Acute Kidney Injury

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Disclosure: NxStage, Astute
Overview

- Defining the Problem
- Epidemiology – Risk Factors
- Outcomes – Link to CKD
- Classification – Sources of AKI
  - Pre- Intra- and Post Renal
- Management
  - Fluids
  - Renal Replacement Therapy (IHD vs. CRRT)
AKI

↓ Drug Metabolism
↓ Renal Perfusion
↓ Immune Function

Sepsis / Infection

↓ Renal Perfusion & Contrast

Nephrotoxins & Contrast

↓ Renal Perfusion

↓ Drug Metabolism
↓ Immune Function

Mech. Vent

Surgery-Ishemia

Comorbidities

Cardio-Renal

Chronic Kidney Disease

Acute Lung Injury

Mech. Vent
Defining AKI

- RIFLE 2003 → AKIN 2007 → KDIGO 2012

- Stage 1
  - Increase in SCr by ≥0.3 mg/dl in 48 hours or
  - Increase in SCr by ≥ 1.5-1.9 x baseline in 7 days
  - Urine Volume < 0.5 ml/kg/hr for six hours

- Stage 2
  - Increase in SCr by ≥ 2.0-2.9 x
  - Urine < 0.5 ml/kg/hr ≥ 12 hours

- Stage 3
  - Increase in SCr ≥ 3.0 x
  - Increase in SCr > 4.0 mg/dL
  - Need for RRT
  - Urine < 0.3 ml/kg/ht for ≥ 24 hrs
AKI: Markers of Disease

- Creatinine
  - Small molecule produced by muscle & excreted by kidneys
  - ↓ in GFR → ↑ in creatinine
  - Cheap & easy to measure – BMP, CMP

- Problems
  - Is not only filtered but can be secreted → tends to overestimate GFR at lower levels
  - Dependent on muscle mass
  - Hemodilution with IVF
  - Lag time of 1-2 days from kidney injury
Biomarkers in Relation to Site of Injury in Nephron

Proximal Tubule Injury
- Urine IL-18
- Urine KIM-1
- Urine L-FABP
- Urine Cystatin C
- α1-microglobulin
- β2-microglobulin
- Urine α-GST
- Urine Netrin-1
- Urine NAG

Glomerular Filtration
- Serum Creatinine
- Blood urine Nitrogen
- Serum Cystatin C
- Plasma NGAL

Glomerular Injury
- Urine albumin excretion

Distal Tubule
- Urine NGAL
- Urine π-GST

Loop of Henle Injury
- Uromodulin

Other Mechanisms / Sites of Injury not specific to the Nephron
- Hepcidin – Iron trafficking
- TIMP-2/IGFBP7 – G1 cell cycle arrest

Adapted from Koyner and Parikh-Brenner and Rector’s The Kidney – In press 2014
AKI: Mortality & Morbidity

- AKI- has been shown to be an independent risk factor for mortality in the ICU
- Small changes in creatinine (~25%) have been associated with ↑ mortality
  - 9200 adult admits at Brigham & Women’s in Boston
  - 2 creatinines
  - ↑ 0.5 mg/dl
    - 6.5 RR death
    - 3.5 day LOS
    - $9000

AKI, Weekend Admission and Mortality

- 963,730 admissions (2003-06)
  - ICD-9 code driven
- 214,962 (22%) primary dx = AKI
  - 45,203 on a weekend
  - 169,759 on a weekday
- Adjusted OR was 1.07 (1.01-1.13) for weekend admits
  - More pronounced in smaller hospitals
- Regardless of hospital size, comorbidities increased the risk of death with weekend admits
  - Sepsis, CHF, AMI, PNA, GI bleed
AKI Epidemiology

- AKI developed in 22% (n=71,486)
- Stage I = 0.3 or 50%
- Stage II > 100%
- Stage III > 200%

<table>
<thead>
<tr>
<th>AKI Category</th>
<th>N</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratified by Time Taken to Meet AKI Criteria in ICU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AKI &lt;48 hrs</td>
<td>52,884</td>
<td>2.52</td>
<td>2.45–2.60</td>
</tr>
<tr>
<td>AKI &gt;48 hrs</td>
<td>18,602</td>
<td>4.66</td>
<td>4.47–4.85</td>
</tr>
<tr>
<td>Stratified by Severity of AKI Reached during ICU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage I AKI</td>
<td>57,126</td>
<td>2.23</td>
<td>2.17–2.30</td>
</tr>
<tr>
<td>Stage II AKI</td>
<td>7934</td>
<td>6.08</td>
<td>5.74–6.44</td>
</tr>
<tr>
<td>Stage III AKI</td>
<td>6426</td>
<td>8.6</td>
<td>8.07–9.15</td>
</tr>
<tr>
<td>AKI requiring dialysis (subgroup of Stage III AKI)</td>
<td>3140</td>
<td>5.78</td>
<td>5.30–6.31</td>
</tr>
</tbody>
</table>

Thakar et al Crit Care Med 2009
<table>
<thead>
<tr>
<th>Variable</th>
<th>Cleveland Score(^a)</th>
<th>Mehta Score(^b)</th>
<th>SRI Score(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Definition</td>
<td>Points</td>
<td>Definition</td>
</tr>
<tr>
<td>Age</td>
<td>—</td>
<td>—</td>
<td>Varies</td>
</tr>
<tr>
<td>Race</td>
<td>—</td>
<td>—</td>
<td>Nonwhite</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Preop kidney function</td>
<td>SCr, 1.2-2.1 mg/dL</td>
<td>2</td>
<td>SCr</td>
</tr>
<tr>
<td></td>
<td>SCr &gt;2.1 mg/dL</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>CHF</td>
<td>Yes</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>NYHA class</td>
<td>—</td>
<td>—</td>
<td>Class IV</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>Insulin requiring</td>
<td>1</td>
<td>Orally controlled</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Insulin dependent</td>
</tr>
<tr>
<td>COPD</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>Recent MI (≤21 d)</td>
<td>—</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>LVEF</td>
<td>&lt;35%</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Previous surgery</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>Preop IABP</td>
<td>Yes</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>—</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>Timing of surgery</td>
<td>Emergency</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Type of surgery</td>
<td>CABG only</td>
<td>0</td>
<td>CABG</td>
</tr>
<tr>
<td></td>
<td>Valve only</td>
<td>1</td>
<td>Aortic valve only</td>
</tr>
<tr>
<td></td>
<td>CABG + valve, or other</td>
<td>2</td>
<td>Aortic valve + CABG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mitral valve only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mitral valve + CABG</td>
</tr>
<tr>
<td>Score range</td>
<td>0-17</td>
<td>—</td>
<td>0-83</td>
</tr>
</tbody>
</table>
AKI Severity and Long-Term Mortality

AKIN- CV Surgery

Survival

Days after surgery

No AKI  Stage 1  Stage 2  Stage 3
Figure 2. Risk of Chronic Dialysis in Association With Acute Kidney Injury and Adverse Outcomes

A Chronic dialysis risk

Cumulative Risk of Chronic Dialysis, %

- Acute kidney injury and dialysis
- No acute kidney injury

Follow-up, y

No. at risk

| Acute kidney injury and dialysis | 3769 | 2761 | 2116 | 1683 | 1305 | 964 | 676 | 462 | 294 | 158 | 58 |
| Acute kidney injury and dialysis | 13598 | 10224 | 7850 | 6080 | 4639 | 3383 | 2342 | 1555 | 905 | 473 | 169 |

Adj. Hazard - 3.5

Wald et al. JAMA 2009—Vol 302, No. 1
But not all AKI requires RRT
Risk of ESRD
AKI+CKD=41x
AKI only = 13x
CKD only = 8x
No AKI-No CKD - ref

Ishani et al. JASN 2009
Transient RRT

AKI

↑Risk of Death

ESRD

CKD

Koyner et al. Chest 2012
Estimates of AKI burden in developed countries and outcomes of survivors.

Goldstein S L et al. CJASN 2013;8:476-483
Differential Diagnosis of AKI
Increasing enthusiasm to include biomarkers in assessment panel in patients with AKI

- Biomarker Negative:
  - No functional changes or damage
- Biomarker Positive:
  - Damage without loss of function

Creatinine Negative:

Creatinine Positive:

“Subclinical AKI”

Adapted from Endre, Kellum Koyner Goldstein et al Contrib Neph 2013 - Courtesy of Steve Coca
Acute renal failure

- **Prerenal causes**
  - Tubular necrosis
    - Ischemia (50% of cases)
  - Toxins (35% of cases)

- **Intrinsic causes**
  - Interstitial nephritis (10% of cases)

- **Postrenal causes**
  - Acute glomerulonephritis (5% of cases)

Decreased Effective Circulating Volume: “Pre-Renal”

- Volume depletion
  - Renal loss (Diabetes Insipidus)
  - Extra-renal: vomiting, diarrhea, burns, bleeds
- Hypotension
- Cardiovascular
  - CHF / Low EF
  - Arrhythmias
- Liver Disease
  - Hepatorenal syndrome / Acute
  - Cirrhosis with ascites
- Intrarenal vasoconstriction
  - Radiographic contrast
  - NSAIDs
  - Cyclosporin & tacrolimus
  - ACE inhibitors / ARB
  - Renin Inhibitor
  - Amphotericin B
- Hyper-calcemia
  - Nephro-genic DI - Downregulate Aquaporin 2
    - Decreased concentrating ability
    - Calcium sensing receptors
    - Loop of Henle
Urine lytes for AKI

- Urine Creatinine, Sodium, Urea
- Most diuretics work by exchanging sodium into the urine space
- If urine sodium is low (e.g. < 25), while on diuretics it means the kidney is over-riding the medication
- Caution with on-line calculators – units, units, units…..
### AKI: Diagnosis

<table>
<thead>
<tr>
<th></th>
<th>Prerenal</th>
<th>Renal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinalysis</td>
<td>Hyaline casts</td>
<td>Abnormal</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.020</td>
<td>1.010</td>
</tr>
<tr>
<td>Osmolality (mmol/kg)</td>
<td>&gt;500</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Sodium (mmol/L)</td>
<td>&lt;20</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Fractional excretion of sodium (%)</td>
<td>&lt;1</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Fractional excretion of urea (%)</td>
<td>&lt;35</td>
<td>&gt;35</td>
</tr>
<tr>
<td>Fractional excretion of uric acid (%)</td>
<td>&lt;7</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Fractional excretion of lithium (%)</td>
<td>&lt;7</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Low-molecular-weight proteins</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Brush-border enzymes</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

**Table 2:** The most important urinary variables in the differential diagnosis between prerenal and renal acute renal failure.

Decreased Effective Circulating Volume: “Pre-Renal” Treatment

- Treat the source of volume depletion
  - Stop the diuresis, treat the nausea etc.
- Limit exposure to medications
- Volume Expand as much as possible
  - D5W with 3 amps of Sodium Bicarb
  - Lactated Ringers
  - Avoidance of hyper-chloremic normal Saline
  - Yunos, Bellomo et al. JAMA 2012
Acute renal failure

Prerenal causes

Tubular necrosis

(50% of cases)

Ischemia

(50% of cases)

Intrinsic causes

Interstitial nephritis

(10% of cases)

Toxins

(35% of cases)

Postrenal causes

Acute glomerulonephritis

(5% of cases)
AKI: Etiology

- Postrenal
  - Prostate hypertrophy
  - Neurogenic bladder
  - Intraureteral obstruction: stones, clots,
  - Extraureteral obstruction: retroperitoneal urological

- Have high index of suspicion when only one kidney (transplant)!

- Treatment is to relieve obstruction

Time = Nephrons
Diagnosing Obstruction

- Renal Ultrasound
  - Avoids contrast – but so does CT scan
    - Stone Protocol CT don’t require contrast
    - Full evaluation of GU tract does require contrast
  - Ideal to Rule out cystic disease
  - User dependent

Acute renal failure

Prerenal causes

Intrinsic causes

Tubular necrosis

Interstitial nephritis (10% of cases)

Ischemia (50% of cases)

Toxins (35% of cases)

Postrenal causes

Acute glomerulonephritis (5% of cases)

Toxins

- Variety of different mechanisms
- Most common in ICU:
  - Radiocontrast
    - Cardiac Cath
  - CT scan
  - Aminoglycosides
  - Colistin (Amongst other antibiotics)
  - Chemo
    - Cisplatin
    - Clofarabine

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in renal perfusion through alteration of intra-renal hemodynamics</td>
<td>NSAIDs, angiotensin-converting–enzyme inhibitors, cyclosporine, tacrolimus, radiocontrast agents, amphotericin B, interleukin-2*</td>
</tr>
<tr>
<td>Direct tubular toxicity</td>
<td>Aminoglycoside antibiotics, radiocontrast agents, cisplatin, cyclosporine, tacrolimus, amphotericin B, methotrexate, foscarnet, pentamidine, organic solvents, heavy metals, intravenous immune globulin†</td>
</tr>
<tr>
<td>Heme-pigment–induced tubular toxicity (rhabdomyolysis)</td>
<td>Cocaine, ethanol, lovastatin‡</td>
</tr>
<tr>
<td>Intratubular obstruction by precipitation of the agent or its metabolites or by-products</td>
<td>Acyclovir, sulfonamides, ethylene glycol,§ chemotherapeutic agents,¶ methotrexate</td>
</tr>
<tr>
<td>Allergic interstitial nephritis</td>
<td></td>
</tr>
<tr>
<td>Hemolytic–uremic syndrome</td>
<td>Cyclosporine, tacrolimus, mitomycin, cocaine, quinine, conjugated estrogens</td>
</tr>
</tbody>
</table>

Urine Sediment: Predicting Outcomes

### Table 1: Renal Tubule Epithelial Cells

<table>
<thead>
<tr>
<th>RTE cells (per HPF)</th>
<th>Granular Casts (per LPF)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 (0 Points)</td>
<td>1 (1 Point)</td>
<td>≥6 (2 Points)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1 to 5 (1 point)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>≥6 (2 points)</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Values denote total points awarded.

### Table 2: Odds Ratios

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% Confidence Limits</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>Score</td>
<td>2.86</td>
<td>1.88</td>
<td>4.36</td>
</tr>
<tr>
<td>Male gender</td>
<td>0.65</td>
<td>0.31</td>
<td>1.38</td>
</tr>
<tr>
<td>Age</td>
<td>1.02</td>
<td>1.00</td>
<td>1.05</td>
</tr>
<tr>
<td>Change in serum creatinine (baseline to consult)</td>
<td>1.14</td>
<td>0.86</td>
<td>1.52</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.20</td>
<td>0.08</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Disclaimer about UOP

Oliguria (400 ml / day) may be appropriate in patients with hypovolemia and intravascular depletion

- Adequate volume expansion reverses oliguria

Oliguria is maladaptive in patients with congestive heart failure, cirrhosis, and acute tubular necrosis

- Positive fluid balance causes volume overload
- Cardio-renal syndromes
Diuretics don’t increase renal blood flow, or improve clearance (non-electrolyte solute excretion)

- Only electrolytes and associated water are excreted in the extra urine output (UOP)
- Diuretics can prevent volume overload in AKI, but not nitrogenous waste accumulation (azotemia), and may be associated with worse outcome
AKI: Management

- Fluid management
  - Early goal directed therapy to improve renal perfusion
  - Therapy often initiated in emergency department
  - Recent studies refute the utility of goal directed therapy
  - Unclear ideal method for resuscitation

Rivers E, et al. NEJM 2001; 345:1368
Process Study. NEJM, 2014 May
Arise – Anizics NEJM October 16, 2014
# Chloride Fluid Content and AKI Risk

## Table 3. Incidence of Acute Kidney Injury Stratified by Risk, Injury, Failure, Loss, and End-Stage (RIFLE) Serum Creatinine Criteria

<table>
<thead>
<tr>
<th>RIFLE class</th>
<th>Control Period (n = 760)</th>
<th>Intervention Period (n = 773)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk</td>
<td>71 (9.0) [7.2-11.0]</td>
<td>57 (7.4) [5.5-9.0]</td>
<td>.16</td>
</tr>
<tr>
<td>Injury</td>
<td>48 (6.3) [4.5-8.1]</td>
<td>23 (3.0) [1.8-4.2]</td>
<td>.002</td>
</tr>
<tr>
<td>Failure</td>
<td>57 (7.5) [5.6-9.0]</td>
<td>42 (5.4) [3.8-7.1]</td>
<td>.10</td>
</tr>
<tr>
<td><strong>Injury and failure</strong></td>
<td><strong>105 (14) [11-16]</strong></td>
<td><strong>65 (8.4) [6.4-10.0]</strong></td>
<td><strong>&lt;.001</strong></td>
</tr>
</tbody>
</table>

*The control period was from February 18 through August 17, 2008, and the intervention period was from February 18 through August 17, 2009.*
Volume Overload in AKI

- 618 pts in a prospective multicenter observational trial
- Fluid Overload = 10% increase in weight
- Increased mortality regardless of RRT

**RRT**

**Non-RRT**
Fluid Balance: The RENAL Study

90-day Mortality Rates
- Negative Balance - 38%
- Positive Balance - 49%

More Evidence that Not all Renal Support is Dialysis

Early Renal Consult for AKI Interventions
Diagnostic Urine Studies – 79%
Holding ACE/ARB 48%
IV Fluid adjustment – 45%
Diuretic adjustment – 35%
Other Rx adjustment - 19%
Contrast issues – 8%
28% of patients in ICU

On to RRT…. for now
Indications for RRT

- Acidosis (metabolic)
- Electrolytes
  - Hyperkalemia
  - Hyperphosphatemia
  - Dyscalcemia
- Intoxications
  - Lithium
  - Metformin / volatile acids
- Volume Overload
- Uremia
  - Encephalopathy
  - Pericarditis
- Bleeding diathesis

- "Non-renal" indications
  - Hyper-ammonemia
  - The team wants it
Hyperkalemia: Not all from AKI / ESRD

- Hyporenin – hypoaldo
  - DM (Type 4 RTA)
  - Obstruction
  - NSAIDs
  - SLE, Amyloid

- Hyper-renin – hypo-aldo
  - ACE-I, ARB, Renin agent
  - Heparin

- Aldo deficiency – inactivity
  - Sickle Cell
  - Spironolactone
  - Obstruction

- Sodium Channel Blockade
  - Bactrim
  - K+ sparing diuretic
  - Pentamidine

Psuedohyperkalemia
- Hemolysis
- Thrombocytosis (500K – 1,000K)
- Leukocytosis (50-100K)

K-loading
- Supplements, Mrs. Dash
- Blood / Bleeding

Other
- Exercise, β-blockers, acidosis, Digoxin
<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Dose</th>
<th>Onset</th>
<th>Duration</th>
<th>Repeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Gluconate</td>
<td>1g in 10ml of 10% solution</td>
<td>&lt;5 Minutes</td>
<td>30-60 minutes</td>
<td>1x in 5-10 min.</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>1g in 10ml of 10% solution</td>
<td>&lt;5 Minutes</td>
<td>30-60 minutes</td>
<td>1x in 5-10 min.</td>
</tr>
<tr>
<td>Insulin and Glucose</td>
<td>10 units with 100 cc of 50% solution</td>
<td>10-20 min</td>
<td>2-4 hours</td>
<td>As needed</td>
</tr>
<tr>
<td>β-Agonists</td>
<td>10-20mg in 4 ml over 20 min.</td>
<td>10-20 min</td>
<td>2-4 hours</td>
<td>As needed</td>
</tr>
<tr>
<td>Bicarb</td>
<td>50meq in 5 minutes</td>
<td>15-30min</td>
<td>1-2 hrs</td>
<td>No mix Ca+</td>
</tr>
<tr>
<td>Cation Resins</td>
<td>15-60g</td>
<td>1-2 hrs</td>
<td>-</td>
<td>Not long term</td>
</tr>
<tr>
<td>Diuretics (loop)</td>
<td>20-200 mg IV</td>
<td>30-60min</td>
<td>6 hrs</td>
<td>As needed</td>
</tr>
</tbody>
</table>
Acute HD Access: NKF-K/DOQI Guidelines

- For Acute RRT < 2-3 weeks: non-cuffed, double-lumen, percutaneously inserted catheter
- Tri-alysis lines – are a newer option Bedside placement
  3 sites, US guidance and CXR for neck lines
- Avoid subclavian
- Avoid PICC lines – central stenosis – limits AV access
- Femoral catheters:
  - should be ≥19cm to minimize recirculation
  - for bed-bound patients
  - ≤ 5 days
- all 13.5 french catheters; Smaller = less clearance
Triple Lumen Dialysis Catheters

Triple lumen lines – provide less clearance

Would not recommend them for CRRT – as folks need extra gtt – for their pressors
How to Choose your Modality?

- Availability
- Clinician Expertise
- Contra-indication to a modality (e.g. ↑ICP)
- Hemodynamic Stability
  - Blood Pressure
  - Respiratory Status
- Vascular Access
- Patient Needs
  - Solute removal
  - Ultra-filtration
Common Renal Replacement Therapies

- Intermittent Hemodialysis (IHD) (diffusion)
- Isolated Ultrafiltration (IUF) (no clearance)
- Continuous Venovenous Hemo-filtration (CVVH)-(convection)
- Continuous Venovenous Hemo-dialysis (CVVHD)-(diffusion)
- Continuous Venovenous Hemo-diafiltration (CVVHDF) – diffusion and convection
- Slow Continuous Ultrafiltration (SCUF) (no clearance)
- Sustained Low Efficiency Dialysis (SLED) (diffusion)
- Slow Low Efficiency Daily Dialysis (SLEDD) (diffusion)
- Extended Daily Dialysis (EDD) (diffusion)
- Urgent Start Peritoneal Dialysis (diffusion and osmosis)
Intermittent Hemodialysis

- Favors removal of small molecules
  - Pro: Clearance of ~ 200 ml/min
  - Con: Rebound effect: high volume of distribution
  - Con: Rapid changes in osmolarity: disequilibrium – cerebral edema

- Performed without Anticoagulation

- Many patients in 1 day with 1 machine

- Patients mobile as treatments last 3-5 hours

- Requires clean, reliable water source

- Special training – nurses / technicians
Rebound Effect

![Graph showing plasma potassium levels during and after hemodialysis.](image)

- Plasma potassium in mmol/L
- Time during and after dialysis, hours (0-44)
- Hemodialysis

Typical IHD Prescription for AKI

- Initial treatments –
  - escalating treatment times (2hr, 3hr and 4hr)
  - Catheter blood flow rates (200, 250, 300)
  - Avoid disequilibrium
- Fluid balance: per target net fluid removal
  - max of 4-5kgs in 4hrs
- Anticoagulation: none, heparin, argatroban, citrate
- Hypotension avoidance maneuvers
  - Sodium Modeling
  - Decreased Temperature (vasoconstriction)
  - Intravenous Albumin  PRN
Continuous Renal-Replacement Therapy for Acute Kidney Injury

Ashita Tolwani, M.D.
Indications for CRRT

- No clear guidelines on indications however...
  - Hemodynamic instability (≥ 2 vaso-actives)
  - Hyperkalemia > 6.5
  - Metabolic Acidosis (pH < 7.1)
  - Elevated Intracranial Pressure
  - Uncontrollable positive fluid balance
  - Drug overdose with dialyzable toxin
  - Non-traditional toxins
    - Rhabdomyolysis
    - Hepatic Failure
    - Tumor Lysis Syndrome
    - Lactic Acidosis
  - Advance directives that include RRT

Modified from Tolwani NEJM 2012 and – Critical Care Nephrology Eds Ronco Bellomo and Kellum
OMAKI: CVVH vs. CVVHD

- 78 patients – prospectively randomized
- No difference in Mortality (54% vs 55%)
- No difference in 60 day need for RRT (24% vs. 19%)

Wald et al Crit Care 2013
CRRT Dosing: More is not better

Need to provide at least 25 ml/kg/hr of CRRT

Here’s the data......
RENAL Study – CRRT Dose Trial

- 1500 subjects with
  - Acidosis (<7.2)
  - BUN > 70
  - Creatinine > 3.4
  - Oliguria (100cc / 6hr)
  - Organ damage (pulmonary edema)

- Excluded
  - Previous RRT or Txp

- 40 ml/kg/hr vs. 25 ml/kg/hr
In hospital mortality
1.01 (0.92-1.12)

ICU mortality
1.06 (0.90, 1.26)

Renal Recovery (off RRT) in Survivors:
0.99 (0.92, 1.07)

Hypotension:
0.92 (0.72, 1.16)

Rabindranath, Adams et al. Cochrane Database Syst Rev. 2007
Cost: Short and Long-term

![Graph showing 5-year cumulative total cost (RRT + dialysis independence + dialysis dependence) for CRRT and IRRT.](image)

- Ethgren, Bagshaw, Kellum et al. NDT 2014

Nephrol Dial Transplant (2014) 0: 1-8
doi: 10.1093/ndt/gfu314
Hybrid forms of RRT

- Sustained Low Efficiency Dialysis (SLED)
- Slow Low Efficiency Daily Dialysis (SLEDD)
- Extended Daily Dialysis (EDD)
- Prolonged intermittent daily RRT (PIDRRT)
- Extended Daily Dialysis with Filtration (EDDf)
- Extended Dialysis (ED)
Schwenger et al Crit Care 2012

- 232 prospective randomized unblinded
- No difference in 90-day mortality
- SLED more vent-free days
- SLED required less nursing time per patient
- SLED was associated with lower costs
Urgent Start Peritoneal Dialysis

Urgent-Start Peritoneal Dialysis: A Chance for a New Beginning

Rohini Arramreddy, MD,1,2 Sijie Zheng, MD,3 Anjali B. Saxena, MD,1,4
Scott E. Liebman, MD,5 and Leslie Wong, MD1,2

INFRASTRUCTURE REQUIREMENTS FOR AN URGENT-START PERITONEAL DIALYSIS PROGRAM

Arshia Ghaffari, a Vijay Kumar, 2 and Steven Guest3

Urgent-Start Peritoneal Dialysis: What are the Problems and Their Solutions?

Rex L. Mahnensmith
Department of Internal Medicine, Section of Nephrology, Yale University School of Medicine, New Haven, Connecticut

Can peritoneal dialysis be applied for unplanned initiation of chronic dialysis?

Per Ivarsen and Johan V. Povlsen
Department of Renal Medicine, Aarhus University Hospital and Department of Clinical Medicine, Faculty of Health, Aarhus University, Aarhus, Denmark
Summary

- AKI is common and on the rise
- AKI is clearly a risk factor for CKD and ESRD
- The differential diagnosis of AKI is diverse – with the minority of patients requiring RRT
- Several RRT modalities out there – and there is not one best way to do things.
Thank You

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