COVID-19 Associated AKI Recognition and Management

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Capital District Renal Physicians
Albany Medical College

Chair, AKI!Now initiative
Objective

To promote excellence in the prevention and treatment of Acute Kidney Injury (AKI) by building a foundational program that transforms the delivery of AKI care, reduces morbidity and mortality and improves long-term outcomes.

Support for the AKI!Now initiative and webinars is provided by Baxter Healthcare Corporation.

Steering Committee

- Jorge Cerdá, MD, MS, FASN, Chair
- Anupam Agarwal, MD, FASN
- Stuart Goldstein, MD, FAAP, FASN, FNKF
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- Mark D. Okusa, MD, FASN
- Anitha Vijayan, MD, FASN
COVID-19 Associated AKI Recognition & Early Management

MICHAEL J. CONNOR, JR, MD
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Disclosures
• No relevant disclosures for this topic

• Prior Member: ASN AKI Advisory Group
• Prior Advisory Board:
  • CR Bard, Inc
  • Baxter, Inc – Acute Kidney Injury + CRRT (non-compensated)
  • GE Healthcare, Inc – Clinical Events Adjudication Committee
• Prior research collaboration:
  • Baxter, Inc
• Current research collaboration:
  • Potrero, Inc
• Wife (Emory faculty): no conflicts of interest
“It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of light, it was the season of darkness, it was the spring of hope, it was the winter of despair.”

-- Charles Dickens, A Tale of Two Cities

COVID-19 & COVID-AKI


SARS-CoV-2 → COVID-19 Disease

• Wide variability in symptoms & illness severity

• Lungs = most common organ failure

• Wide variety of organ failures reported in ICU COVID-19
  • Direct viral invasion of cells in various organs may be 1 factor → organ failures

Other possible mechanisms of organ failure include:

• Shock – highly unusual at presentation → Later shock = cardiogenic, distributive/vasoplegic (cytokine surge), sepsis (super-infection)

• Hypercoagulable → Micro- & macrovascular thrombosis

• Volume depletion (at initial presentation)
• Other
Epidemiology of acute kidney injury in critically ill patients: the multinational AKI-EPI study

Intensive Care Med (2015) 41:1411–1423
DOI 10.1007/s00134-015-3934-7

- ICU AKI Incidence = 57.3% (95% CI 55-60)
  - Stage 1 AKI: 18.4%
  - Stage 2 AKI: 8.9%
  - Stage 3 AKI: 30.0%

- Received RRT = 13.5% (95% CI 12-15)

- AKI associated with higher mortality risk

SARS-CoV-2 → COVID-19 Disease

- 6-10% of confirmed cases have required ICU admission

- Of those 6-10% in the ICU, 40-60% have AKI

- 20-30% have severe AKI requiring RRT
AKI in COVID-19 Disease

- AKI = common in hospitalized COVID-19 patients
- Exact AKI frequency not clear to date
- Early reports from China → little to no AKI
- Subsequent Italy → 40% in ICU, 20% RRT
- Multiple 1st hand unpublished reports from US & Europe (describe AKI ~ 20% in general hospital, 50% in ICU

- 20-30% of ICU COVID-19 cases requiring RRT (aka AKI-D)

- AKI-D recovery rates unclear but anecdotal reports suggest few have remained dialysis-dependent at hospital discharge.
  - What fosters recovery – a specific fluid mgmt strategy, clearance of viral invasion, appropriate RRT?

COVID-AKI: Possible Disparities

1 Center – Nephrology Consults on COVID cases (PUIs & Confirmed)
AKI RECOGNITION & DIAGNOSIS

• No obvious differences from KDIGO AKI criteria
  • UOP- & creatinine-based criteria

• Urine sediments have been highly variable
  → multiple possible mechanisms of AKI

COVID-AKI: RECOGNITION AND MANAGEMENT

COVID-AKI: RECOGNITION AND MANAGEMENT

Possible Mechanisms

Multiple AKI mechanisms may exist in a single COVID patient.

Hypovolemia
• COVID high-volume, high incident AKI sites reporting concerns of “aggressive diuresis” induced hypovolemia

“ATN”
• Cytokine storm (especially with MAS)
• High-levels of DAMPs from lung injury
• Severe hypoxic respiratory failure

Glomerular / vascular involvement?
• Anecdotal reports

Low Perfusion or venous congestion
• Low EF / cardiogenic shock (acute PE)
• RV failure secondary to high PEEP → venous congestion

Direct viral infection of the renal epithelium
• Evidence of viral RNA in kidney but unclear if viral infection
• Renal epithelium express ACE2r
COVID-19 ICU Management

VTE / PE
- Low threshold for systemic anticoagulation

Not "typical" ARDS
- Caution with high PEEP
- May need more FiO2 than peep
- Secretion clearance paramount

High attention to "optimal" critical care management
- ? Early intubation
- Lung protective ventilation
- Euvolemia
- Nutrition support
- Minimize sedation

COVID-AKI: MANAGEMENT

Emory Healthcare: VTE and Prophylaxis Guidelines for ICU COVID-19

**Level 1:** No VTE and D-dimer < 3,000*
- LMWH 0.5mg/kg/day
- Dose adjustments for obesity and renal impairment +/- UFH
- Discharge with 7 days DOAC (> LMWH)

Routine laboratory tests
Daily DIC panel
Q Mon/Th MOCHA panel, PAI-1

**Level 2:** No VTE and D-dimer ≥ 3,000*
- LMWH 0.5mg/kg/Q12 (or 1mg/kg/day) OR
- Heparin low-standard
- Discharge with 4-6 weeks DOAC (> LMWH)

LE Doppler US
Baseline for Level 2 and with changes in clinical status

Laboratory monitoring (where available)
Anti-Xa levels
Antithrombin (AT) levels

**Level 3:** Known or suspected VTE**
- LMWH 1mg/kg/Q12 OR
- Heparin high-standard
- Discharge with 3 months DOAC (> LMWH, warfarin)

Heparin resistance
Treat with direct thrombin inhibitor (DTI) if AT < 40%

*At EDH, D-dimer threshold = 3.0 FEU/ml (i.e., 6x ULN)
**Consider for unexplained increase in oxygen requirement, dead space, or organ failure (e.g., AKI, MSOF).
COVID-AKI: EARLY MANAGEMENT

- AKI is common
  - Explore mechanisms & determine causes

- Focus early AKI mgmt on determining true volume status

- Return to euvoemia → FST has prognostic value

COVID-AKI: Acute RRT

- Timing of RRT initiation = no new insights
  - Volume control = most common indication
  - Failed FST may be important

- RRT circuit thrombosis has been major challenge
COVID-AKI: RRT Circuit Maintenance

- Excellent dialysis vascular access = paramount importance
- (C)RRT anticoagulation is vital

CRRT Anticoagulation Guidelines – COVID-19
Goal: Maximize CRRT circuit survival in any patient running continuously to max 72 hrs

Regional Citrate Anticoagulation
- Standard EHC Citrate CRRT Protocol
- Infuse via pre-filter pigtail catheter on CRRT machine
- Measure heparin levels from patient & adjust to based on heparin level target
- Stop citrate protocol

Low-standard Therapeutic Heparin
- Infuse via systemic IV
- Measure heparin levels & adjust to based on heparin level target
- Stop heparin infusion

Direct Thrombin Inhibitor
- Argatroban preferred
- Bivalirudin alternative
- Infuse via systemic IV
- Adjust by PTT levels
- Stop heparin infusion

COVID-19 Associated AKI: Pathophysiology & General Management

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Division of Nephrology & Hypertension
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Disclosures

- Employer: Mayo Clinic
- Consultancy Agreements: AM Pharma
- Research Funding: La Jolla Inc.
- Scientific Advisor or Membership: MediBeacon Inc.; La Jolla Inc.; GE

The topic of this presentation is not relevant to my work with these entities.

Outlines

- Epidemiology
- Pathophysiology
- General management
## ARDS and AKI

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Cohort</th>
<th>Outcome(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chu (2005)</td>
<td>Retrospective</td>
<td>536 SARS patients</td>
<td>ARDS independent risk factor for developing AKI RR 37.91 (7.9-180.4)</td>
</tr>
<tr>
<td>Rocha (2005)</td>
<td>Retrospective</td>
<td>296 patients after lung transplantation</td>
<td>MV associated with AKI OR 6.16 (1.70-22.24)</td>
</tr>
<tr>
<td>Darmon (2014)</td>
<td>Prospective</td>
<td>8,029 consecutive ICU patients</td>
<td>AKI more common in ARDS → 44.3 vs. 27.4% AKI in MV without ARDS → OR 4.34 (3.71-5.10)</td>
</tr>
<tr>
<td>Van den Akker (2013)</td>
<td>Systematic review and meta-analysis</td>
<td>31 studies (10,333 patients) reporting relation between use of invasive MV and AKI were included</td>
<td>AKI on MV OR 3.16 (95% CI: 2.32-4.28).</td>
</tr>
<tr>
<td>McNicholas (2019)</td>
<td>2° analysis of</td>
<td>1,794 ARDS patients in 50 multinational ICUs</td>
<td>765 (39%) moderate to severe AKI; Rate of mortality higher among those with AKI</td>
</tr>
</tbody>
</table>

ARDS and AKI

N = 8,029

- AKI incidence:
  - No ARDS $\rightarrow$ 27%
  - ARDS $\rightarrow$ 44%
- OR for AKI
  - MV without ARDS
    - 4.3, 95% CI 4-5
  - ARDS
    - 11, 95% CI 7-18


ARDS and AKI

N = 10,333

van den Akker et al. (2013). Crit Care 17(3): R98
AKI in COVID-19

<table>
<thead>
<tr>
<th>Author (Journal)</th>
<th>Region</th>
<th>Patients (N)</th>
<th>AKI (%)</th>
<th>RRT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guan (NEJM)</td>
<td>China</td>
<td>173</td>
<td>0.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Arentz (JAMA)</td>
<td>USA</td>
<td>201</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Wang (JAMA)</td>
<td>China</td>
<td>36</td>
<td>8.3</td>
<td>5.6</td>
</tr>
<tr>
<td>Huang (Lancet)</td>
<td>China</td>
<td>13</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Yang (Lancet/Resp)</td>
<td>China</td>
<td>52</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>Cao (ICM)</td>
<td>China</td>
<td>18</td>
<td></td>
<td>22.2</td>
</tr>
<tr>
<td>Ling (CC Resuscit.)</td>
<td>HK</td>
<td>8</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Cheng (medRxiv)</td>
<td>China</td>
<td>710</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1,211</strong></td>
<td><strong>11.4</strong></td>
<td><strong>5.8</strong></td>
</tr>
</tbody>
</table>

Courtesy of Eric Hoste

Kidney in COVID-19

- N=99
  - ↑ BUN 6%; ↑ Scr 3%; ↑ Myoglobin 15%; ↑ CK 13%
- N=1,099
  - ↑ Scr 1.6%; ↑ CK 14%; AKI 0.5%; Rhabdomyolysis 2%
- N=710
  - Proteinuria 44%; hematuria 26.9%; AKI 3.2; ↑ BUN 14%; ↑ Scr 15.5%
- N=59
  - Proteinuria 63% (3% +++); hematuria 26.9%; AKI 3.2; ↑ BUN 27%; ↑ Scr 11%

Chen et al. (2020). The Lancet 395(10223): 507-513
Guan et al. (2020). N Engl J Med
Li et al. (2020). medRxiv
Cheng et al. (2020). medRxiv
AKI in COVID-19 and mortality

- N=710; HR for death:
  - ↑ Scr
  - Proteinuria
  - Hematuria

<table>
<thead>
<tr>
<th>Variables</th>
<th>HRs</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteinuria 1+</td>
<td>2.47</td>
<td>1.16-5.33</td>
</tr>
<tr>
<td>Proteinuria 2+ or 3+</td>
<td>0.80</td>
<td>0.37-1.75</td>
</tr>
<tr>
<td>Hematuria 1+</td>
<td>3.04</td>
<td>1.05-8.66</td>
</tr>
<tr>
<td>Hematuria 2+ or 3+</td>
<td>0.89</td>
<td>0.41-1.91</td>
</tr>
<tr>
<td>Elevated baseline serum creatinine</td>
<td>2.04</td>
<td>1.02-4.07</td>
</tr>
<tr>
<td>Peak serum creatinine + 123g/mol</td>
<td>3.09</td>
<td>1.80-5.27</td>
</tr>
</tbody>
</table>

Cheng et al. (2020). Kidney International

COVID-19 ASSOCIATED AKI

Etiology
Pathophysiology

Jin et al. (2020). Viruses 12(4)
Coronavirus life cycle

1. Spike attachment to ACE2
2. TMPRSS + endosomal Cathepsin L → Membrane fusion → viral RNA release
3. Cellular ribosome + viral RNA → Nonstructural protein
4. Viral proteases → Replicase
5. Replicase → Transcribes mRNA
6. Ribosomes + mRNA → Translate structural proteins
7. Structural Pr. + viral RNA → Replicated virus
8. Exocytosis

Du et al. (2009). Nature Reviews Microbiology 7(3): 226-236

AKI in COVID-19

Etiology

- Known causes of AKI in critically ill patients
- Fluid balance
- Interaction between ARDS and AKI
- Cytokine storm and multi-organ failure
- Direct viral cytotoxicity
- Rhabdomyolysis
- Hypercoagulability
- ? Collapsing Glomerulopathy
Common causes of AKI

Fluid balance

- At presentation:
  - Fever
  - N/V/D
  - Hyperventilation
- During hospitalization:
  - Fluid resuscitation
  - Fluid creep
Fluid management

ARDS and AKI

SARS-CoV2 Pneumonia
**Pathophysiological mechanisms**

<table>
<thead>
<tr>
<th>Hemodynamic effects</th>
<th>Inflammatory / Immune-mediated effects</th>
<th>Effects of altered acid-base status</th>
<th>Effects of impaired gas exchange</th>
<th>Neuro–hormonal effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ PA pressure → Venous congestion IAH</td>
<td>↑ Pro-inflammatory &amp; ↓ Anti-inflammatory mediators</td>
<td>↑ O2 consumption in PT cells</td>
<td>Hypercapnia → ↓ Autoregulation Severe hypoxemia → ↓ RBF</td>
<td>↑ RAAS ↓ ANP / BNP ↑ Sympathetic never system</td>
</tr>
</tbody>
</table>

**Mechanical Ventilation**

| Pathophysiological mechanisms | ↑ Intrathoracic pressure → ↓ CO, preload | Injurious ventilation → ↑ IL-6, PAI-1, TNFR-1, TNFR-2 | ↑ epithelial cell apoptosis | | |

**Parameters to monitor**

- CVP, MAP, CO, renal PP, cumulative FB, PEEP, TV, PIP

- Inflammatory markers

- Arterial pH

- PaO₂

- PaCO₂

- O₂ saturation

- BNP

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**SARS-CoV2 infection**

**URI:**

- Droplet/aerosols
- Fecal/oral
- Contact

**Lower Respiratory tract**

- GI mucosa

**Asymptomatic**

- ACE2 Downregulation/shedding

**Cell Damage**

- Death

**Organ involvement**

- Cell Damage

**Viral Replication**

- Systemic viral sepsis SIRS

**Over-activation of T cells**

- Antibody dependent enhancement Anti-S-IgG

**RAAS dysfunction**

- Pulmonary Capillary leak Pulmonary edema

**Immune dysfunction**

**Cytokine storm**

**ARDS**

**Multorgan failure**

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Jin et al. (2020). Viruses 12(4)
Cytokine storm

Several ACE2 protein-altering variants in human can alter interaction with S-protein in viral spikes

Genetic Susceptibility

Pan et al. (2020). Intensive Care Medicine
Stawiski et al. (2020). bioRxiv
Direct kidney toxicity: Pathology
N = 26 post-mortem examination; Age 69 yo; 35% AKI/proteinuria

• LM:
  • Glomeruli
    • Fibrin Thrombi
    • Ischemic collapse
    • Capsular protein leak
  • ATN
    • Non-isometric vacuolar degeneration
    • Frank tubular cell necrosis
    • Brush border loss
    • Protein reabsorption vacuoles

Su et al. (2020). Kidney International

Direct kidney toxicity

• EM:
  • Viral clusters
    • Proximal/Distal tubules
    • Podocytes

Su et al. (2020). Kidney International
Direct kidney toxicity

• IF:
  • ACE2 in Proximal tubules
  • SARS-CoV nucleoprotein antibody in tubules

Su et al. (2020). Kidney International

Rhabdomyolysis in COVID-19

• N=99
  • ↑ Myoglobin 15%; ↑ CK 13%
• N= 1,099
  • ↑ CK 14%; Rhabdomyolysis 2%
• Case reports

Chen et al. (2020). The Lancet 395(10223): 507-513
Guan et al. (2020). N Engl J Med
Jin et al. (2020). Emerging Infectious Diseases 26(7)
Suwanwongse et al. (2020). Cureus
Collapsing glomerulopathy
CG; Protein reabsorption vacuoles; ATN

63 yo, AA ♂; COVID-19 +;

Kissling et al. (2020). *Kidney International*
COVID-19 ASSOCIATED AKI

General management

Prevention is the best treatment

Future vaccine

Diagnosis and Evaluation | Limiting Severity and Duration of AKI | Prevention avoidable AKI Complications

- AKI stage-dependent threshold met
- Nephrotoxin or contributing medication
- Poor hemodynamics
- Cause-specific diagnosis delayed

- High frequency of hyperkalemia in patients with AKI
- Poor extubation rates in patients with AKI due to volume overload
- Adverse drug events

**Recognition**

- Context-appropriate evaluation
  - Physical examination
  - History
  - Kidney function and injury biomarkers
  - Urine analysis
  - Hemodynamic variables
  - Radiology and serology tests
  - Kidney biopsy
  - Other context-specific tests

- "Nephrotoxin Stewardship"
  - Asses and optimize hemodynamics
  - Avoid hyperglycemia
  - Nephrology referral guidelines
  - Monitoring of kidney function with serum creatinine and urine output

- Improved monitoring for complications (e.g. BMP/bicarbonate/phosphorus measurement)
- Risk reduction strategies (e.g. reduced K intake, unnecessary maintenance fluids, review of appropriate dosing of meds)
- Management of complications (e.g. treatment of hyper K, fluid removal)

**Action**

- Improved frequency of context-appropriate diagnostic evaluation
- Improved recognition of cause-specific AKI

- Improved rates of nephrotoxin alerting/evaluation/discontinuance
- Hemodynamic intervention applied
- Improved timeline of cause-specific diagnosis/interventions
- Reduced duration and severity of AKI (e.g. maximum stage, length, recovery)

- Process (improved monitoring/detection, reduction in unnecessary K supplementation, med reconciliation/evaluation)
- Clinical (reduced incidence of severe hyperkalemia, treatment of severe acidosis pH <7.2, less adverse drug events related to inappropriate drug dosing/selection in AKI)

**Results**


AKI management

**KDIGO Staging of Acute Kidney Injury**

- **High Risk**
  - Discontinue all nephrotoxic agents when possible
  - Ensure volume status and perfusion pressure
  - Consider functional hemodynamic monitoring
  - Monitor serum creatinine and urine output
  - Avoid hyperglycemia
  - Consider alternatives to radiocontrast procedures

- **AKI stage 1**
  - Non-invasive diagnostic work-up
  - Check for changes in drug dosing

- **AKI stage 2**
  - Consider replacement therapy

- **AKI stage 3**
  - Consider ICU admission
  - Avoid subclavian catheters if possible

Unproven treatment
Pending RCTs; IDSA recommend only be used for research

- Antivirals
  - Chloroquine and hydroxychloroquine
  - Lopinavir/Ritonavir
  - Oseltamivir
  - Remdesivir
- Steroids
- Cytokine removal therapies
  - Extracorporeal
  - Anti-IL6
- Anticoagulation (LMWH prophylaxis particularly on DIC or d-dimer >6X UNL)
- Convalescent plasma therapy

Thachil et al. (2020). Journal of Thrombosis and Haemostasis

Summary

- Rapidly growing knowledge related to COVID-19
  - Highly transmissible and associated with high mortality
  - Variability in incidence of reported AKI/RRT
  - Complex pathophysiology
  - The best treatment of COVID-19 associated AKI is prophylaxis
    - Only proven benefit is excellent clinical care
- Anecdotal therapy option data
  - Only should be used for clinical trials / ?compassionate
General RRT Management in COVID-19 Patients

STUART L. GOLDSTEIN, MD, FAAP, FASN, FNKF
Director, Center for Acute Care Nephrology
Cincinnati Children’s Hospital Medical Center

Thank you for your kind attention
General RRT Management in COVID-19 patients

Stuart L. Goldstein, MD, FAAP, FASN, FNKF
Director, Center for Acute Care Nephrology
Cincinnati Children's Hospital Medical Center

Disclosures

• Baxter Healthcare
  • Grant Support/Expert Panel/Consultant
  • Baxter had no input into or control over the content of this presentation
  • I mention CRRT as part of this presentation

• Biporto
  • Grant Support/Consultant
  • Biporto had no input into or control over the content of this presentation

• MediBeacon
  • Consultant, Director of Clinical Development, Shareholder
  • MediBeacon had no input into or control over the content of this presentation
  • The topic of this presentation is not relevant to my work with MediBeacon

• La Jolla Pharmaceuticals, Akebia, Medtronic, Reata, CHF Solutions, Fresenius, Renibus, Otsuka, and Kaneka, Inc.
  • Consultant
  • The topic of this presentation is not relevant to my work with these entities

• Vigilanz
  • Patent/Invention
More Important Disclosure

I am a pediatric nephrologist working in a children’s hospital. While we have planned for treatment of COVID-19 patients in our setting using some of the guidelines I will be presenting, RRT requiring COVID-19 is very rare in children, so many of these recommendations are based on what I have learned from my adult colleagues on the front lines (especially Dr. Connor—thank you for your slides!)

Outline

• Fluid balance
• Resource utilization and conservation
  • Fluids
  • Modality selection
  • Personnel
• Anticoagulation
Fluid Management

• Current standard practice
• What’s potentially different about the COVID-19 patient?
• Maintenance of fluid balance homeostasis and/or prevention of worsening fluid overload
  • Assess patient’s needs for all fluids (nutrition, medications, blood products) and associated daily volumes
  • Assess patient’s ability to maintain fluid balance
    • UOP
    • Stool losses
    • Chest tubes
  • Assess patient’s current fluid accumulation status

The Dilemma and Decision

If the patient with AKI cannot tolerate the needed fluid volumes without developing worsening fluid overload

A. Fluid restrict
B. Diuretics
C. Consider renal replacement therapy to maintain fluid homeostasis
Fluid Overload and Mortality in Children Receiving Continuous Renal Replacement Therapy: The Pediatric Patients Continuous Renal Replacement Therapy Registry

Mortality Rate

50% Fluid Overload
10%-20% Fluid Overload
220% Fluid Overload

36.7%
22.1%
10%
75.4%
55.8%
65.6%
43.1%
29.4%
29.1%

American Journal of Kidney Diseases, Vol 55, No 2 (February), 2010: pp 316-325

Fluid accumulation, survival and recovery of kidney function in critically ill patients with acute kidney injury

Fluid Overload

Survival

In-hospital days from AKI diagnosis

Kidney International (2009; 76: 422-427)
What is Different About COVID-19?

- Patients with very high fevers
- Risk of intravascular dehydration
- Hypercoaguability
- All lead to a reconsideration against an overly fluid restrictive strategy
Fluid Management in Acute Kidney Injury

Stuart L. Goldstein, MD

Emory Healthcare
Renal Replacement Therapy Surge Plan

EHC RRT Surge Planning Committee
Last Update Date: 4/6/2020
Renal Replacement Therapy (RRT) During ICU Surge Situation

Background

• RRT is commonly required life-support tool for critically ill ICU patients
  • 15-30% ICU patients require RRT
• Multiple methods to provide RRT
  • All methods effective when used appropriately

Challenge

• RRT is a finite resource due to limitations in:
  • Machines
  • Supplies
  • Personnel depending on the type of RRT performed
• Surge in ICU census → surge RRT needs

RRT Surge Plan

• Goal:
  • Use multiple methods of RRT to maximize # of patients who can receive appropriate RRT to meet their individual support needs.
  • Equitable distribution and utilization of RRT resources to provide benefit to the most patients.

• Challenge:
  • Develop resource distribution systems to meet this goal.
    • Staffing
    • Supply chains
    • Machine use → when machines are limited, system to minimize machine down-time
### Acute Renal Support in the ICU

**Spectrum of RRT – Duration of RRT**

- **CRRT**
  - Cardiovascular instability (cardiogenic shock, septic shock, acute liver failure)
  - Metabolic acidosis
  - Volume control
  - Cerebral edema

- **IHD/PIRRT**
  - Hyperkalemia
  - Profound acidosis
  - Drug poisonings
  - Anticoagulation issues with CRRT

---

### Acute RRT Options in ICU

<table>
<thead>
<tr>
<th>CRRT – 24h</th>
<th>Shift-based CRRT</th>
<th>PIRRT/SLED</th>
<th>Intermittent Hemodialysis (IHD)</th>
<th>Peritoneal Dialysis (PD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Prismaflex CRRT machine</td>
<td>- Prismaflex CRRT machine</td>
<td>- Conventional HD machine</td>
<td>- Conventional HD machine</td>
<td>- 2 Options:</td>
</tr>
<tr>
<td>- 24hr continuous RRT</td>
<td>- 10-12 hr RRT sessions</td>
<td>- or Tablo®</td>
<td>- 3-4 hr RRT sessions</td>
<td>- Continuous treatments (CAPD)</td>
</tr>
<tr>
<td>- Work force = ICU RNs</td>
<td>- Work force = ICU RNs</td>
<td>- 6-8 hr RRT sessions</td>
<td>- Work force = Hemodialysis RN</td>
<td>- Automated PD (APD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Usually overnight</td>
<td></td>
<td>- CAPD: exchanges q3-4 hrs, 24 hrs/day by ICU or general ward RN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- APD: HD RN sets up &amp; starts APD session lasting 10-12 hr</td>
</tr>
</tbody>
</table>
**EHC: Pandemic ICU RRT Surge Plan**

**Plan A:** Conventional Operations
- 24h CRRT
- IHD only if clinically indicated
- CRRT preferred to decrease exposure of additional RNs needed for HD

**Plan B:** Machine Load Balance
- 24h CRRT
- IHD only if clinically indicated
- Intermittently move CRRT machines between EHC institutions as load balance needed
- CRRT preferred to decrease exposure of additional RNs needed for HD

**Plan C:** Mixed CRRT Duration
- Mix of CRRT-24h & shift-based CRRT based on clinical needs of patient
- Some CRRT machines will perform RRT on 2+ patients per day
- IHD only if clinically indicated
- CRRT machine use preferred to decrease exposure of additional RNs needed for HD

**Plan D:** Mixed CRRT + HD/SLED
- Mix of CRRT-24h & shift-based CRRT based on clinical needs of patient
- Some CRRT machines will perform RRT on 2+ patients per day
- Overnight SLED with HD machines
- IHD as soon as clinically appropriate

**Plan E:** CAPD + all hemoRRT
- Acute bed-side PD catheter insertion & CAPD
- Sedated/mech vented COVID+ patients
- Mix of CRRT-24h & shift-based CRRT based on clinical needs of patient
- Overnight SLED with HD machines
- IHD as soon as clinically appropriate

**Determinant of RRT Surge Plan**

**Plan A:** Conventional Operations

**Plan B:** Machine Load Balance

**Plan C:** Mixed CRRT Duration

**Plan D:** Mixed CRRT + HD/SLED

**Plan E:** CAPD + all hemoRRT

Total # of Patients needing ICU RRT
### RRT Surge Plan: Contingency vs Crisis

**Contingency Plans/Mode**

- **Plan A:** Conventional Operations
- **Plan B:** Machine Load Balance
- **Plan C:** Mixed CRRT Duration
- **Plan D:** Mixed CRRT + HD/SLED
- **Plan E:** CAPD + all hemoRRT

**Crisis Plans/Mode**

- No significant new risks
- Supply Chains Intact
- Staffing Intact (generally)

**Risk of errors**

- Disposable Supplies & Machines

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**Plan A – Conventional Operations**

**Challenges**

- No specific new challenges
- Enough machines & disposable supplies to meet ICU RRT demands with 24h CRRT & IHD
- Usual challenges:
  - ICU RN & HD RN staffing
  - Adequate distribution of supplies including filters, CRRT solutions, citrate/calcium availability

**Pandemic Surge Preparations**

- Plan adapted for pandemic isolation needs
- Prefer CRRT use to minimize additional staff exposures to isolation environment
  - HD RN to deliver IHD
- IHD may continue in ICUs
  - Facilitate liberation from CRRT for PT/OT
  - ESRD patient with native AVF/AVG
Plan B – Machine Load Balance

**Surge Challenge**
- Surge of patient at a given EHC facility → do not have enough machines to meet demand at a given facility
- Supply chains intact:
  - RRT supplies come from EHC offsite warehouse → easy to increase deliveries to meet demand
- Limited staffing impact

**Pandemic Surge Preparations**
- Move RRT machines periodically between EHC institutions to meet RRT demands
- Coordination between:
  - Biomedical engineering departments
  - Clinical leadership teams
  - Asset administration
  - Movers
  - Others
- Takes time to implement

Plan C – Mixed CRRT Durations

**Challenges**
- Unable to meet RRT demands
  - # of ICU RRT pts > CRRT machines
- Different patients will require different RRT plans
  - One shift-based RRT plan will not fit all
- Highly complex to orchestrate
  - Matching available machines to appropriate pts
  - Complex scheduling

**Surge Preparations – Needs**
- Operational expertise to implement
- Daily CRRT machine deployment schedule
  - Staff to develop deployment schedule
- Staff to orchestrate machine deployment
- Appropriate RRT orders to match plan
Plan D – Mixed CRRT + HD/SLED

Challenges

- Unable to meet RRT demands
  - # of ICU RRT pts > CRRT machines (even with shift-based CRRT implementation)
- Will have to more widely use HD machines & HD RNs for ICU HD & SLED
  - HD RN staffing impact \( \Rightarrow \) ? less non-ICU HD
- Highly complex to orchestrate
- ICU RNs unfamiliar with HD equipment

Surge Preparations – Needs

- New machine: Tablo® – 10 have been ordered
- EHC Fresenius HD Machines: require chip upgrade to perform SLED
- Operational expertise to implement
- Daily CRRT & HD machine & staff deployment schedule \( \Rightarrow \) staff needed to develop schedule & orchestrate deployments
- SLED: Overnight HD RN(s) to set-up, initiate, terminate HD sessions & to make rounds while patients are running on SLED.

Plan E – CAPD & all HemoRRT

Challenges

- Unable to meet RRT demands
  - # of ICU RRT pts > CRRT + HD machine + staff availability
- ICU RNs CAPD educational needs
  - CAPD performed rarely in EHC ICUs
- Bed-side PD catheter insertion \( \Rightarrow \) surgeons
- CAPD charting

Surge Preparations – Needs

- Identifying & train surgeon partners
- RN training for and delivery of CAPD versus
- HD RN performing APD with limited ICU RN involvement
- Continue need for CRRT & HD machine & staff deployment program/resources
- Determine supplies for CAPD & purchase soon
  - Surgeons’ & nephrologists’ preferred PD catheter
  - Disposable supplies for PD exchanges
  - PD solutions
Anticoagulation

- Unfractionated heparin
- Low molecular weight heparin
- Regional citrate
- None

What’s Different About COVID-19?

- Reports of significant hypercoagulability and early filter clotting
- First option should be regional citrate anticoagulation (if center has a standard protocol) aiming for circuit iCa <0.35 mmol/L
- Second option should be unfractionated heparin and use standard monitoring protocol with more frequent measurements (heparin level, PTT, ACT)
- Third option should be agatroban or LMWH and monitor effect frequently
Questions

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Closing Remarks

JORGE CERDÁ, MD, MS, FASN  
Capital District Renal Physicians  
Albany Medical College  
Chair, AKI!Now initiative
Thank you for your participation.

For further questions and comments about this webinar, please contact ntds@asn-online.org.

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