Medical Practice Improvement CRRT and SLED

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Disclosures

- None

Learning Objectives

- Understand the Mechanism of Action and Clinical Indications for CRRT
- Identify and Differentiate Between Types of CRRT
- Analyze the Components and Functionality of the CRRT Machine
- Recognize the primary components of the CRRT machine (blood pump, dialyzer, replacement fluid) .
- Evaluate the Benefits and Risks of CRRT in Critically Ill Patients

What is CRRT?

- Continuous Renal Replacement Therapy (CRRT) is a dialysis technique primarily used for critically ill patients who experience acute kidney injury (AKI) and require continuous renal support. Unlike traditional hemodialysis, CRRT operates over a longer period (typically 24 hours or more) and allows for more gradual removal of waste products and excess fluids. This slow and steady process helps maintain hemodynamic stability, making it especially valuable in patients who are too unstable for conventional intermittent dialysis (Kellum, 2002).
- CRRT is commonly used in intensive care units (ICUs) to treat patients with conditions like multi-organ failure, septic shock, or severe fluid overload that cannot be managed with intermittent dialysis. The therapy is designed to replicate kidney function by removing excess water and solutes and correcting metabolic imbalances such as electrolyte disturbances (Forni, 2012).

Types of CRRT

- There are several types of CRRT, each suited for different clinical scenarios based on the patient's needs:

1. **Continuous Venovenous Hemofiltration (CVVH):** CVVH primarily removes waste products and excess fluid through ultrafiltration (convection). This process involves pushing plasma water through a filter, allowing large solutes to pass through while small solutes (such as waste) are retained (Cheung & McCarthy, 2000). The removed fluid is then replaced with a sterile replacement fluid to avoid negative fluid balance. This method is particularly useful for fluid overload without excessive loss of electrolytes.
2. **Continuous Venovenous Hemodialysis (CVVHD):** CVVHD utilizes both convection and diffusion to clear solutes. Diffusion relies on a concentration gradient to move solutes like urea from the blood into the dialysate, while ultrafiltration removes excess fluid. This method is beneficial for managing metabolic acidosis and clearing smaller molecular weight toxins (Clark & MacLeod, 2014).

Types of CRRT

1. **Continuous Venovenous Hemodiafiltration (CVVHDF):** CVVHDF combines the benefits of both CVVH and CVVHD, employing both diffusion and convection. This method is often used in patients who require both fluid removal and efficient toxin clearance, as it can manage a wider range of solute sizes (Levy & Hebert, 2006).
2. **Sustained Low-Efficiency Dialysis (SLED):** SLED is a hybrid technique that combines the principles of intermittent hemodialysis (IHD) with CRRT. It operates with a longer duration, typically 6-12 hours, and uses a slower flow rate to avoid causing rapid shifts in fluid and electrolytes. SLED is particularly useful for patients who need intermittent dialysis but have the potential benefit of slower fluid and solute removal (Patel, 2010). This method is well-suited for patients with mild to moderate AKI who require dialysis but are hemodynamically stable enough to tolerate the extended duration of therapy.

How is CRRT Used?

- CRRT is initiated and monitored in an intensive care setting, often under the supervision of nephrologists or intensivists. It is used when patients experience severe, acute kidney dysfunction that cannot be managed with traditional treatments, such as diuretics or intermittent dialysis.
- **Indications for CRRT:**
- **Hemodynamic Instability:** CRRT is particularly valuable in critically ill patients with low blood pressure (hypotension) or those at risk of hemodynamic compromise (Ronco & Bellomo, 2009). The continuous, gradual nature of CRRT avoids the rapid fluid shifts associated with intermittent hemodialysis, which can worsen hypotension.
- **Fluid Overload:** CRRT is used to address fluid overload in patients who have severe fluid retention that cannot be corrected with diuretics. This is common in patients with AKI, sepsis, or heart failure (Bouchard & Mehta, 2013).
- **Electrolyte Imbalances and Toxin Removal:** CRRT provides excellent control over electrolyte imbalances, such as hyperkalemia, and clears toxins like urea and creatinine. It can be tailored to remove specific solutes at varying rates based on patient needs (Goldstein & Kirkendall, 2005).
- The process typically requires blood access via a central venous catheter, which draws the patient's blood, filters it through a dialyzer or hemofilter, and returns the cleaned blood to the patient. Replacement fluids may also be used to replace fluids lost through ultrafiltration and to correct any electrolyte imbalances (Levy & Hebert, 2006).

How is CRRT Used?

- CRRT provides multiple advantages in the treatment of critically ill patients:

1. **Hemodynamic Stability:** CRRT's slow, continuous nature avoids the rapid fluctuations in blood pressure often seen with traditional intermittent hemodialysis. This makes it ideal for critically ill patients who are unable to tolerate the stress of rapid fluid removal (Kellum, 2002).
2. **Management of Fluid Overload:** In cases of severe fluid retention, CRRT allows for gradual removal of excess fluid, minimizing the risk of adverse outcomes such as pulmonary edema or heart failure exacerbations. This is particularly important in patients with conditions like AKI or multi-organ failure, where fluid balance is a critical factor (Bouchard, 2013).
3. **Electrolyte and Toxin Clearance:** CRRT allows for more precise control over electrolytes such as potassium, sodium, and calcium, making it effective in managing hyperkalemia, hyponatremia, and metabolic acidosis. Additionally, CRRT is highly effective in removing nitrogenous waste products like urea and creatinine, which accumulate in patients with AKI (Goldstein & Kirkendall, 2005).
4. **Toxin Removal:** In cases of poisoning or toxin buildup, CRRT can be used to filter out harmful substances from the bloodstream. This is especially useful in patients with sepsis, drug overdoses, or other conditions that cause the accumulation of metabolic toxins (Levy & Hebert, 2006).

How Does the CRRT Machine Work?

- The CRRT machine is a complex piece of equipment that helps manage kidney failure by performing several essential functions:

1. **Blood Pump:** The blood pump continuously circulates the patient's blood through the dialysis circuit, ensuring that blood flows at a consistent rate through the filter or dialyzer (Forni, 2012).
2. **Dialyzer/Filter:** The dialyzer, also known as a filter, is the core component of CRRT. It is made of a semipermeable membrane that allows small molecules like urea and creatinine to pass through while retaining larger molecules like proteins and blood cells. This filtration process clears toxins from the blood (Cheung & McCarthy, 2000).

How Does the CRRT Machine Work?

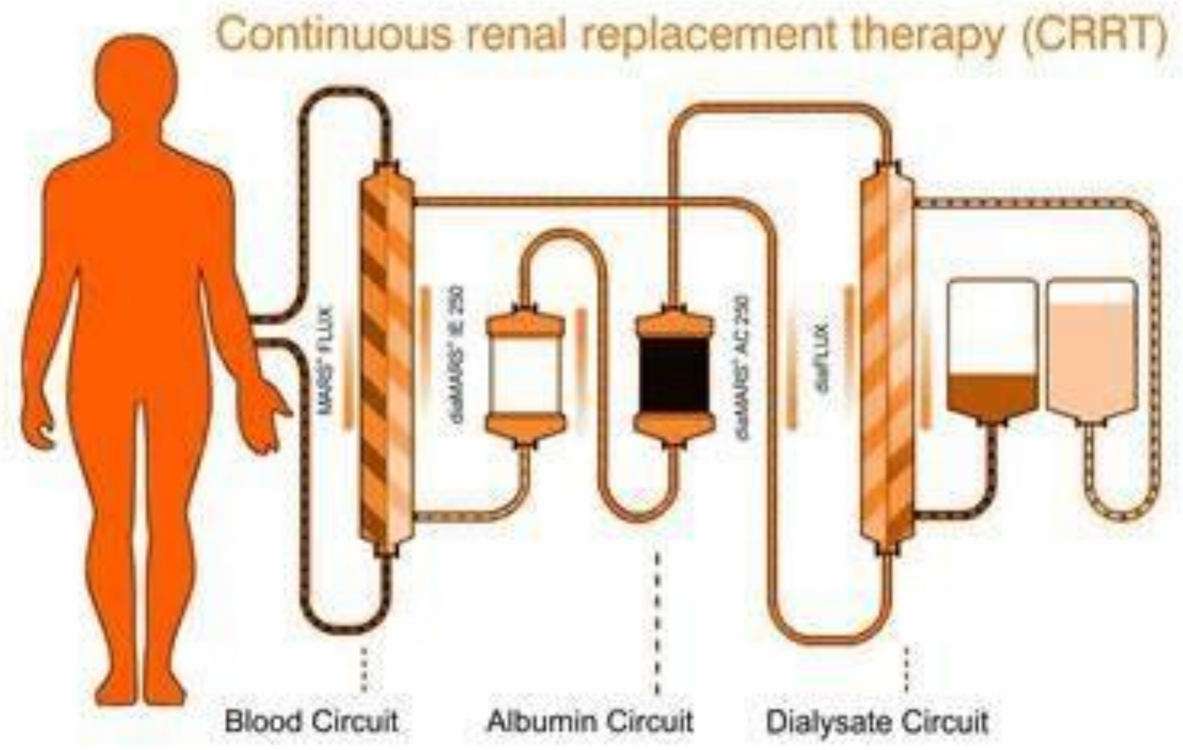
1. **Replacement Fluid:** In addition to filtering the blood, CRRT uses a replacement fluid that is added to replace the fluid lost through ultrafiltration. This fluid is designed to match the patient's electrolyte needs and prevent any imbalances (Kellum, 2002).
2. **Ultrafiltration:** Ultrafiltration is a process that removes excess fluid from the blood. The CRRT machine applies a pressure gradient across the filter to pull water from the blood, which is then discarded or replaced with a replacement fluid (Clark & MacLeod, 2014).

How Does the CRRT Machine Work?

- The blood is continuously processed through the system, and spent blood is returned to the patient after filtration. This ongoing process allows for gradual, controlled removal of fluids and solutes, which is particularly useful for critically ill patients who cannot tolerate more aggressive, intermittent dialysis (Levy & Hebert, 2006).

The Machinery

CRRT Machine in Action



Continuous renal replacement therapy (CRRT) is any extracorporeal blood purification therapy designed to substitute for impaired renal function over an extended period, and intended to be applied for up to 24 hours a day.

Citrate:

- **Mechanism of Action:**
  Citrate works by binding calcium, which is essential for clotting cascades. By chelating calcium, citrate prevents the activation of coagulation factors, thus inhibiting clot formation in the extracorporeal circuit (Kellum, 2002).
- **Advantages:**
  - **Less Systemic Anticoagulation:** Citrate primarily acts within the CRRT circuit, limiting systemic anticoagulation. This makes it ideal for patients who are at a high risk of bleeding or those with a contraindication to systemic anticoagulants (e.g., active bleeding) (Luft, 2007).
  - **Reversible:** Citrate's effects can be reversed by administering calcium, which makes it a safer option in case of over-anticoagulation (Ronco, 2009).
  - **Better Control of Calcium:** Citrate allows for controlled management of calcium levels, as it can be removed or adjusted within the CRRT process (Kellum, 2002).
- **Disadvantages:**
  - **Metabolic Alkalosis:** Excess citrate can lead to metabolic alkalosis and electrolyte imbalances, especially in patients with liver dysfunction or impaired metabolism (Bellomo, 2012).
  - **Risk of Hypocalcemia:** If not managed properly, citrate can cause hypocalcemia, which requires careful monitoring of calcium levels (Luft, 2007).

Why CRRT is Important in Trauma?

- Trauma patients frequently develop **acute kidney injury (AKI)** due to:
- Hemorrhagic shock → renal hypoperfusion
- Rhabdomyolysis (crush injuries) → myoglobin-induced nephrotoxicity
- Sepsis → inflammatory-mediated renal injury
- Massive transfusion → metabolic derangements
- Nephrotoxic medications (contrast, antibiotics)
- CRRT allows renal support without causing further hemodynamic instability.

Indications for CRRT in Trauma

- Classic indications (similar to dialysis, but CRRT preferred if unstable):
- **1. Hemodynamic Instability**
- Patients on vasopressors
- Ongoing resuscitation
- CRRT avoids rapid fluid shifts seen in intermittent dialysis
- **2. Fluid Overload**
- Common after massive transfusion or resuscitation
- Especially important in:
  - ARDS
  - Pulmonary edema
  - Abdominal compartment syndrome

Indications for CRRT in Trauma

- **3. Severe Acute Kidney Injury**
- Oliguria/anuria
- Rising creatinine and BUN
- **4. Electrolyte Abnormalities**
- Hyperkalemia (life-threatening)
- Severe metabolic acidosis
- **5. Rhabdomyolysis**
- Helps clear myoglobin (limited but supportive role)
- Prevents worsening AKI
- **6. Sepsis and Cytokine Modulation (Adjunctive)**
- Some CRRT modalities may help remove inflammatory mediators (controversial but used in select cases)

Advantages in Trauma Patients

- Better **hemodynamic tolerance**
- Precise **fluid balance control**
- Continuous **acid-base correction**
- Improved management of **catabolic states**
- May help reduce **intracranial pressure** in traumatic brain injury by avoiding osmotic swings

Special Trauma Considerations

- **1. Rhabdomyolysis**
- Early CRRT may be considered in severe cases
- High-volume hemofiltration sometimes used
- **2. Traumatic Brain Injury (TBI)**
- Avoids rapid osmotic shifts → prevents ICP spikes
- Allows controlled sodium/osmolality management
- **3. Massive Transfusion**
- Helps manage:
  - Citrate toxicity
  - Electrolyte imbalances (Ca, K)
  - Volume overload
- **4. Abdominal Compartment Syndrome**
- Assists in fluid removal and reducing intra-abdominal pressure

Anticoagulation in Trauma CRRT

- A major challenge due to bleeding risk:
- **Regional citrate anticoagulation (preferred)**
  - Less systemic bleeding risk
- **Heparin (used cautiously)**
- **No anticoagulation**
  - Often used in active bleeding or post-op trauma patients (shorter filter life)

Complications

- Hypothermia
- Electrolyte disturbances (especially hypophosphatemia)
- Filter clotting
- Infection (line-related)
- Nutrient loss (amino acids, vitamins)

Heparin:

- **Mechanism of Action:**
  Heparin works by activating antithrombin III, which in turn inhibits thrombin and other coagulation factors (particularly Factor Xa), thus preventing the formation of clots (Bellomo, 2012). Heparin's anticoagulant effect is systemic, meaning it can affect the patient's overall blood coagulation.
- **Advantages:**
  - **Proven Effectiveness:** Heparin has a long history of use in dialysis, including CRRT, and is well-studied. It provides reliable and potent anticoagulation (Luft, 2007).
  - **Easier to Manage:** Heparin is easier to administer and doesn't require special adjustments based on patient metabolism, unlike citrate, which may require careful monitoring of calcium levels (Bellomo, 2012).
- **Disadvantages:**
  - **Systemic Anticoagulation:** Heparin's effect is not limited to the CRRT circuit, and it can increase the risk of bleeding, especially in patients with liver dysfunction, low platelet counts, or those requiring surgery (Luft, 2007).
  - **Heparin-Induced Thrombocytopenia (HIT):** There is a risk of developing HIT, a serious condition where antibodies form against heparin-platelet complexes, leading to thrombosis (Bellomo, 2012).
  - **Need for Monitoring:** Heparin requires regular monitoring of activated partial thromboplastin time (aPTT) or anti-Xa levels to avoid over-anticoagulation and bleeding complications.

Conclusion:

- **Citrate** is often preferred in critically ill patients with a high risk of bleeding or those with liver dysfunction, as it primarily acts within the circuit, limiting systemic anticoagulation.
- **Heparin** is more commonly used in stable patients without significant bleeding risks and requires close monitoring to avoid systemic complications.
- Both anticoagulants have their place in CRRT, but the choice between them should be based on the patient's condition, bleeding risk, and clinical scenario (Ronco, 2009).

Comparison

Summary Comparison:

Feature	Citrate	Heparin
Mechanism	Binds calcium, inhibits clotting in the circuit	Activates antithrombin III to inhibit thrombin and Factor Xa
Systemic Anticoagulation	Limited to the circuit	Affects entire body, increases bleeding risk
Advantages	Less bleeding risk, reversible, better control over calcium	Proven effectiveness, easy to manage
Disadvantages	Risk of metabolic alkalosis, hypocalcemia	Increased bleeding risk, HIT risk, requires monitoring
Clinical Use	Preferred for patients at risk of bleeding or with liver dysfunction	Commonly used, particularly for patients without bleeding risk

Practical Pearls for Trauma Teams

- Start CRRT early in **high-risk AKI + instability**
- Prioritize in **volume overloaded + ventilated patients**
- Use cautiously but effectively in **TBI**
- Coordinate closely with:
  - Nephrology
  - ICU team
  - Trauma surgery

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