
    • Heart failure
    • Liver disease
    • Autonomic insufficiency
  – Jugular venous distension but
    • Pulmonary HTN
  – Lungs for rales
  – Peripheral edema but
    • Chronic venous stasis
• Other Clinical tools
Measuring and Evaluating Body Fluid

- Gold standard
  - Tracer Dilution methods

- Relative blood volume monitoring (Crit-Line)

- Bioimpedance spectroscopy (BIS)

- Inferior vena cava diameter

- Lung ultrasound
Relative Blood Volume Monitoring (Crit-Line)

- Continuous monitoring of the hematocrit
  - By photo-optical technology
  - Every 20 seconds
- No change in the red cell mass during hemodialysis
- The percentage increase in hematocrit during ultrafiltration estimates the percentage of decrease in blood volume.
- “Window” to the vascular compartment
No change in Hct: Plasma refill rate is occurring at the same or a greater rate than ultrafiltration.

Volume-overloaded State

<1.33%/hour
Gradual Increase in Hematocrit

Best compromise between the UF rate and prevention of hypotension

1.33%-8%/hour
Steep Increase in Hematocrit

A rapid decrease in blood volume, and higher risk for hypotensive symptoms & cramps

>8%/hour
Bio-Impedence Analysis

- **Principle**: Electric current flows at different rates through the body depending upon its composition.
- **Resistance**: Water < muscle/bone < fat
  - High-frequency current passes through the total body water (TBW)
  - Low-frequency current cannot penetrate cell membranes and thus flows exclusively through the extracellular water (ECW).
- **BIA**: TBW = ECW + ICW
- **Over hydration** is assessed using known formula for that specific population
Effect of BIA-guided Ultrafiltration on Pulse-Wave Velocity and Heart

Measuring and Evaluating Body Fluid

- Gold standard
  - Tracer Dilution methods

- Relative blood volume monitoring (Crit-Line)

- Bioimpedance spectroscopy (BIS)

- Inferior vena cava diameter

- Lung ultrasound
UltraFiltration Failure in PD Patients

- Failure to remove enough fluid to maintain euvolemic state
  - Net UF of less than 400 mL after a 4-hour dwell
- Most commonly occurs in high transporters
- Etiology
  - Peritoneal membrane changes over the years
  - Peritonitis
  - Inherent high transporter state

ICODEXTRIN

- High molecular weight (16.8 Kda) polymer of glucose
- Iso-osmotic, Oncotic pressure
- Reflection coefficient of 0.76 as compared to 0.03 of glucose
Contrasting Dextrose vs. Icodextrin Net UF Profile

Temporal Decline vs. Sustained Effect

[Graph showing net UF (ml) over time (hr) for different concentrations of dextrose and icodextrin]

Ho-Dac-Pannekeet et al, Kid Int 1996; 50:979-86
Douma et al, Kid Int 1998; 53:1014-21
Summary

• Fluid overload is a common problem shared by heart and kidney disease patients.
• More literature is suggestive the worse prognosis it imparts on these patients.
• “It takes a village” to keep dialysis patients euvolemic or at True Dry Weight.
• Maintaining residual kidney function and low dietary sodium intake – crucial
• Newer technology may help determining the DW and achieving in difficult patients.
THANK YOU!

Questions?