# Continuous Renal Replacement Therapy (CRRT)

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**Citation**

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**Abstract**

CRRT is a mode of renal replacement therapy for hemodynamically unstable, fluid overloaded patients and patients with sepsis and septic shock inmanagement of acute renal failure especially in the intensive careunit setting. The popularity of 'slow continuous therapies' for the treatment ofcritically ill patients with renal failure is increasing. The techniques which are most commonly used are slow continuous hemodialysis and hemodiafiltration. Slow continuous hemofiltration and slow continuous ultrafiltration also are commonly used.Management in initial hours to counter the derangementsin critically ill patients is the most vital thing in the therapy. CRRT initiated for ARF in critically ill patients should serve as a renal 'replacement' therapy mimicking as artificial kidney support. It should enhance recovery of the native kidneys with prevention of hyperkalemia, hyper/hyponatremia, acidosis/alkalosis and rapid correction of pulmonary/peripheral edema by gradual and consistent removal of extra fluid retained in the body.

## INTRODUCTION

Intermittent dialysis treatments are treatments that are provided for brief intervals, usually every day or every 2-3 days as required (e.g. intermittent hemodialysis or peritoneal dialysis). Continuous Renal Replacement Therapies (CRRT) are dialysis treatments that are provided as a continuous 24 hour per day therapy.

Both intermittent hemodialysis and continuous hemodialysis circuits utilize the same principles. Blood is removed from the patient, pumped through a dialysis filter and returned to the patient following removal of surplus water and wastes. The filter performs many of the functions of the kidney's nephron unit, hence, it is referred to as an "artificial kidney".

The major difference between intermittent and continuous therapies is the speed at which water and wastes are removed. Intermittent hemodialysis removes large amounts of water and wastes in a short period of time (usually over 2-4 hours), whereas, continuous renal replacement therapies remove water and wastes at a slow and steady rate. While intermittent dialysis allows chronic renal failure patients to limit the amount of time that they are connected to a machine, the rapid removal of water and wastes during intermittent treatments may be poorly tolerated by hemodynamically unstable patients.

So CRRT is a mode of renal replacement therapy for hemodynamically unstable, fluid overloaded, catabolic septic patients and finds its application in management of acute renal failure especially in the critical care /intensive care unit setting. The popularity of 'slow continuous therapies' for the treatment of critically ill patients with renal failure is increasing. The techniques most commonly used are slow continuous hemodialysis and hemodiafiltration. Slow continuous hemofiltration and slow continuous ultrafiltration also are commonly used.

## ADVANTAGES OF CRRT

1. CRRT by its lower rate of fluid removal can lead to steady state fluid equilibrium in hemodynamically unstable, critically ill patients with associated comorbid conditions eg. M.I, ARDS, septicemia, bleeding disorders.

2. It provides excellent control of azotemia, electrolytes and acid base balance. These patients are catabolic thus, removal of urea is mandatory to effectively control azotemia.

3. It is efficacious in removing fluid in special circumstances – post surgery pulmonary edema; ARDS etc.

4. CRRT can help in administration of parenteral nutrition and obligatory I.V medications like pressors & inotropes by creating an unlimited space by virtue of Continuous ultrafiltration.

5. Hemofiltration modality is effective in lowering intracranial tension v/s routine intermittent hemodialysis

which can sometimes raise intracranial tension.

6. Proinflammtory mediators of inflammation are also shown to have been removed by this modality eg.IL-1, IL-6, IL-8, TNF-a.

## DISADVANTAGES

This mode of therapy requires regular monitoring of hemodynamic status and fluid balance (ultrafiltration rate, replacement fluid); regular infusion of dialysate; continuous anticoagulation; ongoing alarms and an expensive mode of therapy above all.

## COMPLICATIONS

A.Technical-1.vascular access malformation 2.Air embolism 3.circuit blood

clotting and decreased blood flow 4.Fluid and electrolyte imbalance.

B.Clinical-1.Bleeding 2.Thrombosis 3.Infection/sepsis 4.Bioincompatibility of

membranes 5.Hypothermia 6.Nutrient losses.

INDICATIONS OF CRRT

a. RENAL CAUSES

1. ARF with cardiovascular instability

2. ARF with septicemia

3. ARF with septicemia and ARDS.

4. ARF with cerebral edema

b. NONRENAL CAUSES

1. Systemic inflammatory response syndrome

2. Crush syndrome

3. Lactic acidosis

4. C.H.F

## ACCESS

Historically, early circuits removed blood from arterial access sites and returned the purified blood via a venous catheter. This promoted blood flow through the filter by utilizing the patients own arterial to venous blood pressure gradient.

Advantage:

No pump is required. The mean arterial pressure drives the blood into the filter

/dialyzer.

Risks

1. Atheroembolism

2. Ischemia of the limb

3. Hematoma formation

4. Hemorrhage

5. Arterial wall injury

6. Spasm of the artery cannulated

Although arterial-to-venous access sites are still used in patients with end-stage renal failure, arterial-to-venous pressure gradients are no longer needed. Modern continuous and intermittent hemodialysis circuits utilize blood pumps to remove blood from the access site, allowing venous-to-venous catheters to be used.

An example of an arterial-to-venous access site is a fistula.

In critical care, temporary double-lumen venous dialysis catheters are the most common form of access. They can be inserted quickly at the bedside and used immediately. This method gives rapid and constant blood flow rate; improved dialyzer performance and decreased line and dialyzer clotting. CVVH with its ease of cannulating a central vein and use of a pump in the circuit is used more frequently as a CRRT procedure in the ICU setting with greater removal of urea, metabolic wastes and surplus fluid by adjusting the pump speed.

Disadvantages:

Air embolism; hemorrhage due to inadvertent disconnection; longer blood lines used in extra corporeal circuit which are more liable to clot; central vein thrombosis and stenosis risk; and addition of gadgets in the circuit like, air bubble trap, alarms etc.

Dialysis catheters are easy to differentiate from regular intravenous lines by their red and blue hubs. The red lumen denotes the side of the venous catheter that is used to pull blood from the patient, and is referred to as the access lumen. The blue lumen is the return site and is used to reinfuse the patient's blood after it passes through the

dialysis filter. If an adequate flow rate cannot be achieved by removing blood from the access side of a catheter, the catheter limbs can be reversed. Reversal of the limbs does produce a small reduction in clearance due to recirculation.

## CAUTIONARY NOTE

A double-lumen venous dialysis catheter can be used as a central venous infusion site during an emergency, however, to ensure the line remains patent for subsequent dialysis treatments, and to reduce the risk for infection, it is preferrable that these catheters used for dialysis only. If it is the only vascular access available in a life-threatening emergency, it can be used as a central line, HOWEVER, always assume that the catheter contains heparin. When a double lumen catheter is not in use for dialysis, some form of anticoagulant is always instilled into each lumen to maintain patency. If heparin is used, the concentration may be as high as 5,000 - 10,000 units per mL. Because each lumen contains a volume of ~1 to 2 ml, the two lumens could contain up to 40,000 units of heparin! ALWAYS assume that each lumen contains full strength heparin (even if it is labeled as containing saline). Always withdraw at least 5 ml of blood from EACH lumen prior to using the catheter as an intravenous line.

In CCTC, 4% Citrate is used to block all dialysis catheters. Citrate binds to calcium to prevent clotting and does not affect the aPTT, therefore, it is useful when anticoagulation is contraindicated. Citrate is the standard for blocking all CRRT catheters in CCTC, even when heparin has been used to maintain filter patency.

Although citrate 4% is the usual catheter blocking agent, heparin may still be used at the end of intermittent treatments or when lines are blocked by nephrology residents after insertion. It is always safest to assume that heparin could be present in all dialysis catheters between treatments.

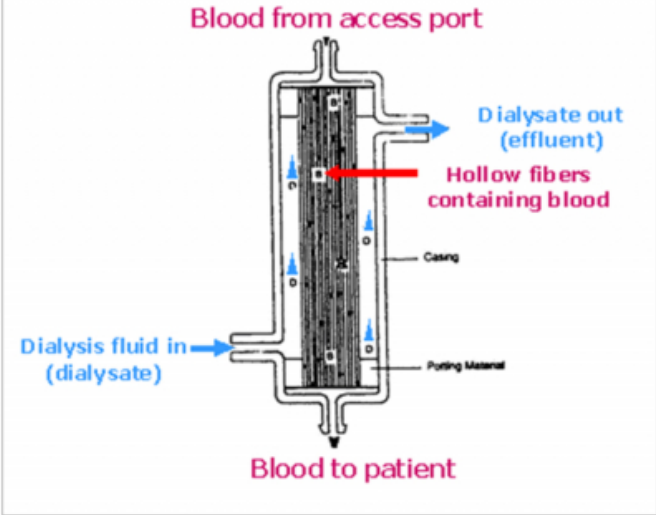
## PRINCIPLES

Hemodialysis employs the principles of diffusion, hemofiltration and convection, using an external filter to create an artificial nephron unit.

## ARTIFICIAL KIDNEYS

The dialysis filter is referred to as an artificial kidney. Blood is pulled from the patient and carried into the filter. Once inside, the blood travels through many tiny tubules called hollow fibers. Water and solutes can pass across the semi-permeable membrane between the blood and the fluid that surrounds the hollow fibers. Any fluid or solutes that enters the filter canister will be drained out as waste.

**Figure 2**




Schematic of dialysis filter (artificial kidney)

(dialysis filter has structural similarities to the nephron unit. Blood arrives at the filter via the access tubing (afferent arteriole). Blood enters the small hollow fibers within the filter (glomerulus). Water and solutes diffuse across the semi-permeable membrane of the hollow fibers and collect in the canister (Bowman's Capsule). Collected fluid (filtrate or effluent) is then removed via the drainage tubing (collecting tubule). Blood that remains in the hollow fibers is returned to the patient via the return side of the filter (efferent arterial).

**Figure 3**

$$K = \frac{Q(blood)in \times C(blood)in - Q(blood)out \times C(blood)out}{C(blood)in} \quad (ml/min)$$

This can be simplified to:

$$K = \frac{Q(blood)in \times (C(blood)in - C(blood)out)}{C(blood)in} \quad (ml/min)$$

Although similarities exist between the nephron unit and the artificial kidney, the artificial kidney has limited capabilities. In the nephron unit, filtered water and waste enters the proximal tubule. Because the nephron unit removes

significantly more water and solutes than needed, most of the water and electrolytes that enter the tubule system are reabsorbed.

Unlike the nephron unit, the artificial kidney cannot reabsorb water or solutes that enter the filter canister Any filtrate that enters the filter canister will be removed via the drainage tubule. Consequently, one of the differences in the artificial kidney is the absence of the proximal tubule, loop of henle and distal tubule where water and solute reabsorption and secretion occurs. Thus, the drainage tubule that exits the filter is similar to the collecting tubule of the nephron unit, not the proximal tubule. To compensate for the inability to reabsorb water and solutes following removal from the blood, the artificial kidney is manipulated to restrict the actual removal to only surplus water and wastes. This is done by adjusting dialysis solutions and ultrafiltration rates. If more water or solutes are removed than desired, they may need to be given back via intravenous infusions.

The artificial kidney does not replace other important kidney functions, including stimulation of red blood cell production (erythropoietin), blood pressure and sodium regulation (renin) and calcium uptake by the GI tract (vitamin D synthesis). The nephron normally traps and recycles bicarbonate to maintain acid base balance. Bicarb is given to patients during hemodialysis to compensate for bicarb deficits.

The principles used during hemodialysis are reviewed below:

## DIFFUSION

Diffusion is the movement of particles (solutes) across a semi-permeable membrane. Diffusion is the movement from the side with the highest concentration of particles, to the side with the lowest concentration.

## DIALYSIS FLUID (DIALYSATE):

Dialysate is the fluid that is pumped into the filter canister, surrounding the hollow fibers. The concentration of solutes in the dialysis fluid determines diffusion gradients. The removal of surplus solutes from the blood is achieved by infusing dialysate fluid that contains a lower solute concentration than the serum concentration (e.g. dialysate does not contain urea or creatinine).

Usually the dialysate does not come in contact with blood except during high flux dialysis where dialysate can backleak into the blood compartment leading to permeation of bacterial endotoxins.

Glucose rich solutions can lead to hyperglycemia. Lactate is commonly used as buffer. In conditions where inadequate lactate metabolism takes place (eg. in liver failure) the bicarbonate based dialysate is preferred.

A. Dialysate A solution-contains 4.5 litres of electrolyte solution with calcium, magnesium lactic acid which increases carbondioxide which prevents precipitation of calcium and magnesium.

B. Dialysate B solution contains 8.4% bicarbonate.

To maintain normal serum electrolyte levels, dialysate fluid contains sodium, chloride and magnesium levels that are equal to serum concentrations (thus, removal of these electrolytes should only occur if the blood level exceeds normal serum concentrations). In renal failure, potassium is often high at the start of a treatment, therefore, we may begin dialysis with a low concentration of potassium in the dialysate. Because potassium is easily removed during dialysis, and continued dialysis will be required to ensure removal of other wastes such as urea and creatinine, potassium concentrations in the dialysate often require upward adjustment as the potassium level in the blood falls. Although in theory, potassium levels should not fall below 4 mmol/L in the serum if the dialysate contains 4 mmol/L, a number of factors influence serum potassium levels in critical care. Insulin therapy and the use of sympathomimetic drugs promotes the movement of potassium from the blood into the cells. This can lower serum levels. Additionally, potassium loss through the GI tract can increase the potential for hypokalemia. Low magnesium levels will also suppress the serum potassium levels, therefore, magnesium deficits should be replaced as needed. Additionally, high hemofiltration rates can lead to additional potassium clearance. Potassium levels must be monitored closely and adjusted to maintain normal serum concentrations.

In renal failure, serum bicarbonate levels are generally low, therefore, a source of bicarbonate is added to the dialysate to facilitate diffusion of bicarbonate into the blood. Lactate based formulas provide one source (e.g., Gambro's LG formulas). Higher concentrations of lactate in the dialysate promote diffusion into the blood. If hepatic function is normal, lactate is quickly converted to bicarbonate in the liver. Prisma(TM) and Prismaflex(TM) both use premixed bags of sterile dialysate. Lactate based preparations have a long stability, making them less expensive to prepare.

Because bicarbonate is only stable for a short period in solution, it must be added to the dialysis bags before using.

If 1 L of dialysate is administered per hour, one L of dialysate fluid will collect in the drainage collection bag per hour. This will be in addition to any fluid removed; dialysate doesn't normally cross into the bloodstream.

Concentration gradients play a major role in diffusion. These will be explored further in the discussion on clearance. The other factor that influences diffusion is the type of filter used. Diffusion of solutes cannot occur across a concentration gradient if the pore size is too small to permit passage.

## ULTRAFILTRATION

Ultrafiltration is the movement of water across a semi-permeable membrane because of a pressure gradient (hydrostatic, osmotic or oncotic). The increased blood pressure in the glomerulus creates a favourable driving pressure to force water across the glomerular membrane.

Blood pressure within the hollow fibers is positive, while the pressure outside the hollow fibers is lower. Increased negativity can be generated outside the hollow fibers by the effluent pump by either increasing the fluid removal rate, or by increasing the replacement flow rate. The difference between the blood pressure in the hollow fibers and the surrounding pressure is the TransMembrane Pressure (TMP). The TMP determines the ultrafiltrate production.

Different filter membrane properties can produce different ultrafiltration rates at a constant TMP. A filter that is more permeable to water will allow more water to travel across the membrane at a given TMP. A filter with a high permeability to water is called a high flux membrane.

## HEMOFILTRATION

In hemodialysis circuits, pulling large volumes of water across the semi-permeable membrane creates a convective current that “drags” additional solutes. While diffusion is effective at removing most small molecules, convection enhances the removal of small and mid-sized molecules. Thus, convection can be added to hemodialysis therapy to enhance solute removal. To prevent hypovolemia, any water removed during hemofiltration must be returned to the blood before it reaches the patient. This is called “replacement” fluid. Hemofiltration rates of 1 L/hr mean that one liter of fluid is removed from the patient's blood and eliminated in the drainage fluid AND 1 L of replacement fluid is returned to the circuit before it reaches the patient. We set hemofiltration rates by adjusting replacement rates. Any fluid removed during hemofiltration is given back to maintain a net neutral fluid balance. Replacement fluid must be sterile intravenous fluids with concentrations of electrolytes similar to plasma.

For example, if the CRRT therapy includes a hemofiltration rate of 1 L per hour, and the fluid removal is set at 200 ml per hour, 1200 ml will be pulled from the patient and introduced into the drainage collection bag each hour. Because the 1 L of hemofiltration is replaced, the net fluid removed is 200 ml. Whether hemofiltration is used or not, the net fluid removed is equal to the fluid removal setting.

## PREDILUTION VERSUS POSTDILUTION HEMOFILTRATION

Replacement fluids can be returned either pre or post filter. This is referred to as predilution or post dilution sets. Predilution means that the replacement solution is returned to the blood before it reaches the filter, diluting the blood in the hollow fibers. Postdilution means that the replacement fluid is returned to the blood after the filter (but before the return side of the access catheter). Predilution dilutes the blood in the filter, reducing clotting. Postdilution concentrates the blood in the filter, enhancing clearance.

## CLEARANCE

Creatinine is a byproduct of muscle protein metabolism that is completely filtered by the glomerulus and 100% eliminated. None of the filtered creatinine is reabsorbed from the tubules nor is any additional creatinine secreted into the tubule lumen post glomerulus. This makes it the best indicator of renal failure. Because it is completely eliminated during normal renal function, measurement of creatinine clearance is the best measure of glomerular filtration.

Urea is another byproduct of protein metabolism, however, it is a byproduct of all protein metabolism (not just muscle protein metabolism). It is filtered into the glomerular filtrate. Unlike creatinine, a percentage of filtered urea is reabsorbed from the tubules. Consequently, urea levels can become increased in the presence of a normal creatinine level. For example, urea can increase due to increased urea production (e.g., anabolic or catabolic states) or increased tubule reabsorption of urea (e.g., due to dehydration). Creatinine only increases when renal filtration decreases, or the production of creatinine becomes so high that it exceeds glomerular filtration capabilities. Excessive creatinine

production can occur when significant muscle death has occurred, for example in rhabdomyolysis.

Clearance is the rate at which solutes are cleared from the body. Clearance is abbreviated by the letter K. The clearance (or K) of a solute is the volume of blood from which the substance is completely removed per unit time .It is calculated as follows:

K = excretion rate of solute / blood concentration of solute

To translate this to dialysis: if a dialyzer has the ability to clear 170 ml/min of urea at a blood flow rate of 200 ml/min, it means that for every 200 ml of blood that flows through the filter, 170 ml will be returned urea free. The remaining 30 ml will have the same concentration of urea as the blood entering the filter. The 200 ml of blood being returned each minute to the systemic circuit will have significantly less urea than without dialysis, but will still have to mix in with the systemic volume. Thus, blood must continually circulate through the filter before the total systemic level will begin to fall.

The following formula can be used to calculate the clearance of a solute in ml/min at the dialysis membrane. To calculate the rate of clearance of a solute, the following formula can be used, where Q(blood)in is the flow of blood into the filter, Q(blood)out is the flow of blood out of the filter, C(blood)in is the concentration of the solute in the prefilter serum and C(blood) is the concentration of the solute in the post filter blood. Q(blood)in and Q(blood)out are the same and equal to the blood flow rate.

{image:3}

## FILTERS

Dialysis membranes need to be efficient at clearing wastes, but must also be biocompatible with human blood. Compatibility means that exposure of blood to the dialysis membrane produces minimal of adverse effects.

Filter permeability is influenced by pore size, the number of pores and the thickness of the membrane. Generally, high flux membranes which have more or larger pores allow more solutes and ultrafitrate to move across the membrane. Thinner membranes offer less resistance to solute movement by decreasing the distance the solute must travel across the membrane and also favours increased filtration.

Solutes are pass through the membrane according to solute size. Imagine taking a flour sieve and filling it with a mixture of sand, small rocks and debris. Shaking up the contents would cause the smallest particles to move towards the bottom, passing through the openings easily. Particles would be filtered through according to increasing size until you are left with particles to large to fit through the sieve. Dialysis membranes act the same way, allowing small and mid sized molecules to pass across the membrane, without the loss of larger proteins. High flux membranes that have a larger pore size increase clearance by allowing larger molecules to pass through the membrane, and by allowing more ultrafiltrate flow. The standard AN69 filter used with CRRT is a high flux membrane. Sieving properties of a membrane describe the membrane's permeability to solutes during ultrafiltration. Permeability of solutes decrease as the the molecular size increases. The cut-off point for a membrane is defined by the molecular weight where only 10% of the solute is filtered.

The surface area of the membrane determines the available area for diffusion and ultrafiltration. The internal volume of the dialysis filter should be small enough to limit the amount of blood that is outside of the vascular compartment at any given time. This volume is important if the filter clots before blood can be returned to the patient.

Finally, adsorption is the ability of larger solutes to adhere to the surface of the dialysis membrane. AN69 filters used in CRRT have strong adsorptive properties. Adsorption of mid sized molecules including inflammatory mediators have been demonstrated by a drop in serum concentrations following initiation of a new filter. The greatest benefit appears to occur in the first few hours; once the filter becomes saturated with proteins, further removal from the serum is limited. While these proteins are too large to pass through the filter and be removed in the filtrate, the removes the cytokines from the blood by allowing the to collect (like a sponge) in the filter.

TMP is the pressure exerted on the dialysis membrane during operation and reflects the difference between blood and fluid compartments. A TMP above +350 mmHg will produe an advisory alarm. A TMP > 450 will produce a “TMP excessive” alarm. The amount of increase and the rate of TMP increase contribute to the “Filter is Clotting” alarm.

Filter Pressure drop is another indicator of clotting. It is an indication of the pressures in the hollow fibers of the filter. It will slowly rise with filter use as the hollow fibers become filled with microscopic clot. The amount and rate of increase determines the activation of the “filter is clotting alarm”.

## DIFFUSION

Small molecular weight solutes are easily removed by diffusion (dialysis). The higher the concentration gradient, the higher the diffusion rate. Solutes will move across a semipermeable membrane until the two solute concentrations become equal.

As solutes move into the dialysate fluid, the dialysate concentration of the solutes increase, reducing the diffusion gradient. Once the dialysate concentration of a solute becomes equal to the blood concentration, diffusion stops. To maintain a high diffusion gradient, the difference between the blood and dialysate concentrations must be maintained. Clearance can be increased by higher dialysate or blood flow rates. Increasing the dialysate rate maintains a low concentration of solutes on the dialysate side by increasing their removal from the dialysate fluid. Increasing the blood flow rate brings more solutes to the filter, promoting continuous diffusion. The smaller the molecule, the greater the clearance by dialysate/blood flow increases.

Although higher blood flow rates will increase the rate of clearance, CRRT circuits have limitations. The smaller filter size (compared to hemodialysis circuits) limits the blood flow rates. Blood flows can be increased substantially with hemodialysis, however, blood flow rate adjustments are limited with CRRT.

While increased dialysate flow rates enhance the clearance of small molecules, middle sized molecule clearance is more dependent upon the size of the filter pores. The only way to increase the clearance of middle sized molecules is to add convection (hemofiltration).

Optimal solute clearance is produced when dialysate flow rates are approximately double that of the blood flow rates. CRRT blood flow rates are typically 150 ml/min. A dialysate flow rate of 1 L per hour, provides a dialysate flow of 16 ml/min. Increasing the dialysate flow will have a greater effect than any increase in blood flow rates with CRRT.

Dialysate flows countercurrent, or in the opposite direction to blood flow. This promotes continual clearance by ensuring an adequate diffusion gradient is maintained. Dialysate fluid is introduced at the return end of the filter, where the serum concentration of solutes has begun to fall (due to removal from the blood within the filter). The dialysate fluid flows towards the access end of the filter where the fluid drainage tubing is located. Diffusion of solutes along the filter makes the concentration of wastes highest in the dialysate at the access end of the filter. At the access end, the blood concentration of the solute is highest , counterbalancing the rising dialysate concentration.

## HEMOFILTRATION

Dialysis effectively removes small (e.g. electrolytes) and small to mid size molecular weight solutes (e.g. glucose, urea, creatinine). The pore size limits the ability to diffuse middle sized molecules. One way to increase the clearance of all small and more of the mid sized molecules is to pull large quantities of water across the semi-permeable membrane, “dragging” additional solutes by convection.

Higher hemofiltration rates are of interest in critical care. Higher pre dilution rates may be a successful alternative to anticoagulant therapy, although, research is needed to examine this option. There is also interest in the potential clearance of mid sized molecular weight solutes including inflammatory mediators. In a European trial, hemofiltration rates of 35 ml/kg/hr were associated with the best survival rates. Although higher hemofiltration rates have been used in CCTC, our current practice uses predilution therapies. In this trial by Ronco, post dilution was used. The significance of high hemofiltration rates using predilution replacement is not known.

While increased ultrafiltration rates during hemofiltration help to remove molecules too large to travel by diffusion, hemofiltration can also lead to excessive removal of small molecules. Consequently, electrolyte removal can be increased beyond that produced by the diffusion gradient alone (e.g., despite a dialysate concentration of sodium that is equal to normal serum levels, sodium levels can fall with high hemofiltration rates).

Alternatively, high infusion rates of replacement fluids containing 0.9 NaCl can lead to hypernatremia. It can also increase chloride levels leading to hyperchloremic acidosis (chloride and bicarbonate are both negatively charged, increased chloride levels can cause a decrease in bicarbonate to maintain anionic balance).

When hemofiltration rates are high, careful monitoring is required to maintain normal electrolyte balance. Replacement fluids may need to be adjusted to keep serum levels within range. Alternatively, intermittent boluses of electrolytes may be required.

## THERAPIES

Original continuous hemodialysis circuits required arterial to venous access sites, because they did not utilize a blood pump to pull blood through the filter. Consequently, they were referred to as CAV (Continuous arterial-venous) circuits. Today's technology uses a blood flow pump, therefore, most continuous circuits are CVV (continuous venous-venous).

SCUF (Slow Continuous Ultrafiltration): SCUF is the removal of water from the patient's blood as it travels through the filter. Water removal is referred to as ultrafiltration. SCUF is a therapy designed to only remove surplus water. The amount of water removed is not sufficient to remove wastes.

CVVH (Continuous Venous-Venous Hemofiltration) CVVH is the removal of large amounts of water across the filter membrane for the purpose of clearing wastes. When large volumes of water are washed across the membrane, solutes are dragged along with the water (convection). Hemofiltration is the removal of water over and above the surplus water removed during ultrafiltration. To prevent hypovolemia, water removed during hemofiltration must be given back before the blood is returned to the patient. This is referred to as replacement. CVVH is the use of replacement fluid without dialysis fluid, plus or minus fluid removal.

CVVHD (Continuous Venous-Venous Hemodialysis): CVVHD is the infusion of dialysis fluid into the filter canister The dialysis fluid (dialysate) surrounds the blood filled filter segments. Solutes that are small enough to fit through the membrane of the dialysis filter will move from an area of high concentration to low concentration (diffusion). The dialysate determines the solutes that will be removed. If we want to remove solutes, the concentration in the dialysate is lower than the blood concentration. If we want to give something to the patient, the concentration in the dialysate is higher than the blood. CVVHD is the removal of wastes by diffusion only, without the use of hemofiltration (replacement fluid). It can be administered with or without fluid removal from the patient.

CVVHDF (Continuous Venous-Venous HemoDiaFiltration): CVVHDF is the use of dialysis AND hemofiltration. Therapy will include the use of both dialysate and replacement fluids and can be administered with or without fluid removal from the patient.

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