Targeting Renal Recovery…. Acute kidney injury treatment with optimized continuous renal replacement therapy (CRRT)

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Continuous Renal Replacement Therapy

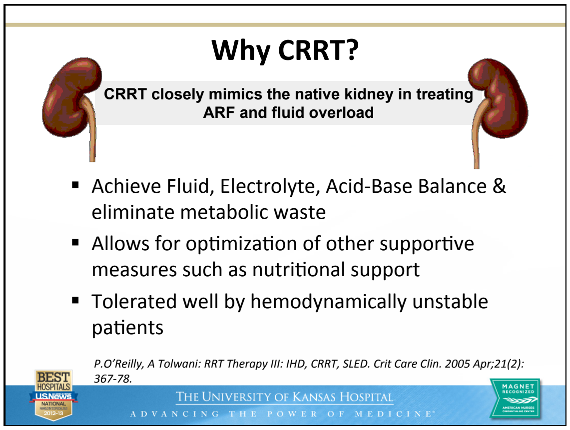
Objectives

- Define continuous renal replacement therapy (CRRT) and its associated modalities.
- Delineate the implications for clinical practice generated by the Kidney Dialysis Improving Global Outcomes (KDIGO) practice guidelines.
- Identify the critical care nurses role in ensuring the patient with kidney injury receive optimal CRRT.

Continuous Renal Replacement Therapy

"Any extracorporeal blood purification therapy intended to substitute for impaired renal function over an extended period of time and applied for, or aimed at being applied for, 24 hours/ day."

Bellomo R, Ronco C, Mehta R (1996). Nomenclature for Continuous Renal Replacement Therapy, AJKD, 28(5) Supp (3).

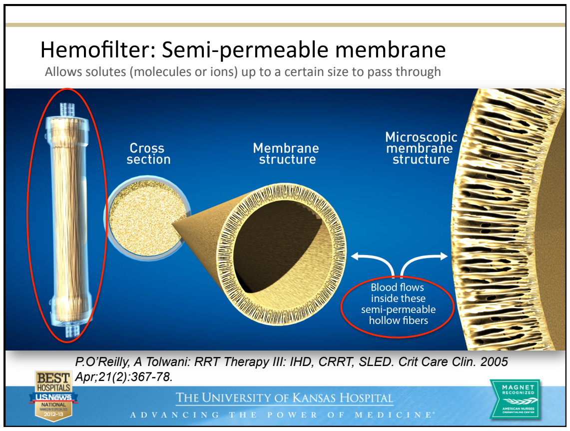


Why CRRT?

CRRT closely mimics the native kidney in treating ARF and fluid overload

- Achieve Fluid, Electrolyte, Acid-Base Balance & eliminate metabolic waste
- Allows for optimization of other supportive measures such as nutritional support
- Tolerated well by hemodynamically unstable patients

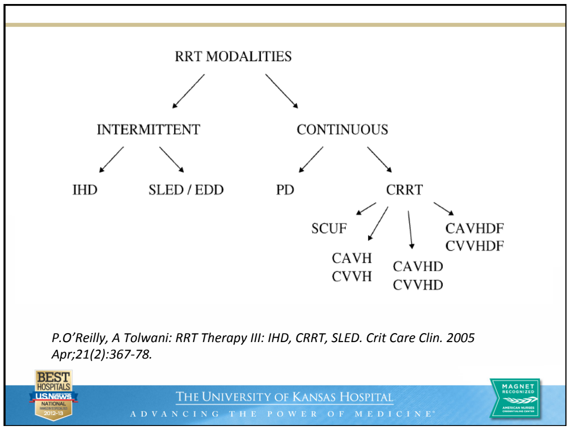
P.O'Reilly, A Tolwani: RRT Therapy III: IHD, CRRT, SLED. Crit Care Clin. 2005 Apr;21(2): 367-78.



Hemofilter: Semi-permeable membrane

Allows solutes (molecules or ions) up to a certain size to pass through

P.O'Reilly, A Tolwani: RRT Therapy III: IHD, CRRT, SLED. Crit Care Clin. 2005 Apr;21(2):367-78.



RRT MODALITIES

INTERMITTENT
CONTINUOUS

IHD
SLED / EDD
PD
CRRT

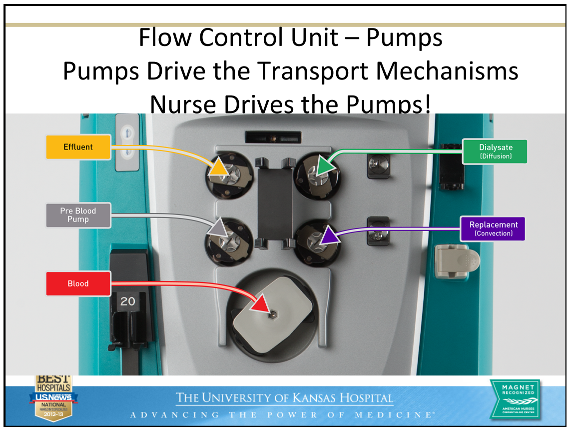
SCUF
CAVH
CVVH
CAVHD
CVVHD
CAVHDF
CVVHDF

P.O'Reilly, A Tolwani: RRT Therapy III: IHD, CRRT, SLED. Crit Care Clin. 2005 Apr;21(2):367-78.

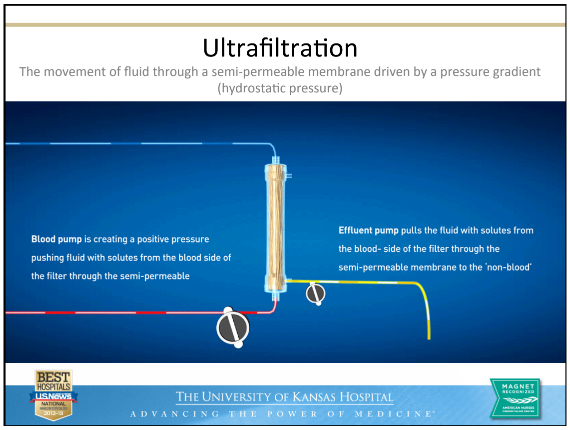
TRANSPORT MECHANISMS

- Fluid & solutes are removed from the blood by various transport mechanism:
  - Ultrafiltration → Fluid Transport
  - Diffusion
  - Convection
  - Adsorption

  } → Solute Transport



Flow Control Unit – Pumps
Pumps Drive the Transport Mechanisms
Nurse Drives the Pumps!

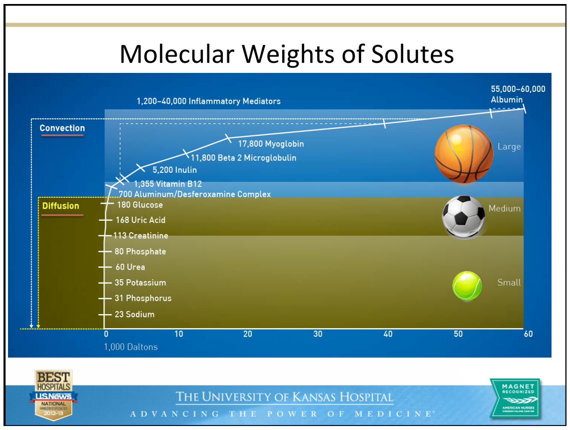


Ultrafiltration

The movement of fluid through a semi-permeable membrane driven by a pressure gradient (hydrostatic pressure)

Blood pump is creating a positive pressure pushing fluid with solutes from the blood side of the filter through the semi-permeable

Effluent pump pulls the fluid with solutes from the blood- side of the filter through the semi-permeable membrane to the 'non-blood'



Molecular Weights of Solutes

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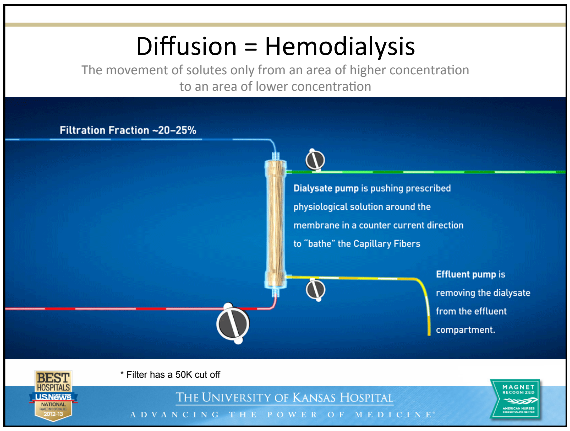

Diffusion = Hemodialysis

The movement of solutes only from an area of higher concentration to an area of lower concentration

Filtration Fraction ~20–25%

Dialysate pump is pushing prescribed physiological solution around the membrane in a counter current direction to "bathe" the Capillary Fibers

Effluent pump is removing the dialysate from the effluent compartment.

* Filter has a 50K cut off

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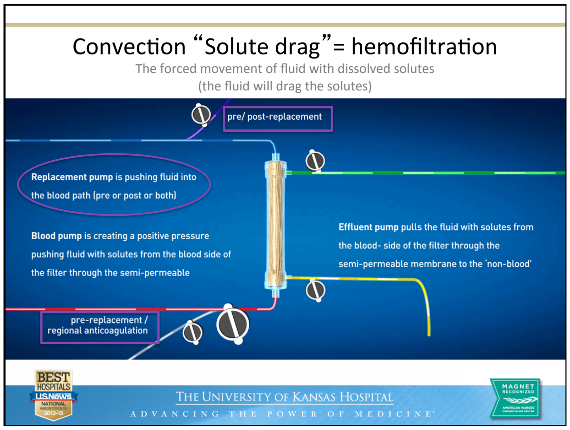

Convection "Solute drag"= hemofiltration

The forced movement of fluid with dissolved solutes (the fluid will drag the solutes)

Replacement pump is pushing fluid into the blood path (pre or post or both)

Blood pump is creating a positive pressure pushing fluid with solutes from the blood side of the filter through the semi-permeable

Effluent pump pulls the fluid with solutes from the blood- side of the filter through the semi-permeable membrane to the 'non-blood'

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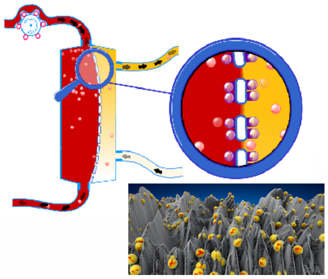
Replacement Solutions

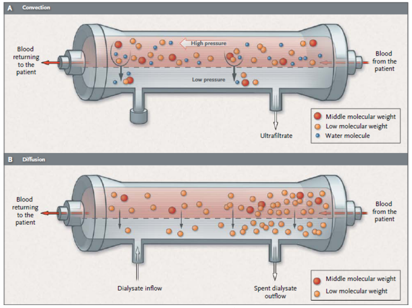
- Infused directly into the blood at points along the blood pathway
  - Pre-Filter
  - Post-Filter
- Drives convective transport; facilitates the removal of small middle and large solutes
- "Replaces" the removed volume and replaces electrolytes
- *Solution choice* depends on patient electrolyte and acid-base needs

SOLUTE TRANSPORT MECHANISM: ADSORPTION

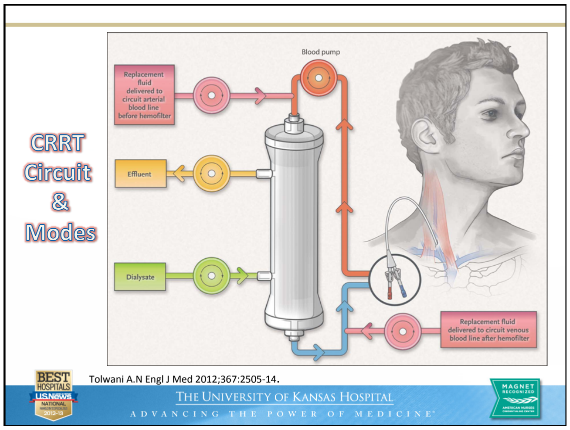


- Molecular adherence of solutes to the surface of the membrane
- AN69 Filter = negative charge
- Solutes = positive charge

Primary Transport Mechanisms: Summary

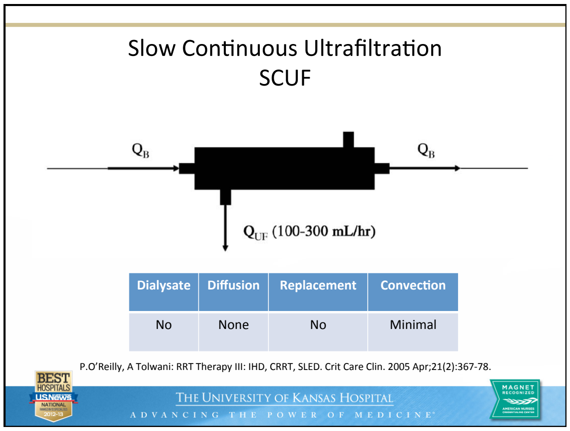


Tolwani A. Continuous Renal-Replacement Therapy for Acute Kidney Injury. N Engl J Med 2012;367:2505-14.



CRRT Circuit & Modes

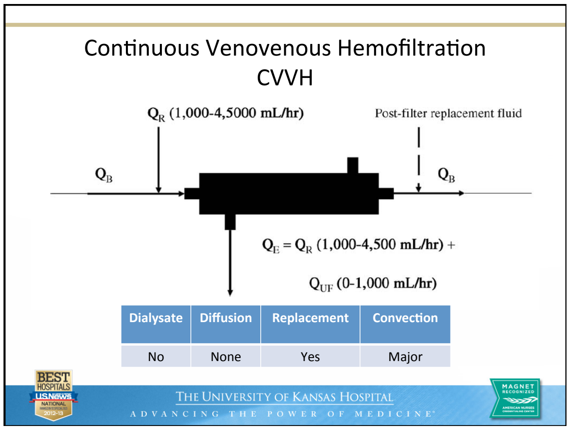
Tolwani A.N Engl J Med 2012;367:2505-14.



Slow Continuous Ultrafiltration
SCUF

Dialysate	Diffusion	Replacement	Convection
No	None	No	Minimal

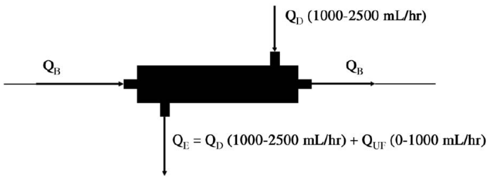
P.O'Reilly, A Tolwani: RRT Therapy III: IHD, CRRT, SLED. Crit Care Clin. 2005 Apr;21(2):367-78.



Continuous Venovenous Hemofiltration
CVVH

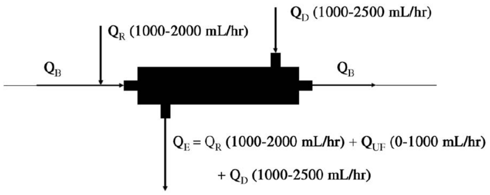
Dialysate	Diffusion	Replacement	Convection
No	None	Yes	Major

Continuous Venovenous Hemodialysis
CVVHD



Dialysate	Diffusion	Replacement	Convection
Yes	Major	No	Minimal

Continuous Venovenous Hemodiafiltration
CVVHDF

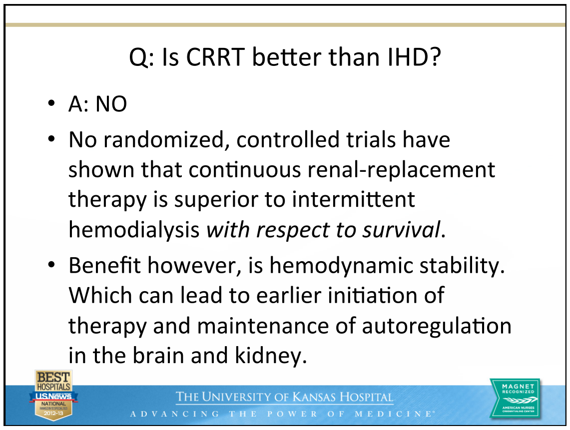


Dialysate	Diffusion	Replacement	Convection
Yes	Yes	Yes	Yes

Which CRRT Modality Is Best?

- There are currently insufficient data to recommend one form of continuous renal-replacement therapy over another.
- The choice of continuous renal replacement therapy is based on individual center experience.
- Selected therapy should be delivered proficiently!

Tolwani A. Continuous Renal-Replacement Therapy for Acute Kidney Injury. N Engl J Med 2012;367:2505-14.



Q: Is CRRT better than IHD?

- A: NO
- No randomized, controlled trials have shown that continuous renal-replacement therapy is superior to intermittent hemodialysis *with respect to survival*.
- Benefit however, is hemodynamic stability. Which can lead to earlier initiation of therapy and maintenance of autoregulation in the brain and kidney.

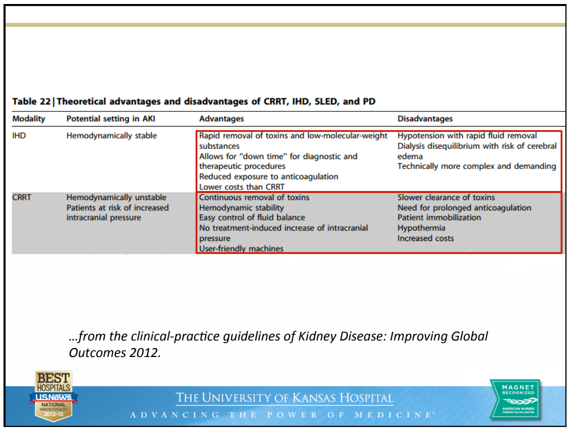
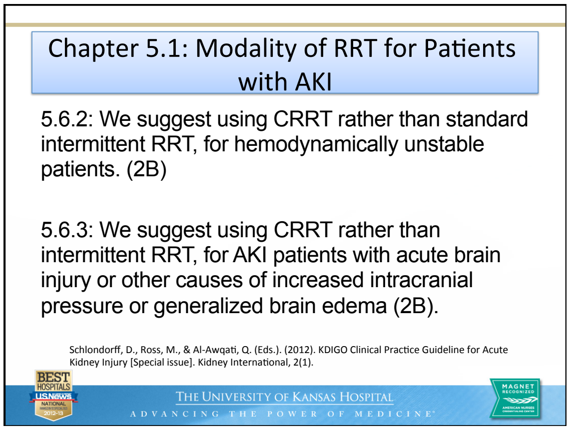


Table 22 | Theoretical advantages and disadvantages of CRRT, IHD, SLED, and PD

Modality	Potential setting in AKI	Advantages	Disadvantages
IHD	Hemodynamically stable	Rapid removal of toxins and low-molecular-weight substances Allows for "down time" for diagnostic and therapeutic procedures Reduced exposure to anticoagulation Lower costs than CRRT	Hypotension with rapid fluid removal Dialysis disequilibrium with risk of cerebral edema Technically more complex and demanding
CRRT	Hemodynamically unstable Patients at risk of increased intracranial pressure	Continuous removal of toxins Hemodynamic stability Easy control of fluid balance No treatment-induced increase of intracranial pressure User-friendly machines	Slower clearance of toxins Need for prolonged anticoagulation Patient immobilization Hypothermia Increased costs

…from the clinical-practice guidelines of Kidney Disease: Improving Global Outcomes 2012.

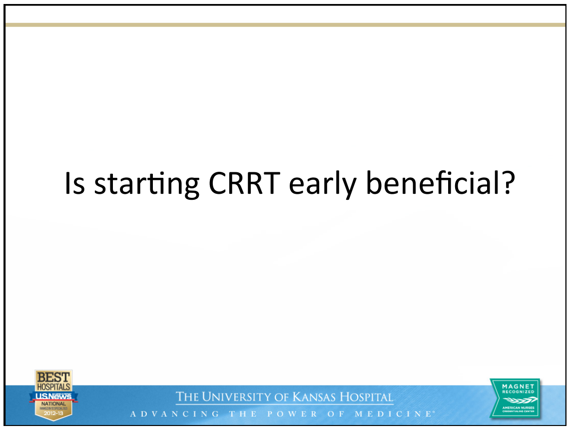


Chapter 5.1: Modality of RRT for Patients with AKI

5.6.2: We suggest using CRRT rather than standard intermittent RRT, for hemodynamically unstable patients. (2B)

5.6.3: We suggest using CRRT rather than intermittent RRT, for AKI patients with acute brain injury or other causes of increased intracranial pressure or generalized brain edema (2B).

Schlondorff, D., Ross, M., & Al-Awqati, Q. (Eds.). (2012). KDIGO Clinical Practice Guideline for Acute Kidney Injury [Special issue]. Kidney International, 2(1).



Is starting CRRT early beneficial?

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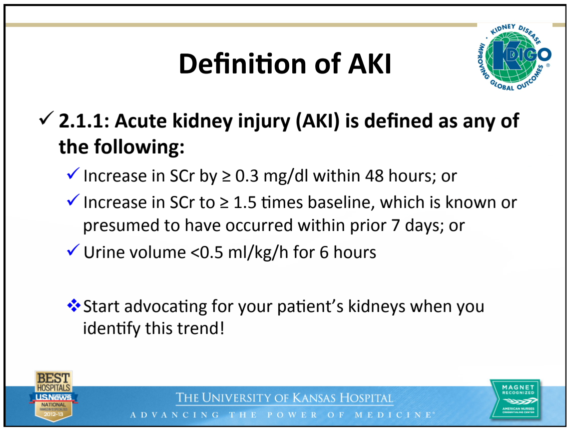

Definition of AKI

- ✓ **2.1.1: Acute kidney injury (AKI) is defined as any of the following:**
  - ✓ Increase in SCr by ≥ 0.3 mg/dl within 48 hours; or
  - ✓ Increase in SCr to ≥ 1.5 times baseline, which is known or presumed to have occurred within prior 7 days; or
  - ✓ Urine volume <0.5 ml/kg/h for 6 hours

❖ Start advocating for your patient's kidneys when you identify this trend!

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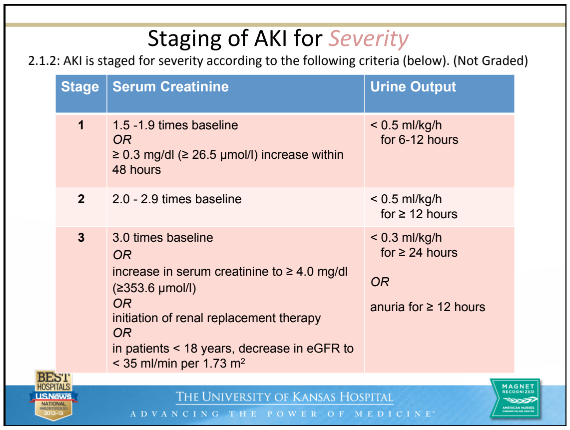

Staging of AKI for *Severity*

2.1.2: AKI is staged for severity according to the following criteria (below). (Not Graded)

Stage	Serum Creatinine	Urine Output
1	1.5 -1.9 times baseline *OR* ≥ 0.3 mg/dl (≥ 26.5 μmol/l) increase within 48 hours	< 0.5 ml/kg/h for 6-12 hours
2	2.0 - 2.9 times baseline	< 0.5 ml/kg/h for ≥ 12 hours
3	3.0 times baseline *OR* increase in serum creatinine to ≥ 4.0 mg/dl (≥353.6 μmol/l) *OR* initiation of renal replacement therapy *OR* in patients < 18 years, decrease in eGFR to < 35 ml/min per 1.73 m^2	< 0.3 ml/kg/h for ≥ 24 hours *OR* anuria for ≥ 12 hours

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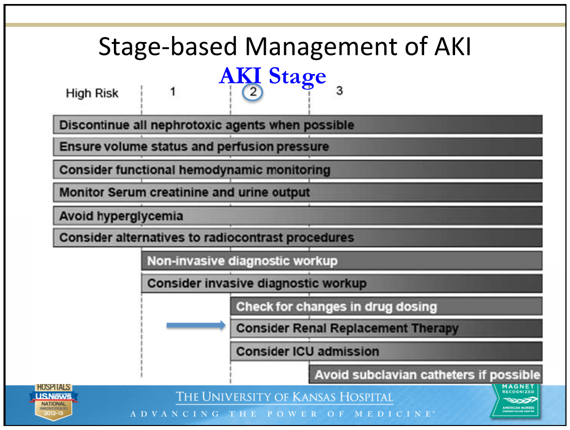
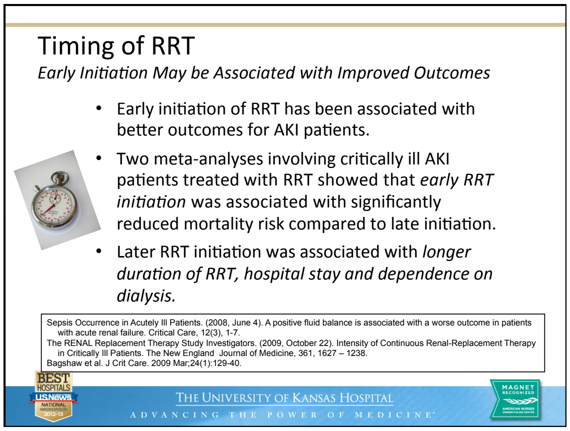


Stage-based Management of AKI

- 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
- Non-invasive diagnostic workup
- Consider invasive diagnostic workup
- Check for changes in drug dosing
- Consider Renal Replacement Therapy
- Consider ICU admission
- Avoid subclavian catheters if possible

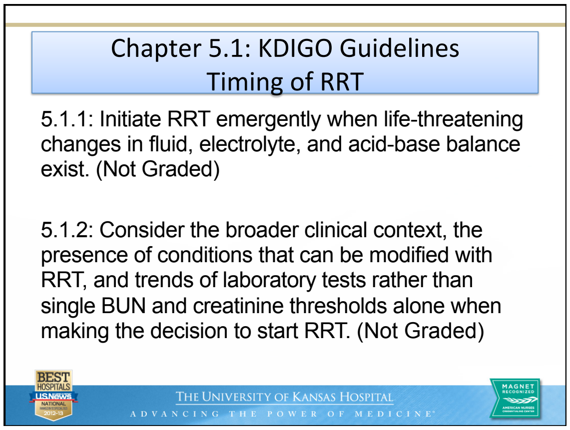


Timing of RRT

Early Initiation May be Associated with Improved Outcomes

- Early initiation of RRT has been associated with better outcomes for AKI patients.
- Two meta-analyses involving critically ill AKI patients treated with RRT showed that *early RRT initiation* was associated with significantly reduced mortality risk compared to late initiation.
- Later RRT initiation was associated with *longer duration of RRT, hospital stay and dependence on dialysis.*

Sepsis Occurrence in Acutely Ill Patients. (2008, June 4). A positive fluid balance is associated with a worse outcome in patients with acute renal failure. Critical Care, 12(3), 1-7.
The RENAL Replacement Therapy Study Investigators. (2009, October 22). Intensity of Continuous Renal-Replacement Therapy in Critically Ill Patients. The New England Journal of Medicine, 361, 1627 – 1238.
Bagshaw et al. J Crit Care. 2009 Mar;24(1):129-40.



Chapter 5.1: KDIGO Guidelines
Timing of RRT

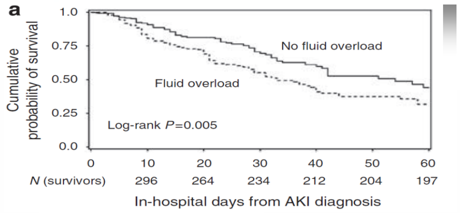
5.1.1: Initiate RRT emergently when life-threatening changes in fluid, electrolyte, and acid-base balance exist. (Not Graded)

5.1.2: Consider the broader clinical context, the presence of conditions that can be modified with RRT, and trends of laboratory tests rather than single BUN and creatinine thresholds alone when making the decision to start RRT. (Not Graded)

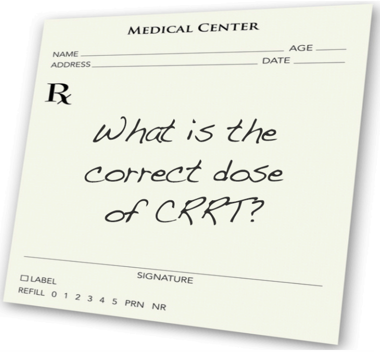
Fluid Overload and Mortality

$$\left(\frac{\text{total fluid input (L)} - \text{total fluid output (L)}}{\text{baseline body weight (kg)}}\right) \times 100$$

0–10% = Fluid accumulation
>10% = Fluid overload



Bouchard J et al. Kidney Int 2009



What is the correct dose of CRRT?

KDIGO Clinical Practice Guideline Chapter 5.8: Dose of RRT in AKI

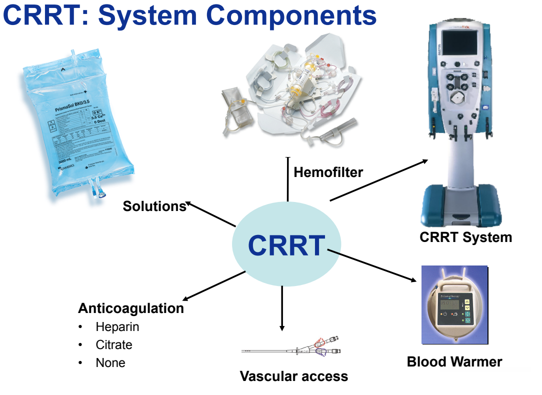
- 5.8.4: We recommend *delivering* an effluent volume of 20-25 ml/kg/hr for CRRT in AKI (1A). This will usually require a higher prescription of effluent volume. (Not Graded)
- *Prescription* should be 30-35 ml/kg/hr to account for therapy downtime.

Schlondorff, D., Ross, M., & Al-Awqati, Q. (Eds.). (2012). KDIGO Clinical Practice Guideline for Acute Kidney Injury [Special issue]. Kidney International, 2(1).

Prescription Decision Points

- 5.8.1: The dose of RRT to be delivered should be prescribed before starting each session of RRT.(Not Graded). We recommend frequent assessment of the actual delivered dose in order to adjust the prescription. (1B)
- 5.8.2: Provide RRT to achieve the goals of electrolyte, acid-base, solute, and fluid balance that will meet the patient's needs. (Not Graded)

CRRT: System Components



Hemofilter

Solutions

CRRT

CRRT System

Anticoagulation
- Heparin
- Citrate
- None

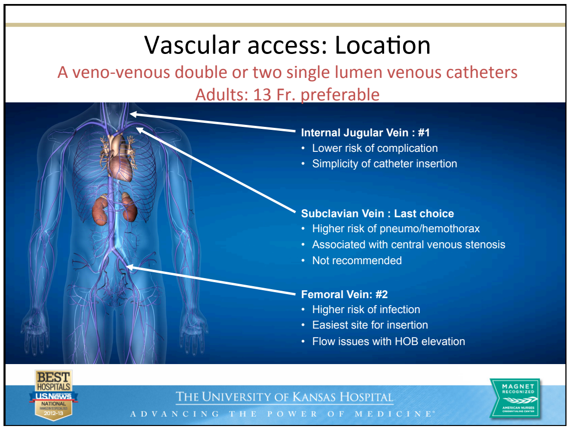
Vascular access

Blood Warmer

KDIGO Clinical Practice Guideline
Chapter 5.4 Vascular Access for RRT

- 5.4.1: Initiate RRT in patients with AKI via an uncuffed nontunneled dialysis catheter, rather than a tunneled catheter. (2D)
- 5.4.2 When choosing a vein for insertion of dialysis catheter in patients with AKI, consider these preferences:
  - 1st choice: right jugular vein
  - 2nd choice: femoral vein
  - 3rd choice: left jugular vein
  - Last choice: SC vein with preference for the nondominant side.

Schlondorff, D., Ross, M., & Al-Awqati, Q. (Eds.). (2012). KDIGO Clinical Practice Guideline for Acute Kidney Injury [Special issue]. Kidney International, 2(1).



Vascular access: Location

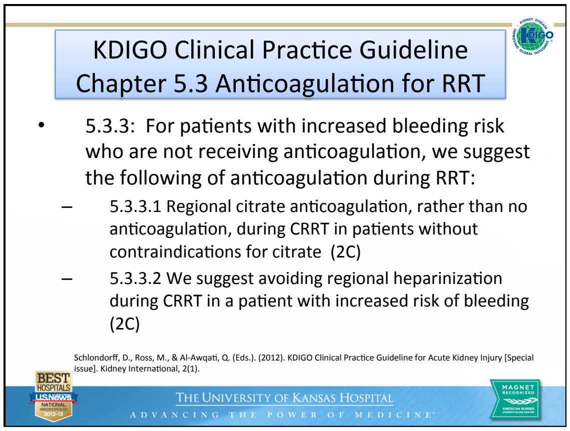
A veno-venous double or two single lumen venous catheters

Adults: 13 Fr. preferable

Internal Jugular Vein : #1
- Lower risk of complication
- Simplicity of catheter insertion

Subclavian Vein : Last choice
- Higher risk of pneumo/hemothorax
- Associated with central venous stenosis
- Not recommended

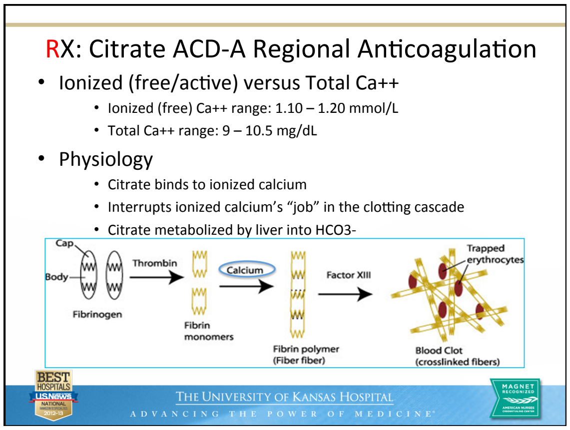
Femoral Vein: #2
- Higher risk of infection
- Easiest site for insertion
- Flow issues with HOB elevation



KDIGO Clinical Practice Guideline Chapter 5.3 Anticoagulation for RRT

- 5.3.3: For patients with increased bleeding risk who are not receiving anticoagulation, we suggest the following of anticoagulation during RRT:
  - 5.3.3.1 Regional citrate anticoagulation, rather than no anticoagulation, during CRRT in patients without contraindications for citrate (2C)
  - 5.3.3.2 We suggest avoiding regional heparinization during CRRT in a patient with increased risk of bleeding (2C)

Schlondorff, D., Ross, M., & Al-Awqati, Q. (Eds.). (2012). KDIGO Clinical Practice Guideline for Acute Kidney Injury [Special issue]. Kidney International, 2(1).

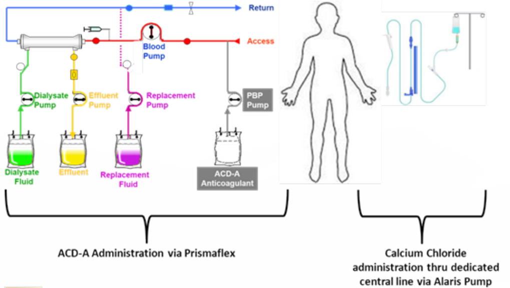


RX: Citrate ACD-A Regional Anticoagulation

- Ionized (free/active) versus Total Ca++
  - Ionized (free) Ca++ range: 1.10 – 1.20 mmol/L
  - Total Ca++ range: 9 – 10.5 mg/dL
- Physiology
  - Citrate binds to ionized calcium
  - Interrupts ionized calcium's "job" in the clotting cascade
  - Citrate metabolized by liver into HCO3-

RX: Anticoagulation

Citrate ACD-A: Equipment/Set-Up



RX: Anticoagulation Citrate ACD-A: Patient Monitoring

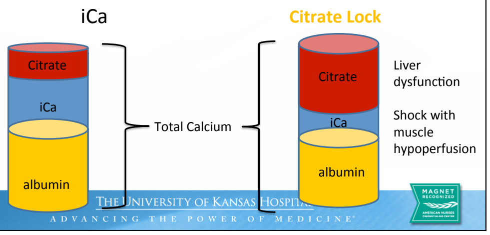
- *Systemic (Patient)* Ionized Calcium
  - Guides titration of **CaCl infusion into patient**
  - First sample prior to citrate therapy
  - Draw sample via vein or line that does not have calcium infusing through *any* of the ports
  - Titrate per *citrate* table
- *Post-Filter* Ionized Calcium
  - Guide titration of **CITRATE infusion into Prismaflex**
  - Draw from **blue**, post-filter port
  - Label sample **"post-filter"!**
  - Titrate per *calcium* table

RX: Citrate Anticoagulation

- Replacement/dialysate solutions must be **calcium-free**
- Stop CaCl infusion **immediately** when citrate or blood pump stops
- Benefits
  - Regional anticoagulation
  - Reduced risk of bleeding
  - Increase filter life
- Risks
  - Hypocalcemia or Hypercalcemia
  - Metabolic Alkalosis
  - Citrate Lock

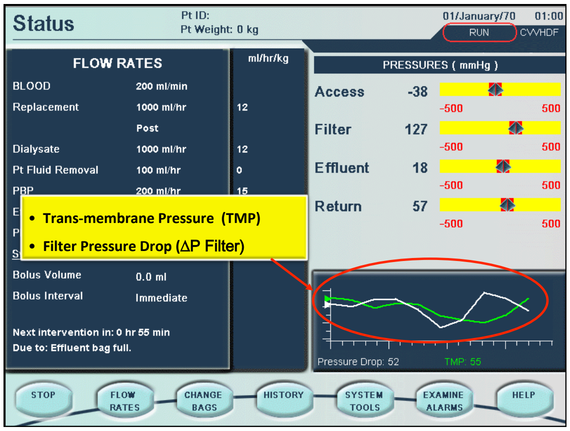
Citrate Toxicity
aka Citrate Lock

- Decreasing ionized Ca (iCa)
- Increasing total Ca.
- Ratio of $\frac{\text{total Ca}}{\text{iCa}} > 2.1$



Liver dysfunction

Shock with muscle hypoperfusion



Status

Pt ID:
Pt Weight: 0 kg

01/January/70 01:00
RUN CVVHDF

FLOW RATES		ml/hr/kg
BLOOD	200 ml/min	
Replacement	1000 ml/hr	12
	Post	
Dialysate	1000 ml/hr	12
Pt Fluid Removal	100 ml/hr	0
PBP	200 ml/hr	15
Bolus Volume	0.0 ml	
Bolus Interval	Immediate	

Next intervention in: 0 hr 55 min
Due to: Effluent bag full.

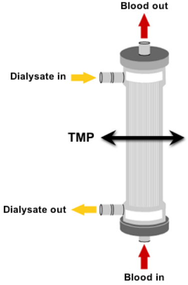
- **Trans-membrane Pressure (TMP)**
- **Filter Pressure Drop (ΔP Filter)**

PRESSURES (mmHg)			
Access	-38	-500	500
Filter	127	-500	500
Effluent	18	-500	500
Return	57	-500	500

Pressure Drop: 52 TMP: 55

Filter Viability
Trans-Membrane Pressure (TMP)

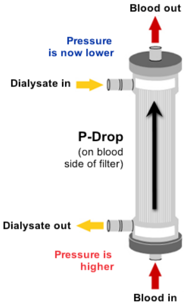
- Reflects pressure difference between fluid and blood compartments of filter
- Calculated and automatically reported:
  - Entering Run mode – when blood flow is stabilized
  - When rate changes are made:
    - Blood flow rate
    - Patient fluid removal rate
    - Replacement solution rate
  - ↑ TMP with ↓ membrane permeability
- **Rising TMP indicates filter is clogging/ plugging due to adsorption**



Filter Viability
Filter Pressure Drop (ΔP Filter)

- Change of pressure from blood entering filter and leaving filter
- Determines pressure conditions inside hollow fibers
- Calculated and automatically recorded:
  - Entering Run mode
  - Blood flow rate is changed

- **Rising Filter Pressure Drop (and TMP) indicates filter is clotting**



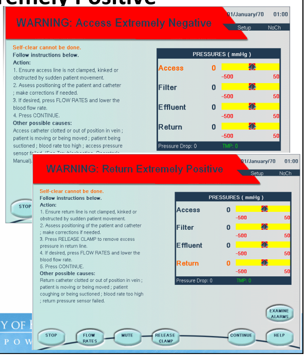
Access and Return Pressures

Is it the vascular access?

Access Pressure Extremely Negative
Return Extremely Positive

Due to vascular access/ catheter

- Sitting against vessel wall
- Fibrin coating on outside of catheter lumens
- Clots on inside of catheter lumens
- Poor flow → reverse lumens
- Size is too small (Adults require 11 Fr or larger)
- Position of patient, internal kinking
- Clamped/kinked line



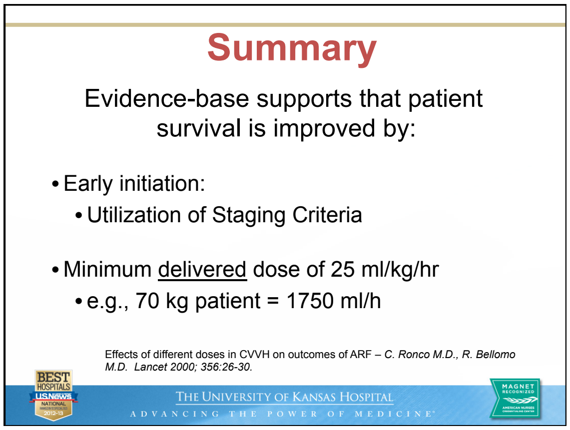
WARNING: Access Extremely Negative

Self-clear cannot be done.
Follow instructions below.
Action:
1. Ensure access line is not clamped, kinked or obstructed by sudden patient movement.
2. Assess positioning of the patient and catheter ; make corrections if needed.
3. If desired, press FLOW RATES and lower the blood flow rate.
4. Press CONTINUE.
Other possible causes:
Access catheter clotted or out of position in vein ; patient is moving or being moved ; patient being suctioned ; blood rate too high ; access pressure sensor f

Manual).

WARNING: Return Extremely Positive

Self-clear cannot be done.
Follow instructions below.
Action:
1. Ensure return line is not clamped, kinked or obstructed by sudden patient movement.
2. Assess positioning of the patient and catheter ; make corrections if needed.
3. Press RELEASE CLAMP to remove excess pressure in return line.
4. If desired, press FLOW RATES and lower the blood flow rate.
5. Press CONTINUE.
Other possible causes:
Return catheter clotted or out of position in vein ; patient is moving or being moved ; patient coughing or being suctioned ; blood rate too high ; return pressure sensor failed.



Summary

Evidence-base supports that patient survival is improved by:

- Early initiation:
  - Utilization of Staging Criteria
- Minimum delivered dose of 25 ml/kg/hr
  - e.g., 70 kg patient = 1750 ml/h

Effects of different doses in CVVH on outcomes of ARF – *C. Ronco M.D., R. Bellomo M.D. Lancet 2000; 356:26-30.*

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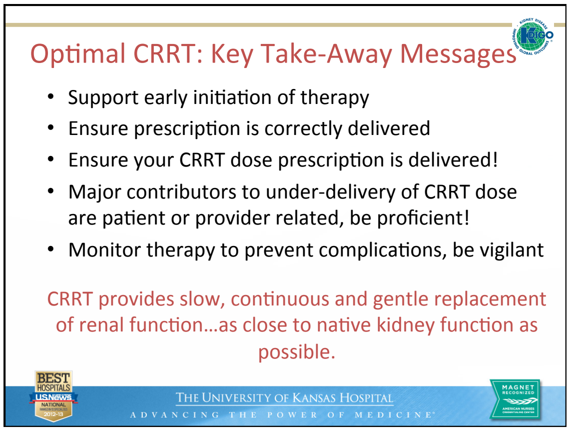

Optimal CRRT: Key Take-Away Messages

- Support early initiation of therapy
- Ensure prescription is correctly delivered
- Ensure your CRRT dose prescription is delivered!
- Major contributors to under-delivery of CRRT dose are patient or provider related, be proficient!
- Monitor therapy to prevent complications, be vigilant

CRRT provides slow, continuous and gentle replacement of renal function…as close to native kidney function as possible.

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