Continuous Renal Replacement Therapy Management

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Goals and Objectives

- Discuss the RIFLE classification scheme in acute kidney injury
- Outline the RRT options available and mechanism of action
- Discuss initiation criteria and process of CVVH
- Discuss correction of electrolyte issues and fluid management with CVVH
- Discuss discontinuation criteria of CVVH and renal recovery
**RIFLE classification**

- Simple, readily available clinical tool to classify AKI in different populations
- Good outcome predictor, with a progressive increase in mortality with worsening RIFLE class
  - Also suggests that even mild degrees of kidney dysfunction may have a negative impact on outcome
Classification of AKI according to RIFLE criteria

RIFLE defines three grades of severity of AKI on the basis of either:
- acute increase in serum creatinine
- decrease in GFR
- decreased urine output.
AKI
CRRT

- Is an extracorporeal blood purification therapy intended to substitute for impaired renal function over and extended period of time and applied for or aimed at being applied for 24 hours a day.

- Indicated in any patient who meets criteria for hemodialysis therapy but cannot tolerate intermittent hemodialysis due to hemodynamic instability.
Goals of CRRT

- Mimic the functions and physiology of the native organ
- Qualitative/quantitative blood purification
- Restoration/maintenance of homeostasis
- Avoid complications and achieve clinical tolerance
- Provide conditions favoring recovery of renal function
CRRT Indications in the CVICU

- Fluid overload
- AKI (either de novo or superimposed on progressive CKD)
- Life-threatening electrolyte/acid-base disturbances
  - Metabolic acidosis
  - Hyperkalemia
  - Hyper/hypocalcemia
Requirements for CRRT

- A central double-lumen veno-venous hemodialysis catheter
  - Or ECMO circuit
- An extracorporeal circuit and a hemofilter
- A blood pump and effluent pump
- With specific CRRT therapies, dialysate and/or replacement pumps are required
Principles of CRRT

- Vascular access
- Semi-permeable membrane
- Transport mechanism
- Dialysate and replacement fluid
Vascular Access

- Internal jugular vein
- Femoral vein
- Subclavian vein
- ECMO circuit
Semi-permeable Membrane

- The basis of all blood purification therapies
- Water and some solutes pass through the membrane, while cellular components and other solutes remain behind
- 2 types: cellulose and synthetic
  - Synthetic membranes allow clearance of larger molecules and are the primary type used in CRRT
- Filters are changed when they become contaminated, clogged or clotted
Albumin (55000 – 60000)

Beta 2 Microglobulin (11800)

Inulin (5200)

Vit B12 (1355)

Aluminium/Desforoxamine complex (700)

Glucose (180)

Uric Acid (168)

Creatinine (113)

Phosphate (80)

Urea (60)

Potassium (35)

Phosphorus (31)

Sodium (23)
CRRT Modalities

- Slow Continuous Ultrafiltration (SCUF)
  - Ultrafiltration
- Continuous Veno-Venous Hemofiltration (CVVH)
  - Convection
- Continuous Veno-Venous Hemodialysis (CVVHD)
  - Diffusion
- Continuous Veno-Venous Hemodiafiltration (CVVHDF)
  - Diffusion and Convection
Ultrafiltration

- The passage of water through a membrane under a pressure gradient
- Driving pressure can be positive (pushing fluid through the filter) or negative (pulling fluid to the other side of the filter)
- Pressure gradient is created by the effluent pump
Convection

- Movement of solutes through a membrane by the force of water “solvent drag”
- The water pulls the molecules along with it as it flows through the membrane
- Can remove middle and large molecules, as well as large fluid volumes
- Maximized by using replacement fluids
Adsorption

- The removal of solutes from the blood because they cling to the membrane
- High levels of adsorption can cause filters to clog and become ineffective
Diffusion

- The movement of a solute across a membrane via a concentration gradient
- For diffusion to occur, another fluid (dialysate) must flow on the opposite side of the membrane
Dialysate and Replacement Fluid

- Dialysate is any fluid used on the opposite side of the filter from the blood during blood purification.
- Countercurrent flow allows a greater diffusion gradient across the entire membrane, increasing the effectiveness of solute removal.
- Typical dialysate flow rates are 600-1800 mL/hr.
The primary indication for SCUF is fluid overload without uremia or significant electrolyte imbalance.

The main mechanism of water transport is ultrafiltration.

Other solutes are carried off in small amounts, but usually not enough to be clinically significant.

The amount of fluid in the effluent bag is the same as the amount removed from the patient.

No dialysate or replacement fluid is used.
CVVH

- An extremely effective method of solute removal and is indicated for uremia or severe pH or electrolyte imbalance with or without fluid overload.
- Particularly good at removal of large molecules, because CVVH removes solutes via convection.
- Solute can be removed in large quantities while easily maintaining a net zero or even a positive fluid balance in the patient.
- The amount of fluid in the effluent bag is equal to the amount of fluid removed from the patient plus the volume of replacement fluids administered.
- No dialysate is used.
CVVH

Return Pressure
Air Detector

Return Clamp
Patient

Syringe Pump

Filter Pressure

Effluent Pressure

Pre

Post

Hemofilter

replacement Pump

Effluent Pump

Pre Blood Pump
Effective for removal of small to medium sized molecules

Solute removal occurs primarily due to diffusion

No replacement fluid is used

Dialysate is run on the opposite side of the filter

Fluid in the effluent bag is equal to the amount of fluid removed from the patient plus the dialysate
CVVHDF

- Effective for removal of small to medium sized molecules
- Solute removal occurs primarily due to diffusion.
- Replacement fluid is used
- Dialysate is run on the opposite side of the filter
- Fluid in the effluent bag is equal to the amount of fluid removed from the patient plus the dialysate
Initiation of Therapy

- Assess and record the patient’s vital signs and hemodynamic parameters prior to initiation of therapy
- Review physician orders and lab data
- Prepare vascular access using unit protocol
- Set fluid removal, dialysate and replacement solution flow rates as prescribed
- Administer anticoagulant and initiate infusion if applicable
- Document patient’s hemodynamic stability with initiation of therapy
Intratherapy Monitoring

- Blood pressure
- Patency of circuit
- Hemodynamic stability
- Level of consciousness
- Acid/base balance
- Electrolyte balance
- Hematological status
- Infection
- Nutritional status
- Air embolus

- Blood flow rate
- Ultrafiltration flow rate
- Dialysate/replacement flow rate
- Alarms and responses
- Color of ultrafiltrate/filter blood leak
- Color of CRRT circuit
Fluid Management

- “The patient will achieve and maintain fluid volume balance within planned or anticipated goals.”

Considerations
- Intake and Output
Fluid Management

- Net fluid removal hourly (physician order)
  - +
    - Intake (IV, TPN, etc.)
  - -
    - Output (urine, etc.)
  =
- Patient Fluid Removal Rate
Electrolyte Management

- Replacement protocols
  - HCO3
  - Ca
  - K
  - Mg
  - PO4
- Dysnatremias
Anticoagulation

- Individualized decision that should be made jointly with nephrology and the cardiothoracic team

- Contraindications
  - Platelet count <50k, INR >2, aPTT >60, active bleeding, hepatic dysfunction, within 24h post-cardiopulmonary bypass or ECMO

- Options
  - Heparin (systemic or regional)
  - Citrate (regional)
  - Prostacyclin
<table>
<thead>
<tr>
<th>Metabolic effect</th>
<th>Metabolic consequence</th>
<th>Consequences for implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>II Citrate acts by chelating Ca(^{2+}) in the filter</td>
<td>At [ica(^{2+})] &lt; 0.35 mmol/l coagulation is inhibited</td>
<td>For stable and safe anticoagulation: couple citrate flow to blood flow</td>
</tr>
<tr>
<td>II Ca/Mg-citrate complexes are freely filtered</td>
<td>Greater loss of Ca(^{2+}) and Mg(^{2+})</td>
<td>Monitor iCa(^{2+})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Replace additional Ca and Mg systematically</td>
</tr>
<tr>
<td>II Citrate is a buffer</td>
<td>1 mol citrate → 3 mol bicarbonate</td>
<td>Use replacement fluid with no or less buffer</td>
</tr>
<tr>
<td>II The amount of citrate lost by ultrafiltration varies with ultrafiltrate flow</td>
<td>Varying amounts of buffer enter the systemic circulation if filtrate flow is not fixed: if filtrate flow drops, more buffer enters the patient</td>
<td>Monitor acid-base</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use fixed filtrate flow, or adjust the amount of buffer in the replacement fluid. Change filter if ultrafiltrate flow drops below a set limit</td>
</tr>
<tr>
<td>II If the liver fails, no buffer is generated and citrate accumulates</td>
<td>Accumulation of citrate → metabolic acidosis, anion-gap ↑, iCa(^{2+}) ↓, totCa/iCa(^{2+}) ↑</td>
<td>Monitor acid-base, iCa(^{2+}) and anion-gap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stop citrate, use bicarbonate buffered replacement</td>
</tr>
<tr>
<td>II If too much citrate infusion is infused accidentally</td>
<td>Metabolic alkalosis occurs if liver function is normal</td>
<td>Reduce citrate dose, use buffer-free replacement, administer calcium</td>
</tr>
<tr>
<td>II The trisodium citrate solution contains a substantial amount of sodium</td>
<td></td>
<td>Replacement fluid should contain less sodium</td>
</tr>
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Extracorporeal Drug Removal

Factors
- Molecular weight
- Volume of distribution
- Plasma protein binding
- Drug charge (Gibb-Donnan effect)
- Membrane, and adsorption to membrane
- Diffusion
- Convection
Complications of CRRT

- Bleeding
- Hypothermia
- Vascular access issues
- Fluid volume deficit (intravascular volume depletion)
- Hypotension
- Inadequate electrolyte or bicarbonate replacement during CRRT
- Blood loss (clotting of filter or hemorrhage due to over-anticoagulation)
- Air embolism
- Arrhythmias or circulatory shock
- Hemolysis
The decision to terminate CRRT is made by the nephrologist based on the patient’s renal recovery or the patient’s status-recovery or decision of the patient and family.

- Hemodynamic stabilization
- Renal recovery underway
- Stable electrolyte/acid-base/volume status
- Futility
Most participants think that establishing ethical criteria for managing CRRT is a medical task

Many physicians would start futile CRRT or maintain it if requested by the family

Only approximately half of physicians believe that informed consent is necessary for initiating CRRT

Most think that every vital support should be withdrawn when futile
Assessing Renal Recovery

- Increasing urine output and improvement in overall fluid status
- Downtrending serum creatinine
- Normalization of electrolyte/acid-base status
- Hemodynamic stabilization
Literature Review


CRRT and ECMO

I’d Like to Help, but… You Need ECMO, Not Elmo.
Initiation of CRRT in ECMO patients is simply an indicator of severity of illness and fatality.

Mortality is higher in these patients as compared to those receiving ECMO alone.

The combination of ECMO and CRRT in a variety of methods appears to be a safe and effective technique that improves fluid balance and electrolyte disturbances.

In the absence of primary renal disease, chronic renal failure did not occur after concurrent use of CRRT with ECMO.
Consult nephrology early to potentially modify/reverse AKI risk factors

Data to suggest starting CVVH early, with the appropriate indication, is favorable for patient outcomes

More may not be better in regards to CRRT dosing

Different modalities of CRRT can be custom tailored to each patient depending on their individual needs

CRRT is not a benign therapy, thus must monitor closely and address any ensuring complications
Questions?

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