CKRT Modes in Children

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RRT: Modalities

- Hemodialysis
- Peritoneal Dialysis
- Renal Transplantation
  - Living-Related, Living-Unrelated
  - Cadaveric
- CRRT
  - CAVH, CVVH, SCUF
  - CAVHD, CVVHD, CAVHDF, CVVHDF
Hemodialysis is for non-functioning kidneys in patients with fairly good health.

CRRT is for saving kidney function in patients with very poor health.
Why continuous Therapies?

Continuous therapies closely mimic the GFR of native kidneys.

Large amounts of fluid and waste products removed over time.

Tolerated well by hemodynamically unstable patients.
Solute Removal Mechanisms in RRT

I – Diffusion

II – Convection

III – Ultrafiltration

IV – Adsorption
Diffusion – movement of molecules from their area of higher concentration to an area of lower concentration across a semi-permeable membrane.

Rate of diffusion $\propto$ concentration gradient $\propto$ $1$/mol weight
Convection - transmembrane solute movement in association with ultrafiltered plasma water ("solvent drag")
Solute clearance depends on its mol wt

Rate of convective clearance

- molecular weight (directly proportional to solute size)
- UF rate (pressure gradient)
- membrane sieving properties (KoA & KUF)
Ultrafiltration

- The movement of water through a semi-permeable membrane across a pressure gradient.

- Pressure gradient:
  - In PD – osmotic pressure (generated by glucose or colloid solutions)
  - In HD – hydrostatic pressure (TMP)

- Results of ultrafiltration
  - fluid removal
  - Convective removal of solutes (esp middle mol)

UF capability of a dialyzer - UF coefficient ($K_{uf}$) – ml/h/mmHg
Adsorption

- Membrane area
- Concentration of solute to be removed
- Hydrostatic pressure
- Can affect the permeability of the hemo membrane from start to end of a hemo session / or if reused
The Dialysis Membrane
Effect of Pore Size on Membrane Selectivity

Creatinine 113 D
Urea 60 D
Glucose 180 D
Vancomycin ~1,500 D
Albumin ~66,000 D
IgG ~150,000 D

Rukshana Shroff - ESPN - Master Class
Co-current vs counter-current circuit
HDF – clearance by diffusion and convection
Continuous Renal Replacement Therapy

Advantages

• Precise volume control

• Very effective control of uremia and ↑ K⁺

• Rapid control of metabolic acidosis

• Suitable for hemodynamically unstable pts

• Improved nutritional support
  – (no need for volume restriction)
Basis for Nomenclature

C  V-V  H

Interval Therapy  Blood Access  Method of Solute Removal
Continuous Renal Replacement Therapy

- Extracorporeal circuit
- Continuous in nature
- Particle removal: Diffusion or Convection
- Fluid removal via ultrafiltration
GFR Criteria | Urine Output Criteria
---|---
Increased creatinine x 1.5 or GFR decrease >25% | $UO < 0.5 \text{mL/kg/hr} \times 6 \text{ hours}$
Increased creatinine x 2 or GFR decrease >50% | $UO < 0.5 \text{mL/kg/hr} \times 12 \text{ hours}$
Increased creatinine x 3 or GFR decrease >75% or Serum Creatinine $\geq 4 \text{ mg/dL}$ | $UO < 0.3 \text{ mL/kg/hr} \times 24 \text{ hours}$ or anuria $\times 12 \text{ hours}$
Persistent ARF = complete loss of renal function $>4 \text{ weeks}$
End-stage renal disease ($>3 \text{ months}$)

Early Initiation
Nomenclature for CRRT Modalities

- **SCUF**
  - Slow Continuous Ultrafiltration
- **CVVH**
  - Continuous Veno-Venous Hemofiltration
- **CVVHD**
  - Continuous Veno-Venous Hemodialysis
- **CVVHDF**
  - Continuous Veno-Venous Hemodiafiltration
CRRT: Principle

- Ultrafiltration: The main driving force
- Diffusion: slow and efficient only with time
- Patient need replacement of fluid loss up to 18 liters/day (in CAVH, CVVH, CAVHDF & CVVHDF)
Clearance: Convection vs. Diffusion

- Diffusive Clearance
- Convective Clearance

Molecular Weight

Clearance
Diffusive Clearance

- CVVHD/HD/PD
- Diffusive clearance
- Dialysate
  - Physiologic sterile solution that is infused countercurrent to the blood flow rate (Qd)
Convective Clearance

- CVVH
- Convective clearance
- Replacement Solutions
  - Physiologic sterile solution that is either infused pre filter (NA) or post filter (outside of NA) that infused at a set rate ($Q_r$)
Convective and Diffusive Clearance

- CVVHDF/CAVHDF
- Convective clearance
  - Replacement Solutions
- Diffusive clearance
  - Dialysis solution
Indications

• Acidemia (pH < 7.1)
• Electrolytes
  – Hyperkalemia (K⁺ > 6.5 mEq/L)
  – Severe dysnatremia (Na⁺ < 115 or > 160 mEq/L)
• Ingestions (Toxins, Drugs)
• Overload/ Oliguria (urine output < 200 mL/12 h)
• Uremia (urea > 30 mg/dL)
  – Uremic encephalopathy
  – Uremic pericarditis
  – Uremic neuro-myopathy
Intermittent vs. continuous RRT

Rate Limitations of Volume Removal

Improved Volume Removal with Slower Ultrafiltration Rates

Extra-Vascular Compartment  Vascular Compartment

Extra-Vascular Compartment  Vascular Compartment

BP

BP Stable
Principals of CRRT

- Vascular access.
- Semi-permeable membrane.
- Transport mechanism.
- Dialysate and replacement fluid.
Basic Components in CRRT

- Solutions
- Hemofilter
- CRRT System
- Anticoagulation
- Vascular Access
- Blood Warmer
Access

Internal Jugular Vein –
• Lower risk of complication
• Simplicity of catheter insertion

Subclavian Vein –
• Higher risk of pneumo/hemothorax
• Associated with central venous stenosis

Femoral Vein –
• Optimal site for immobilized patient
• Easiest site for infection
• Increased chance for infection
SCUF
Slow Continuous UltraFiltration

Diagram showing a medical device with labeled parts:
- Effluent Pump
- Blood Pump
- Return
- Access
- Effluent
- Infusion or Anticoagulant
- PBP Pump
Slow Continuous Ultrafiltration (SCUF)

• Primary therapeutic goal: – Safe management of fluid

• Primary indications: – Fluid overload without metabolic imbalance

• Principle used: Ultrafiltration

• Therapy characteristics: – No dialysate or substitution solutions Fluid removal only
Understanding Flow

- To Patient
- From Patient
- Pump
- Convection Across Pressure Gradient
- Anticoagulant
- Effluent/Filtrate
- Slow Continuous UltraFiltration (SCUF)
CVVH
Continuous VV Hemofiltration

Return
Access

Blood Pump

Replacement Pump 2

Effluent Pump

Replacement Pump 1

Replacement 2

Effluent

Replacement 1

Infusion or Anticoagulant

PBP Pump
CVVH

• Primary therapeutic goal:
  – Solute removal and safe fluid management

• Primary indications:
  Uremia, severe acid/base or electrolyte imbalance
  Removal of larger mol wt. substances

• Principle used: convection

• Therapy characteristics:
  – Substitution solution to drive
  – No dialysate solution

Effective at removing small and large molecules
Understanding Flow

Replacement Fluid

Pump

To Patient

Convection Across Pressure Gradient

From Patient

Pump

Anticoagulant

Effluent/Filtrate

Continuous Veno-Venous Hemofiltration (CVVH)
CVVHD
Continuous VV HemoDialysis
Understanding flow

Continuous Veno-Venous Hemodialysis (CVVHD)

- Dialysate
- To Patient
- From Patient
- Anticoagulant
- Effluent/Filtrate
- Diffusion Across Concentration Gradient
- Pump

Patrick Netter (Copyright 2002)
CVVHD

• Primary therapeutic goal:
  – Solute removal and safe management of fluid volume

• Primary indications:
  – Uremia, severe acid/base or electrolyte imbalance

• Principle used: **Diffusion**

• Therapy characteristics:
  Requires dialysate solution to drive diffusion
  No substitution solution
  Effective at removing **small to medium** molecules
CVVHDF
Continuous VV HemoDiaFiltration

Diagram showing the flow of fluids in a CVVHDF system, including Dialysate Fluid, Effluent, Replacement Fluid, and Infusion or Anticoagulant.
• Primary therapeutic goal:
   Solute removal and safe management of fluid volume

• Primary indications:
   Uremia, severe acid/base or electrolyte imbalance
   Removal of large molecular weight substances is required
   Unstable haemodynamics

• Principle used: **diffusion and convection**

• Therapy characteristics:
  – Requires dialysate fluid and substitution solution to drive diffusion and convection

• Effective at removing **small, medium and large** molecules
Understanding Flow

- Dialysate
- Replacement Fluid
- Diffusion Across Concentration Gradient
- Convection Across Pressure Gradient
- To Patient
- From Patient
- Pump
- Effluent/Filtrate
- Anticoagulant
- Continuous Veno-Venous Hemo-Diafiltration (CVVHFD)
In summary

**CRRT: Types**

- CAVH: UF only
- CVVH: UF only
- SCUF: slow UF
- CAVHD: Dialysis
- CVVHD: Dialysis
- CAVHDF: UF & Dialysis
- CVVHDF: UF & Dialysis
Thanks for your attention