CONTINUOUS RENAL REPLACEMENT THERAPY

Version 02

Renal intensive care - Self learning module

Leading the way

GAMBRO®

Table of Contents

LEARNING OBJECTIVES

This module will allow the learner to acquire an understanding and knowledge of:

- The history of Continuous Renal Replacement Therapy (CRRT)
- The indications for Continuous Renal Replacement Therapy (CRRT)
- The concept of Continuous Renal Replacement Therapy (CRRT) and its target
- The difference between Continuous Renal Replacement Therapy (CRRT), Intermittent Hemodialysis (IHD) and Sustained Low Efficiency Dialysis (SLED)
- Continuous Renal Replacement Therapy (CRRT) modalities (SCUF, CVVH, CVVHD, and CVVHDF)
- The rationale for therapy selection and treatment-related principles
- Continuous Renal Replacement Therapy (CRRT) mechanisms of action related to clearances, types of molecules, flow rates (dialysis and replacement) and choice of therapy
- Membrane types and characteristics as well as membrane-related problems (coagulation, complement activation)
- Solution types and characteristics
- The role of anticoagulation during Continuous Renal Replacement Therapy
- Vascular access
- Pre-CRRT assessment (ANNA Guidelines and Standards for CRRT)
- Initiation of therapy, intratherapy monitoring and complications related to Continuous Renal Replacement Therapy (ANNA Guidelines and Standards)
- Termination of therapy, post-therapy patient assessment (ANNA Guidelines and Standards), evaluation of therapy

1. Introduction

Acute renal failure (ARF) patients requiring dialysis have traditionally been treated with acute intermittent hemodialysis in the intensive care unit (ICU). Over the past decade, the trend has shifted to the more widely accepted practice of slow continuous dialysis or Continuous Renal Replacement Therapy (CRRT) for treatment of acute renal failure, in particular for hemodynamically unstable ICU patients. For many intensive care patients, this therapy may not only be efficacious, but also safer and potentially more cost effective.

This module will provide the learner with knowledge and understanding of the concepts, principles and clinical applications related to Continuous Renal Replacement Therapy (CRRT) in an intensive care setting.

2. Continuous Renal Replacement Therapy (CRRT)

2.1 Definition

Continuous renal replacement therapy (CRRT) is also referred to as slow continuous dialysis. Treatments are performed by a critical care nurse over a 24-hour period, the duration of therapy varying from days to weeks depending on individual patient requirements. Continuous renal replacement therapy is used for the removal of fluid and/or clearance of solutes and waste products. It involves the removal of blood from a vein (or artery) usng a blood pump. In most cases, the blood is anticoagulated prior to being circulated through a semi-permeable membrane hemofilter, after which it is reinfused into the patient. This continuous therapy offers slow, gentle treatment of acute renal failure and is generally well tolerated in hemodynamically unstable critical care patients.

Continuous renal replacement therapy involves various treatment modalities; veno-venous therapies, which will be the focus of this module, are the most frequently used. Continuous renal replacement therapy (CRRT) requires a central double-lumen veno-venous hemodialysis catheter, an extracorporeal circuit and hemofilter, a blood pump and an effluent pump. In some therapies, dialysate and/or replacement pumps are also required.

The various CRRT treatment modalities are:

SCUF:	Slow continuous ultrafiltration
CAVH:	Continuous arterio-venous hemofiltration
CVVH:	Continuous veno-venous hemofiltration
CAVHD:	Continuous arterio-venous hemodialysis
CVVHD:	Continuous veno-venous hemodialysis
CVVHDF:	Continuous veno-venous hemodiafiltration

2.2 History of CRRT

The inception of Continuous Renal Replacement Therapy dates back to the 1950's. The following is a synopsis of the history of evolution of CRRT:

1950's: Inception of the CRRT concept
1960: CAVHD therapy proposed by Dr. Scribner in the context of treatment for acute renal failure
1977: CAVH therapy introduced by Dr. Kramer
1980: SCUF therapy introduced by Dr. Paganini
1987: CVVHD therapy introduced by Dr. Uldall
1990: Transition to veno-venous therapies from arterio-venous therapies. CRRT considered "state-of-art" therapy for treatment of acute renal failure.
1992: CVVH and CVVHD gain acceptance in clinical practice.
1994: First fully integrated CRRT system (PRISMA)*. Introduced by Hospal-Gambro.
1996: First International Conference on CRRT hosted in San Diego by Dr. R. Mehta.

(*Gambro, PRISMA Fluid Management Systems, 2002. ANNA, Core Curriculum for Nephrology, 3rd ed.)

2.3 Target population

The target population for continuous renal replacement therapy is hemodynamically unstable ICU patients with acute renal failure and/or severe fluid volume overload. However, it is important to note that continuous renal replacement therapy is not limited to the above target population as there are many other indications for it. Doctors Bellomo, Ronco, Meyers and Schetz, leaders in the field of CRRT, have published numerous articles on renal and non-renal indications for CRRT.

2.4 Indications for CRRT

Renal Indications

- Non-obstructive oliguria (u/o<400 ml/24h) or anuria
- Severe acidemia (pH<7.1) due to metabolic acidosis
- Azotemia (urea>30 mmol/l)
- Hyperkalemia
- Progressive severe dysnatremia
- Rhabdomyolysis (Crush Injuries)
- Hyperphosphatemia
- ARF in the context of MSOF

Potential Non-Renal Indications

- Significant organ edema (especially lung)
- Sepsis
- SIRS
- MSOF
- ARDS
- Fulminant hepatic failure
- Severe burns
- Cerebral edema
- Tumor lysis syndrome
- Coagulopathy requiring large amounts of blood products in patients at high risk of developing ARDS or pulmonary edema
- Cardiopulmonary bypass
- Suspected uremic organ involvement (pericarditis)
- CHF
- Lactic acidosis
- Drug overdose with a toxin removable by extracorporeal therapy

2.5 Comparison of CRRT, IHD and SLED

Continuous Renal Replacement Therapy (CRRT)

- Slow, continuous, adaptable fluid volume management and solute clearance (over a 24-hour period).
- Prevention of hypotensive episodes related to volume depletion
- Continuous control of uremia, electrolytes and pH
- Potential for optimization of nutritional support, including administration of parenteral nutrition (PN)
- Convective therapy option – wider range of clearance
- Better hemodynamic stability
- No water hookup required – only sterile solutions used
- Compact machine at bedside
- Closed, sterile extracoporeal circuit and hemofilter for greater ease of use, small EC circuit/hemofilter for reduced risk of clotting and subsequent blood loss
- Low extracorporeal circuit volume/high velocity blood flow
- On-screen instructions and on-screen help for alarms
- 24/7 phone support by clinical specialists in CRRT
- Management of therapy by critical care nurse

Intermittent Hemodialysis (IHD)

- Rapid fluid removal and solute clearance (3-4 hours)
- Acute, frequent hypotensive episodes often observed
- Uremic, electrolyte and pH control achieved only during IHD treatment
- Fluid, protein and diet restrictions required between dialysis sessions, making achievement of maximum nutritional support difficult
- Water hookup required
- Treatment based on diffusion, with little convection
- Risk of exposure to pyrogens, bacteria and water contaminants due to use of non-sterile dialysate and stagnant bicarbonate solution, contamination of fluid compartments, or chlorine exposure.
- Hemodialysis equipment required – more QA checks required
- Hemodialysis nurse required for therapy
- No on-screen instructions or on-screen help for alarms

Sustained Low-Efficiency Dialysis (SLED)

- Fluid removal and solute clearance slower than IHD but faster than CRRT. Usually performed over 8-12 hour period, six times a week. Also referred to as nocturnal dialysis. Patient free to undergo treatments and tests during daytime hours.
- Hypotensive episodes possible though less frequent than with IHD
- Better uremic, electrolyte, and pH control than with IHD; however control achieved only during treatment (8-12 hours)
- Fluid management only during treatment
- Maximization of nutritional support difficult
- Water hookup required
- Treatment based on diffusion, with little convection
- Dialysis equipment required – more QA checks required
- Risk of exposure to pyrogens, bacteria and water – see IHD above
- Large hemofilters/EC circuits increase risk of clotting and subsequent blood loss
- Hemodialysis nurse required for therapy
- No on-screen instructions or on-screen help for troubleshooting alarms

2.6 QUIZ

1. The advantages of continuous renal replacement therapy include:
   a) Better hemodynamic stability in treatment of acute renal failure in unstable critical care patients.
   b) Efficient, safe and easy to use therapy.
   c) Performed by critical care nurse and therefore potentially more cost effective.
   d) All of the above

2. The concept of CRRT originated in the 1950's.
   a) True
   b) False

3. CVVH and CVVHD first gained acceptance in clinical practice in:
   a) 1992
   b) 1987
   c) 1990
   d) 1994

4. Continuous renal replacement therapy is performed over a:
   a) 3-4 hour period
   b) 24 hour period
   c) 6-8 hour period
   d) 8-12 hour period

5. Continuous renal replacement therapy requires:
   a) A veno-venous central double lumen hemodialysis catheter
   b) An extracorporeal circuit and hemofilter
   c) A blood pump and effluent pump (and dialysate and replacement pump, depending on therapy chosen)
   d) All of the above

6. Indications for continuous renal replacement therapy include: severe burns, cerebral edema, ARDS, MSOF, CHF, lactic acidosis and fulminant hepatic failure.
   a) True
   b) False

7. Continuous control of uremia, electrolytes and pH as well as maximization of nutritional support can be achieved with which of the following therapy support?
    a) IHD
    b) SLED
    c) CRRT

8. Which therapy option does not require water hookup and hemodialysis nursing support?
    a) SLED
    b) CRRT
    c) IHD

9. Treatment is based on diffusion with little convection in the following therapy options:
    a) SLED
    b) CRRT
    c) IHD
    d) a and c

10. Hypotensive episodes have been observed during both IHD and SLED therapies.
    a) True
    b) False

11. SLED is most often performed overnight (nocturnal) to accommodate treatments and tests that the patient may require during the day.
    a) True
    b) False

12. The larger extracorporeal circuit and hemofilter required for IHD and SLED increase the risk of clotting and potential for blood loss.
    a) True
    b) False

2.7 ANSWERS to quiz

1. The advantages of continuous renal replacement therapy include:
   a) Better hemodynamic stability in treatment of acute renal failure in unstable critical care patients.
   b) Efficient, safe and easy to use therapy.
   c) Performed by critical care nurse and therefore potentially more cost effective.
   d) All of the above

   Continuous renal replacement therapy offers better hemodynamic stability, and is an efficient and safe therapy administered by critical care nurses.

2. The concept of CRRT originated in the 1950's.
   a) True
   b) False

   The concept of CRRT originated in the 1950's.

3. CVVH and CVVHD first gained acceptance in clinical practice in:
   a) 1992
   b) 1987
   c) 1990
   d) 1994

   CVVH and CVHD first gained acceptance in clinical practice in 1992.

4. Continuous renal replacement therapy is performed over a:
   a) 3-4 hour period
   b) 24 hour period
   c) 6-8 hour period
   d) 8-12 hour period

   CRRT is performed over a 24-hour period.

5. Continuous renal replacement therapy requires:
   a) A veno-venous central double lumen hemodialysis catheter.
   b) An extracorporeal circuit and hemofilter.
   c) A blood pump and effluent pump (and dialysate and replacement pump, depending on therapy chosen).
   d) All of the above.

   CRRT requires a veno-venous central double lumen hemodialysis catheter, an extracorporeal circuit /hemofilter, and blood and effluent pumps.

6. Indications for continuous renal replacement therapy include: severe burns, cerebral edema, ARDS, MSOF, CHF, lactic acidosis and fulminant hepatic failure.
   a) True
   b) False

   Indications for CRRT include: severe burns, cerebral edema, ARDS, MSOF, CHF, lactic acidosis and fulminant hepatic failure.

7. Continuous control of uremia, electrolytes and pH as well as maximization of nutritional support can be achieved with which of the following therapy support?
   a) IHD
   b) SLED
   c) CRRT

   Continuous control of uremia, electrolytes and pH as well as maximization of nutritional support can be achieved by CRRT.

8. Which therapy option does not require water hookup and hemodialysis nursing support?
   a) SLED
   b) CRRT
   c) IHD

   Water hook-up and hemodialysis nursing support is not required for CRRT.

9. Treatment is based on diffusion with little convection in the following therapy options:
   a) SLED
   b) CRRT
   c) IHD
   d) a and c

   SLED and IHD therapies are based on diffusion with little convection.

10. Hypotensive episodes have been observed during both IHD and SLED therapies.
    a) True
    b) False

    Hypotensive episodes have been observed with both SLED and IHD.

11. SLED is most often performed overnight (nocturnal) to accommodate treatments and tests that the patient may require during the day.
    a) True
    b) False

    SLED is most often performed as a nocturnal therapy.

12. The larger extracorporeal circuit and hemofilter required for IHD and SLED increase the risk of clotting and potential for blood loss.
    a) True
    b) False

    The larger extracoporeal circuit/hemofilter required for IHD and SLED increase the risk of clotting and subsequent blood loss.

3. CRRT Modalities

SCUF - Slow continuous ultrafiltration. Requires blood and effluent pumps. Pumps used to generate hydrostatic pressure. No dialysate or replacement solutions are required. In this mode, CRRT fluid removal rates up to 2 liters/hr can be achieved.

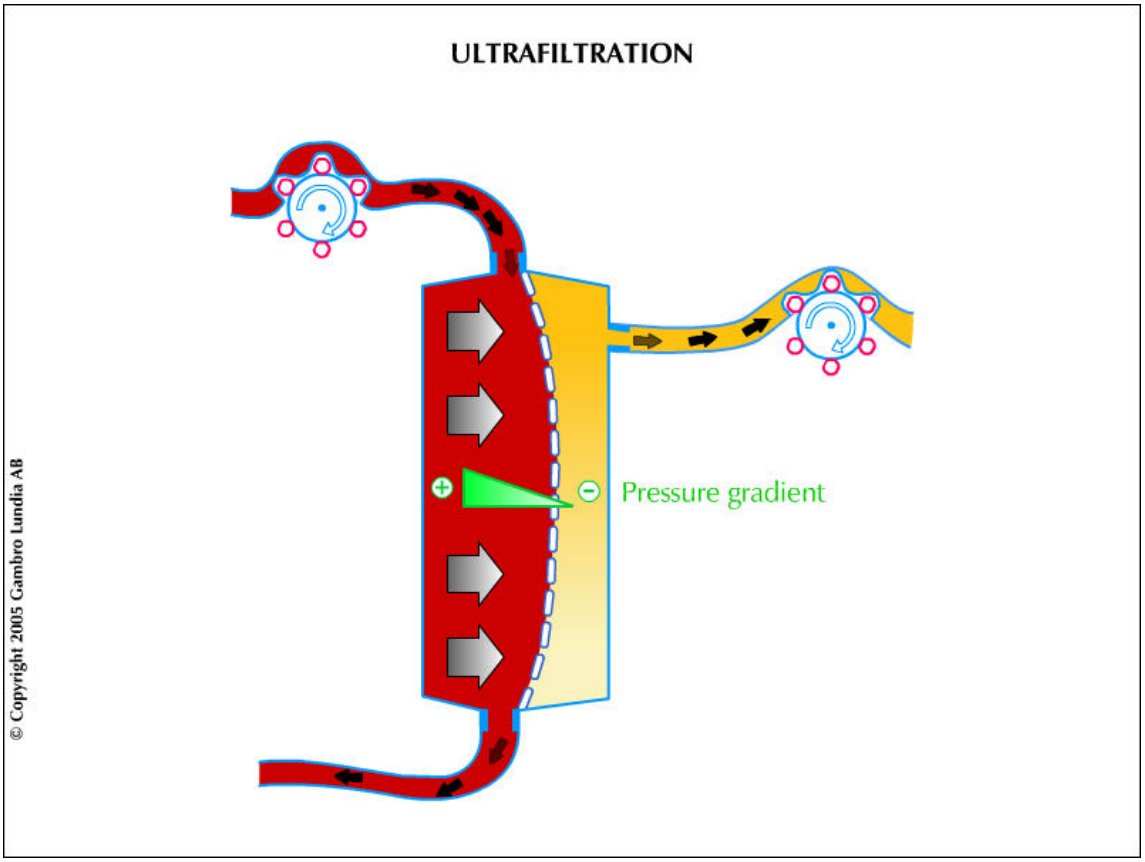
CVVH - Continuous veno-venous hemofiltration. Requires use of blood, effluent and replacement pumps. Dialysate solution is not required. Plasma water and solutes are removed by convection and ultrafiltration.

CVVHD - Continuous veno-venous hemodialysis. Requires the use of blood, effluent and dialysis pumps. Replacement solution is not required. Plasma water and solutes are removed by diffusion and ultrafiltration.

CVVHDF- Continuous veno-venous hemodiafiltration. Requires the use of blood, effluent, dialysate and replacement pumps. Both dialysate solution and replacement solution are used. Plasma water and solutes are removed by diffusion, convection and ultrafiltration.

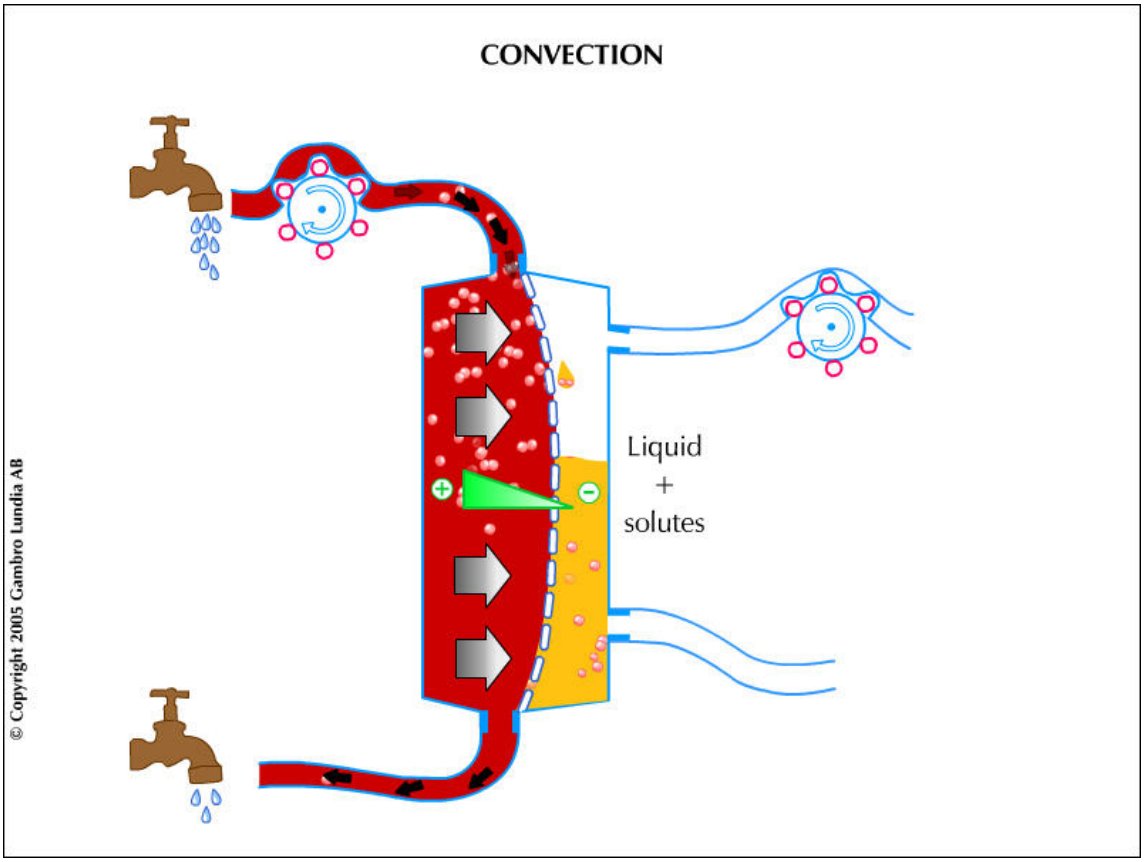
3.1 Principles of treatment and CRRT transport mechanisms

Ultrafiltration - The movement of fluid through a semi-permeable membrane driven by a pressure gradient (hydrostatic pressure). The effluent pump forces plasma water and solutes across the semi-permeable membrane in the filter. This transport mechanism is used in SCUF, CVVH, CVVHDF, and to a smaller extent in CVVHD.



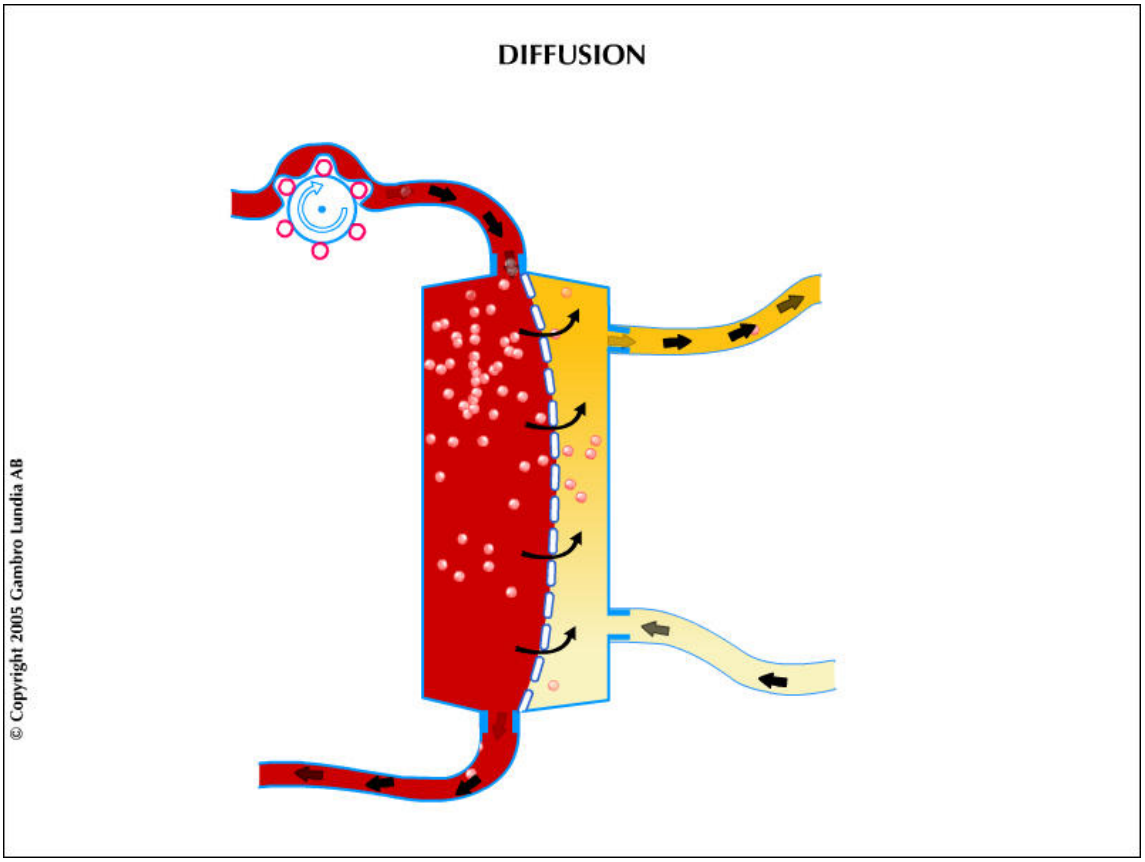
Ultrafiltration. The creation of a pressure gradient forces plasma water and solutes across the semi-permeable membrane.

Convection - The movement of solutes with fluid, often referred to as "solvent drag". Plasma water and certain solutes (depending on molecular weight and filter pore size) are forced across the semi-permeable membrane in the filter by ultrafiltration. Simultaneously, a replacement solution is infused into the blood using a replacement pump. The replacement solution replenishes some or all of the fluid removed as well as desirable solutes and ultrafiltration. As unwanted solutes are not replaced, their concentrations in the patient's blood decrease. Convection is the main transport mechanism used in CVVH and CVVHDF.



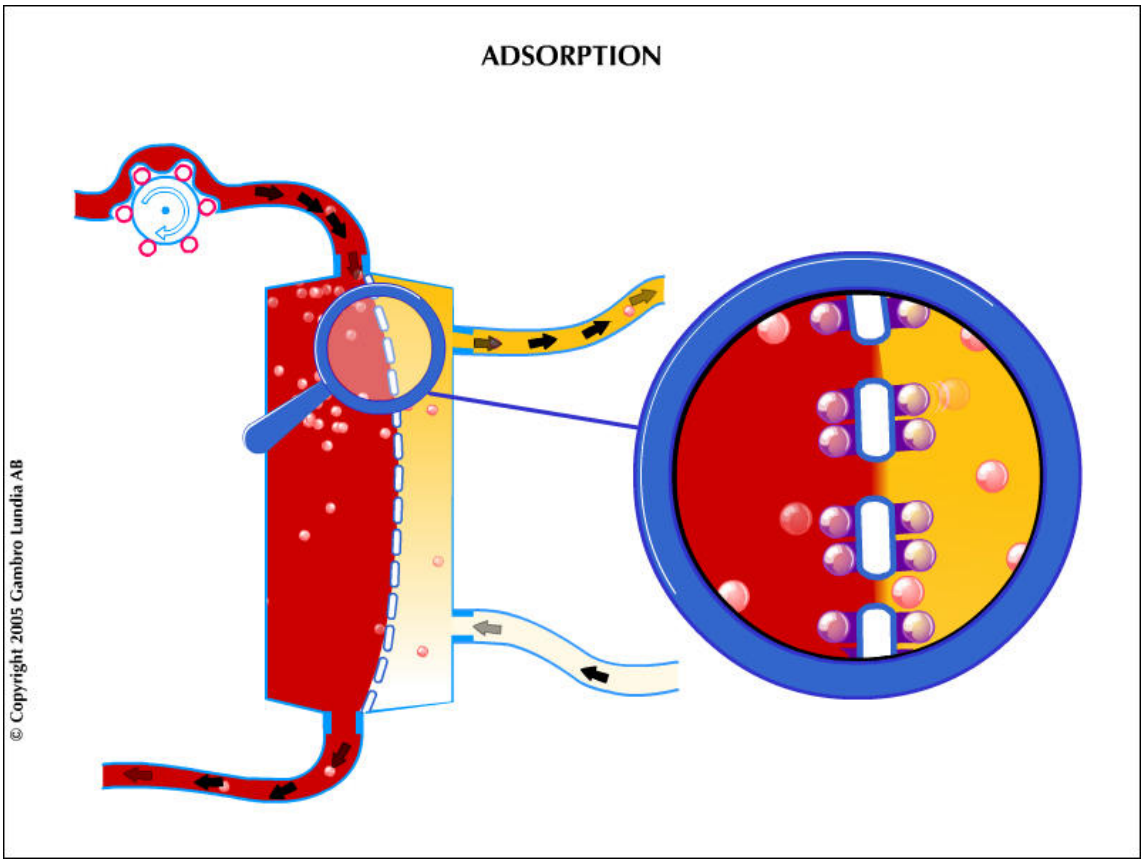
Convection. Solutes are forced with plasma water across the semi-permeable membrane by ultrafiltration. Simultaneously, a replacement solution is infused into the blood using replacement pumps.

Diffusion - The movement of solutes from a higher concentration to a lower concentration. Unwanted solutes from the patient's blood move across a semi-permeable membrane in the filter into the dialysate compartment of the filter membrane. The flow of dialysate is in opposite direction to the flow of blood and requires a dialysate pump. The concentration of unwanted solutes is higher in the patient's blood than in the dialysate, causing the solutes to diffuse across the semi-permeable membrane from higher to lower concentration. Diffusion will occur until solute equilibrium is achieved. This transport mechanism is used in CVVHD and CVVHDF.



Diffusion. Unwanted solutes, which are more concentrated in the patient's blood, diffuse across the semi-permeable membrane from higher concentration to lower concentration.

Adsorption - The molecular adherence to the surface or interior of semi-permeable membrane. With the AN69 filter membrane, molecules such as beta 2-microglobulin, TNF, which are inflammatory mediators, adhere to the membrane surface. Clearance of these inflammatory mediators is achieved through adsorption. This mechanism is used in SCUF, CVVH, CVVHD and CVHDF.



Adsorption. Some molecules, such as inflammatory mediators, adhere to the membrane surface. Clearance is also achieved in this way.

Terminology

The following terminology is frequently encountered in relation to CRRT.

Quf or UFR – ultrafiltration rate, in ml/min. The number of ml of fluid per minute transferred across the membrane for a given pressure gradient (in mmHg) across the membrane.
Qd or DFR – dialysate flow rate, in ml/hr
Qb or BFR – blood flow rate, in ml/min
Qr or RFR – replacement flow rate, in ml/hr
TMP – transmembrane pressure, in mmHg

3.2 QUIZ

1. In the case of CRRT in SCUF mode, fluid removal flow rates of up to 2 liters/hr can be achieved.
   a) True
   b) False

2. In CVVH, plasma water and solutes are removed by convection and ultrafiltration through the use of blood, effluent and replacement (solution) pumps.
   a) True
   b) False

3. The transport mechanisms used in CVVHD are diffusion and ultrafiltration.
   a) True
   b) False

4. The transport mechanisms used in CVVHDF to remove plasma water and solutes are convection, diffusion and ultrafiltration transport.
   a) True
   b) False

5. The movement of fluid through a semi-permeable membrane driven by a pressure gradient is called:
   a) Diffusion
   b) Convection
   c) Ultrafiltration
   d) Adsorption

6. The movement of solutes from a higher concentration to a lower concentration is called:
   a) Convection
   b) Diffusion
   c) Ultrafiltration

7. Convective transport is commonly referred to as "solvent drag".
   a) True
   b) False

3.3 ANSWERS to quiz

1. In the case of CRRT in SCUF mode, fluid removal flow rates of up to 2 liters/hr can be achieved.
   a) True
   b) False

   In SCUF mode, fluid removal flow rates of up to 2 liters/hr can be achieved.

2. In CVVH, plasma water and solutes are removed by convection and ultrafiltration through the use of blood, effluent and replacement (solution) pumps.
   a) True
   b) False

   CVVH uses blood, effluent and replacement pumps to remove plasma water and solutes by convection and ultrafiltration.

3. The transport mechanisms used in CVVHD are diffusion and ultrafiltration.
   a) True
   b) False

   Transport mechanisms used in CVVHD, effected through the use of blood, effluent and dialysate pumps, are diffusion and ultrafiltration.

4. The transport mechanisms used in CVVHDF to remove plasma water and solutes are convection, diffusion and ultrafiltration transport.
   a) True
   b) False

   CVVHDF removes plasma water and solutes by convection, diffusion and ultrafiltration.

5. The movement of fluid through a semi-permeable membrane driven by a pressure gradient is called:
   a) Diffusion
   b) Convection
   c) Ultrafiltration
   d) Adsorption

   The movement of fluid through a semi-permeable membrane driven by a pressure gradient is called ultrafiltration.

6. The movement of solutes from a higher concentration to a lower concentration is called:
   a) Convection
   b) Diffusion
   c) Ultrafiltration

   The movement of solutes from a higher concentration to a lower concentration is called diffusion.

7. Convective transport is commonly referred to as “solvent drag”.
   a) True
   b) False

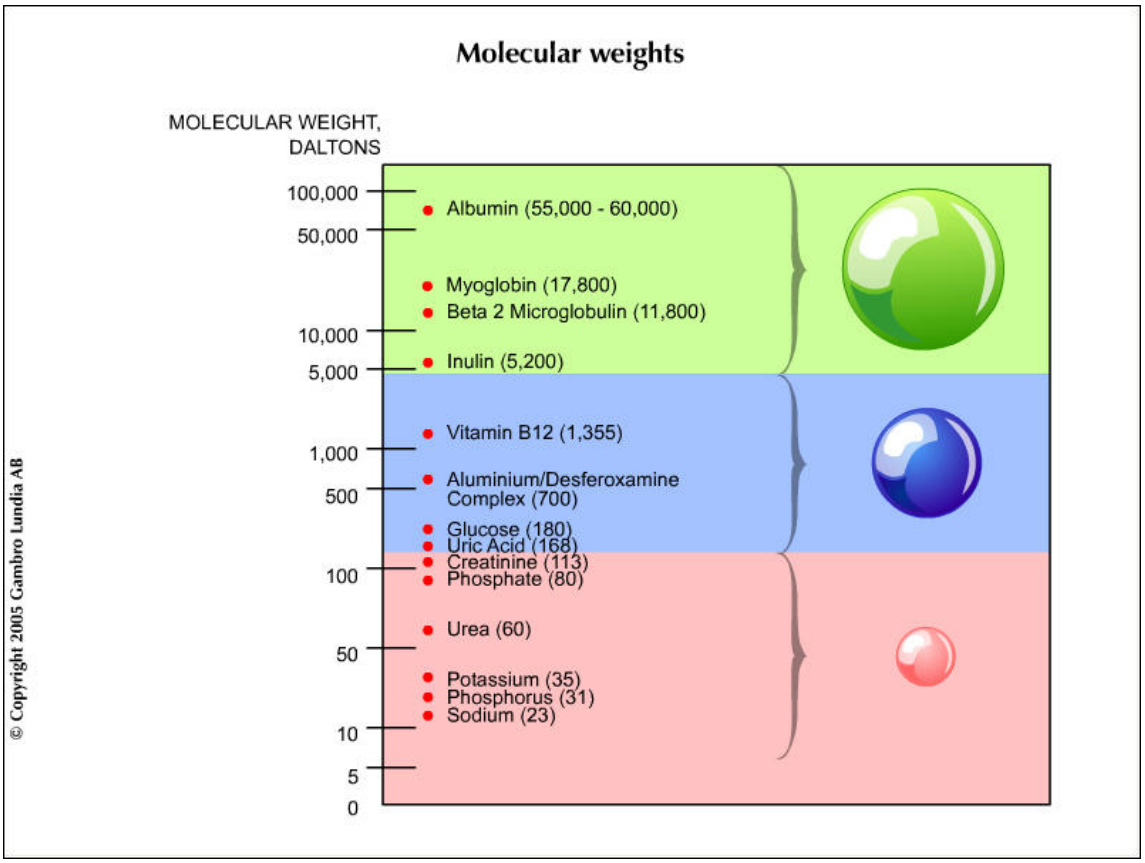
   Convective transport is commonly referred to as “solvent drag”.

4. CRRT Mechanisms of Action

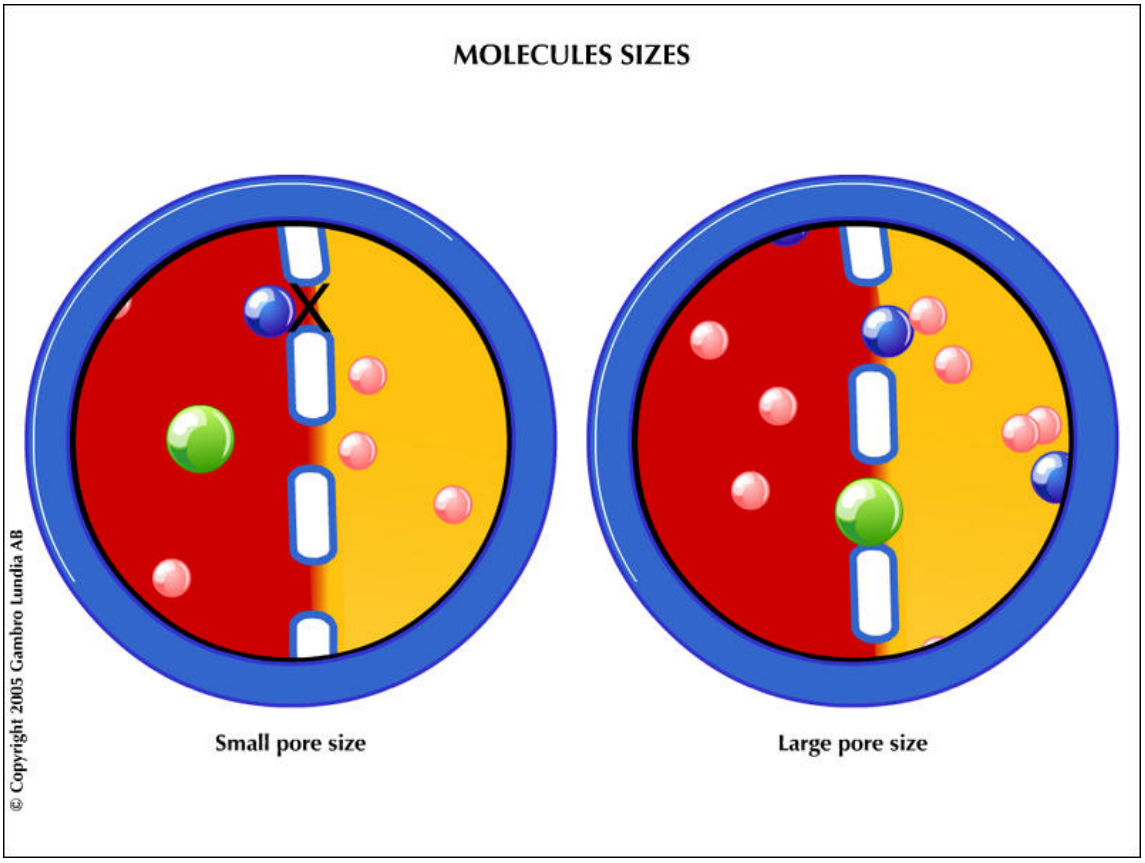
4.1 Principles of CRRT clearance

The effective clearance of solute during CRRT is a function of the size of the solute molecules and the pore size of the semi-permeable membrane. Since effluent rates are usually lower than blood flow rates in CRRT, clearances are said to be dependent on the former rather than the latter. For instance, in CVVH, the higher the ultrafiltration rate (UFR), the greater the effectiveness of solute clearance.

4.2 Molecular size and transport mechanism



Small molecules	< 300 daltons, e.g., urea, creatinine, Na+
Intermediate molecules	500 - 5,000 daltons, e.g., B12
Large molecules	5,000 - 50,000 daltons, e.g., LMW proteins - beta 2 microglobulins, cytokines, myoglobin



Molecular size. Both molecules and pores size determine the solute flow through the semi-permeable membrane. The largest pores allow the most filtration size.

Small molecules will easily go through the semi-permeable membrane, driven by diffusion and convection. Intermediate and large molecules are cleared primarily by convection. The semi-permeable membrane of the hemofilter allows for removal of solutes with a molecular weight up to 50,000 daltons. Plasma proteins or substances highly protein-bound will not be cleared - *e.g.*, albumin (approx. 65,000 daltons).

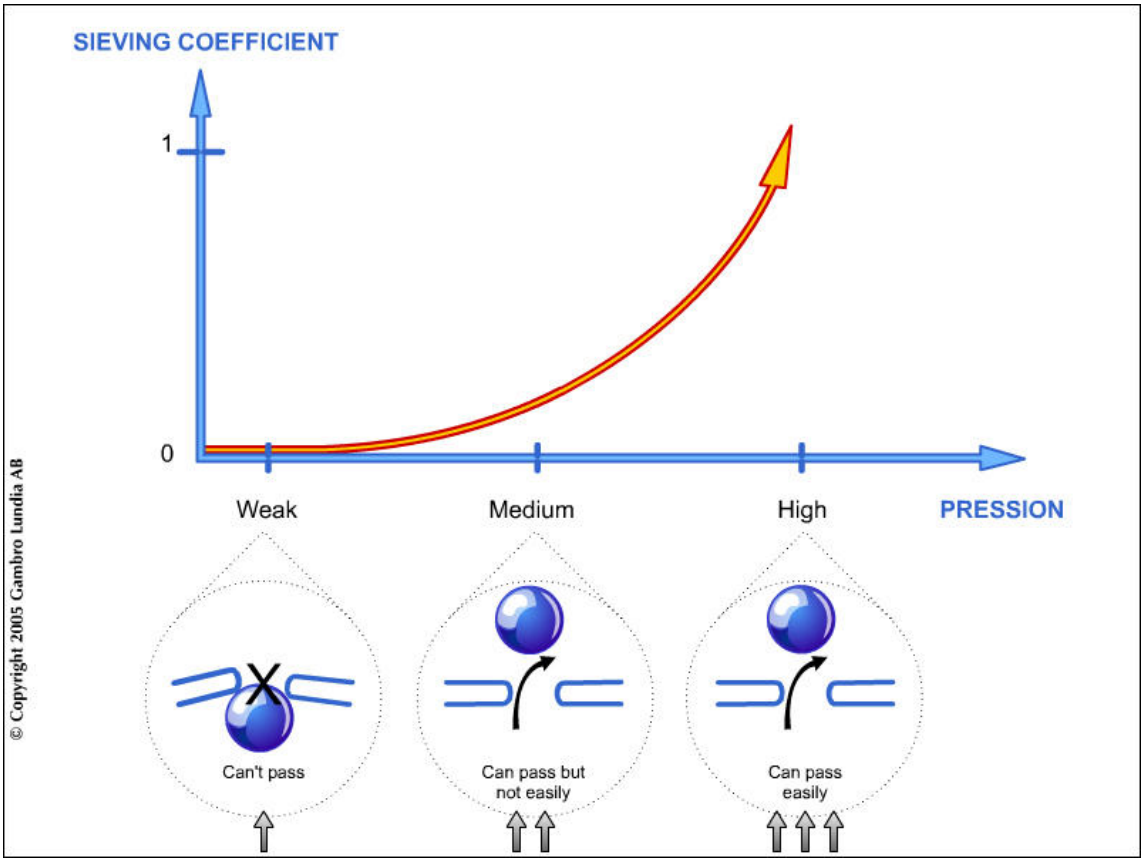
The AN69 hemofilter, whose effective surface area is 0.90 m^2 (Prisma M100 set), will allow passage of dissolved solutes with molecular weight of <50,000 daltons.

Sieving Coefficient - The ability of a substance to pass through a membrane from the blood compartment of the hemofilter to the ultrafiltration (UF) compartment. A sieving coefficient of 1 will allow free passage of a substance while a sieving coefficient of 0 will not allow the substance to pass. For example, chloride has a sieving coefficient of 0.94, Na+, of 1.0, K+, of 1.0, Cr, of 0.95, BUN, of 0.95, and albumin, of 0.

The sieving coefficient of a solute is calculated by dividing the ultrafiltrate solute concentration by the plasma solute concentration.

Solute loss can be calculated as follows:

Ultrafiltration rate (liters/hr) X blood solute concentration X sieving coefficient = solute loss/hr.

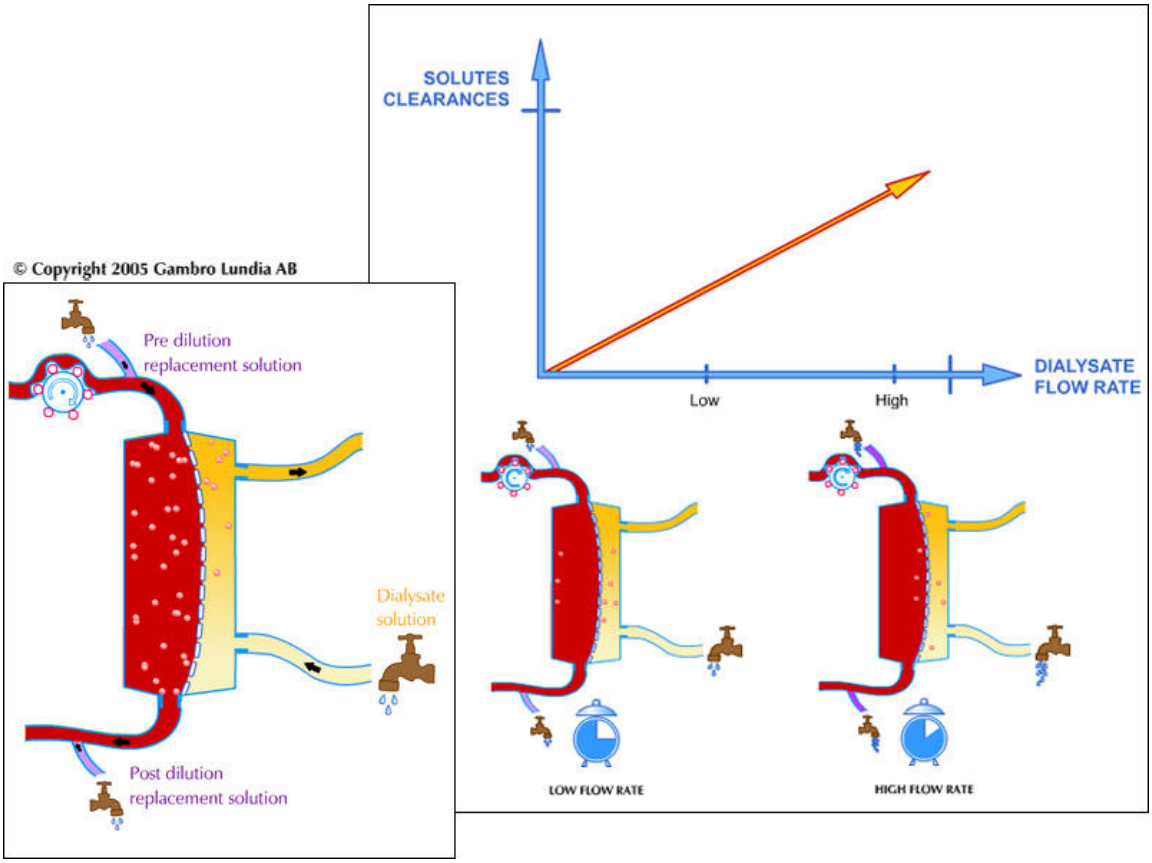


Sieving coefficient. In addition to the molecules and pores sizes, pressures across the membrane also affects the passage through the membrane. The greater the pressure, the greater the sieving coefficient will be.

4.3 Clearances in relation to flow rates and choice of CRRT therapy

In vivo pre-dilution clearances for different replacement and dialysate flow rates using the AN69 hemofilter in CVVH, CVVHD and CVVHDF have been documented by Brunet *et al.** Their findings demonstrated that by increasing the replacement solution flow rate to 2,000 ml/hr in CVVH, or increasing dialysate solution flow rate to 2,500 ml/hr in CVVHD, solute clearance increased.

However, the greatest solute clearances were achieved with CVVHDF, using both replacement and dialysate solutions at maximum flow rates, that is, replacement at 2,000 ml/hr and dialysate at 2,500 ml/hr.



Clearance. Both dialysate and pre/post dilution flow rates contribute to the solute clearance. The greater the replacement and/or dialysate flow rate, the faster maximum solute will be achieved.

*Maisonneuve-Rosemont Hospital and Montreal Heart Institute, Université de Montréal, Canada.
S. Brunet, D. Parent, M. Leblanc, J. Cardinal

4.4 QUIZ

1. The effectiveness of solute clearance is a function of the molecular size of the solute as well as the pore size of the membrane.
   a) True
   b) False

2. Clearances are dependent upon the effluent flow rate rather than the blood flow rate.
   a) True
   b) False

3. Intermediate and large molecules are cleared primarily by diffusion.
   a) True
   b) False

4. Examples of small molecules include urea, creatinine and Na+ and K+.
   a) True
   b) False

5. Plasma proteins will freely pass through the semi-permeable membrane.
   a) True
   b) False

6. Clearance of solutes with CVVH, CVVHD and CVVHDF increases with an increase in the flow rate of the dialysate (to 2,500 ml/hr) and/or the replacement solution (to 2,000 ml/hr).
   a) True
   b) False

7. For *in vivo* pre-dilution clearances observed in a study by Brunet, Parent, Leblanc and Cardinal, the greatest solute clearance was achieved with CVVHDF when using maximum flow rates for both the dialysate and replacement solutions.
   a) True
   b) False

4.5 ANSWERS to quiz

1. The effectiveness of solute clearance is a function of the molecular size of the solute as well as the pore size of the membrane.
   a) True
   b) False

   The effectiveness of solute clearance is a function of the molecular weight of the solute and the pore size of the membrane.

2. Clearances are dependent upon the effluent flow rate rather than the blood flow rate.
   a) True
   b) False

   Clearances are dependent upon the effluent flow rate.

3. Intermediate and large molecules are cleared primarily by diffusion.
   a) True
   b) False

   Intermediate and large molecules are cleared primarily by convection.

4. Examples of small molecules include urea, creatinine and Na+ and K+.
   a) True
   b) False

   Examples of small molecules include urea, creatinine, Na+ and K+.

5. Plasma proteins will freely pass through the semi-permeable membrane.
   a) True
   b) False

   Plasma proteins (65,000 daltons) will not pass through the semi-permeable membrane.

6. Clearance of solutes with CVVH, CVVHD and CVVHDF increases with an increase in the flow rate of the dialysate (to 2,500 ml/hr) and/or the replacement solution (to 2,000 ml/hr).
   a) True
   b) False

   Clearance of solutes increases with an increase in the flow rates of the dialysate and replacement solutions.

7. For *in vivo* pre-dilution clearances observed in a study by Brunet, Parent, Leblanc and Cardinal, the greatest solute clearance was achieved with CVVHDF when using maximum flow rates for both the dialysate and replacement solutions.
   a) True
   b) False

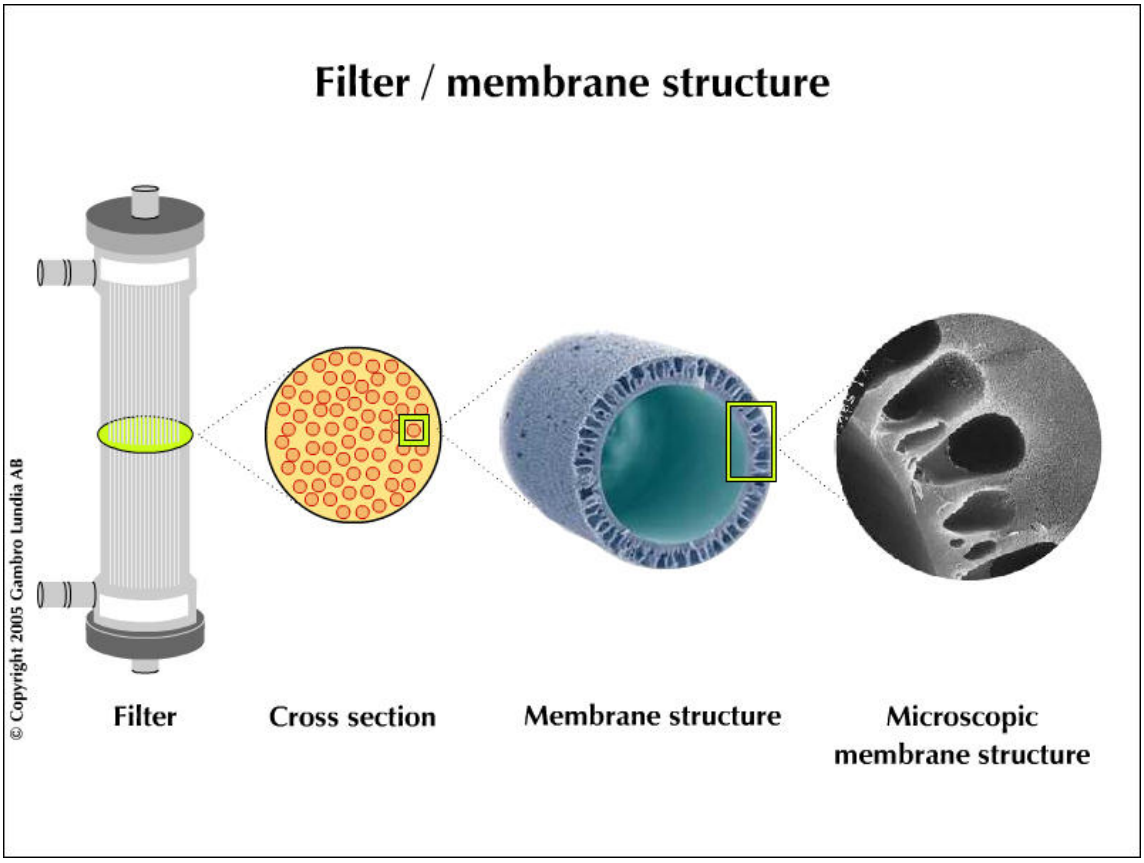
   In CVVHDF mode, the greatest solute clearance was observed when maximum flow rates were used for both the dialysate and replacement solutions.

5. Technical Considerations

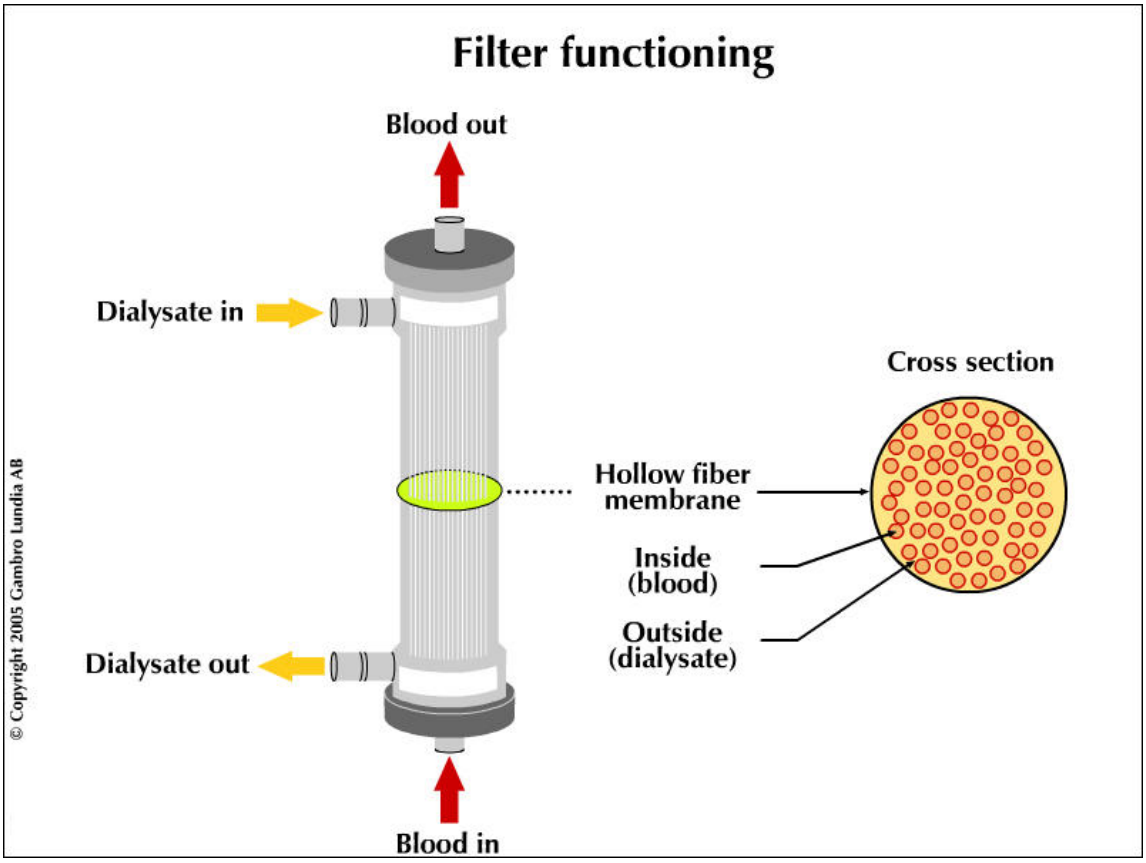
5.1 Membrane types and characteristics

Several commercial hemofilters are available for use in CRRT. These synthetic, biocompatible hemofilter/dialyzers are made of high flux material (polysulfone, polyamide and polyacrylonitrile, or PAN, membranes) following a hollow fiber structural design, and they are characterized by high fluid removal coefficients (which means that, at least in part, they can remove molecules in the 30,000-50,000 daltons range).

These synthetic, biocompatible semi-permeable membranes form an interface between the blood and dialysate compartments. With the use of biocompatible membranes, the risk of severe membrane/blood allergic reactions/interactions (hypotension, hypoxia) and complement activation is minimized.



Filter structure. Everything is done here for enlarged exchange surfaces between blood and dialysate.



Filter functioning. The flow of dialysate travels in opposite direction of the blood travelling inside of the filter and microfilter.

AN69 HF membrane – polyacrylonitrile (PAN) membrane.
(Prisma M60 set & Prisma M100 set)

Filter materials:

AN69 HF hollow fiber:	acrylonritile and sodium methallyl sulfonate copolymer
Housing and headers:	polycarbonate
Potting compounds:	polyurethane

Prisma M60 set	Prisma M100 set
Effective surface area = 0.60 m^2	Effective Surface Area = 0.90 m^2

Filter operating specifications:

Maximum TMP = 450 mmHg	Maximum TMP = 450 mmHg
Minimum BFR = 50 ml/min	Minimum BFR = 75 ml/min

Maximum blood pressure = 500 mmHg

Special Considerations:

Patients receiving angiotensin converting enzyme (ACE) inhibitor medication may develop symptoms of acute allergic (anaphylactic) reactions within the first several minutes of treatment. Treatment should be discontinued immediately after onset of symptoms. Administration of antihistamines is often ineffective, and more aggressive first-line therapy for anaphylactic reactions should be initiated.

Polyarylethersulfone membrane - (Prisma HF 1000 set)

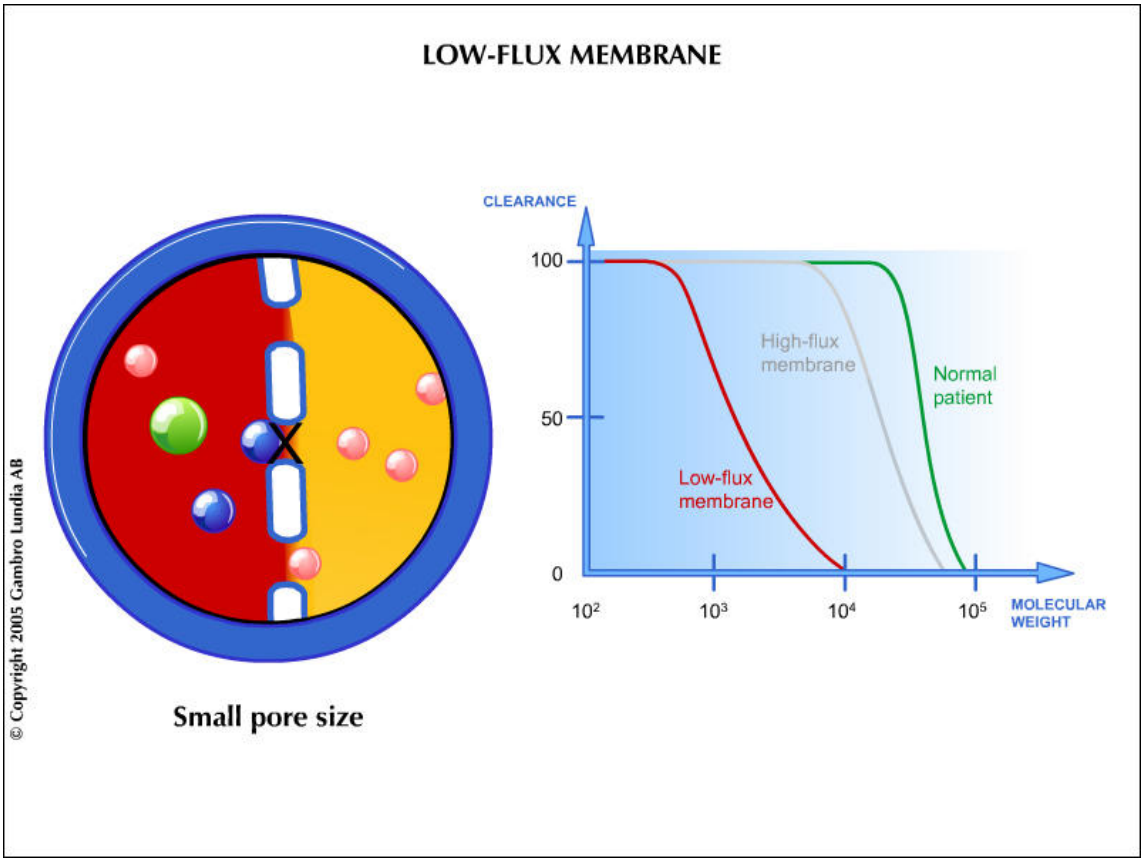
Filter materials:

Hollow fiber membrane:	made of polymer blend of polyarylethersulfone (PAES) and polyvinylpyrrolidone (PVP)
Housing and headers:	polycarbonate
Potting compound:	polyurethane
Effective surface area:	1.15 m^2

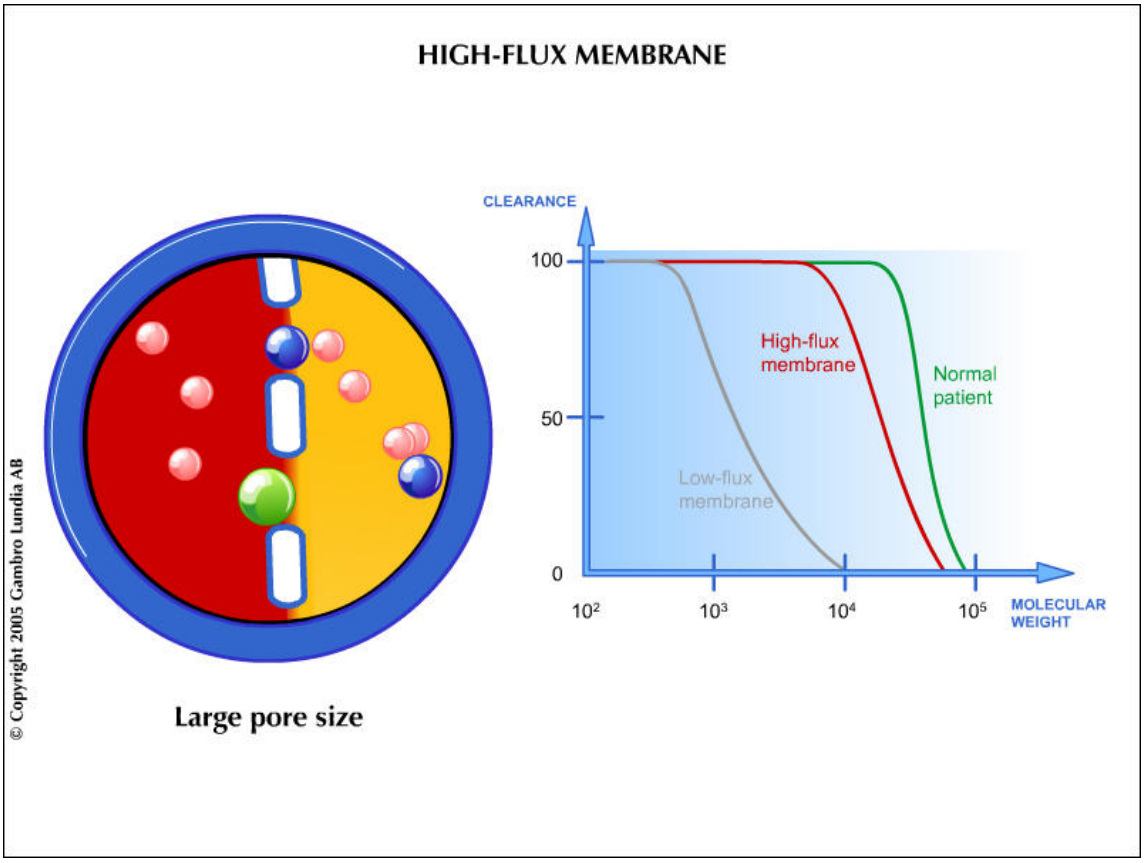
Maximum TMP:	500 mmHg
Minimum BFR:	75 ml/min
Maximum blood pressure:	500 mmHg

Special consideration for patients on ACE inhibitors is not required in the case of the polyarylethersulfone membrane.

*Gqmbro renal product , Renal Intensive Care - Prisma M60, M100 & HF1000 Product Instruction Guides.



Low-flux membrane. Membranes with small pores move the clearance/molecular weight cure to the left .



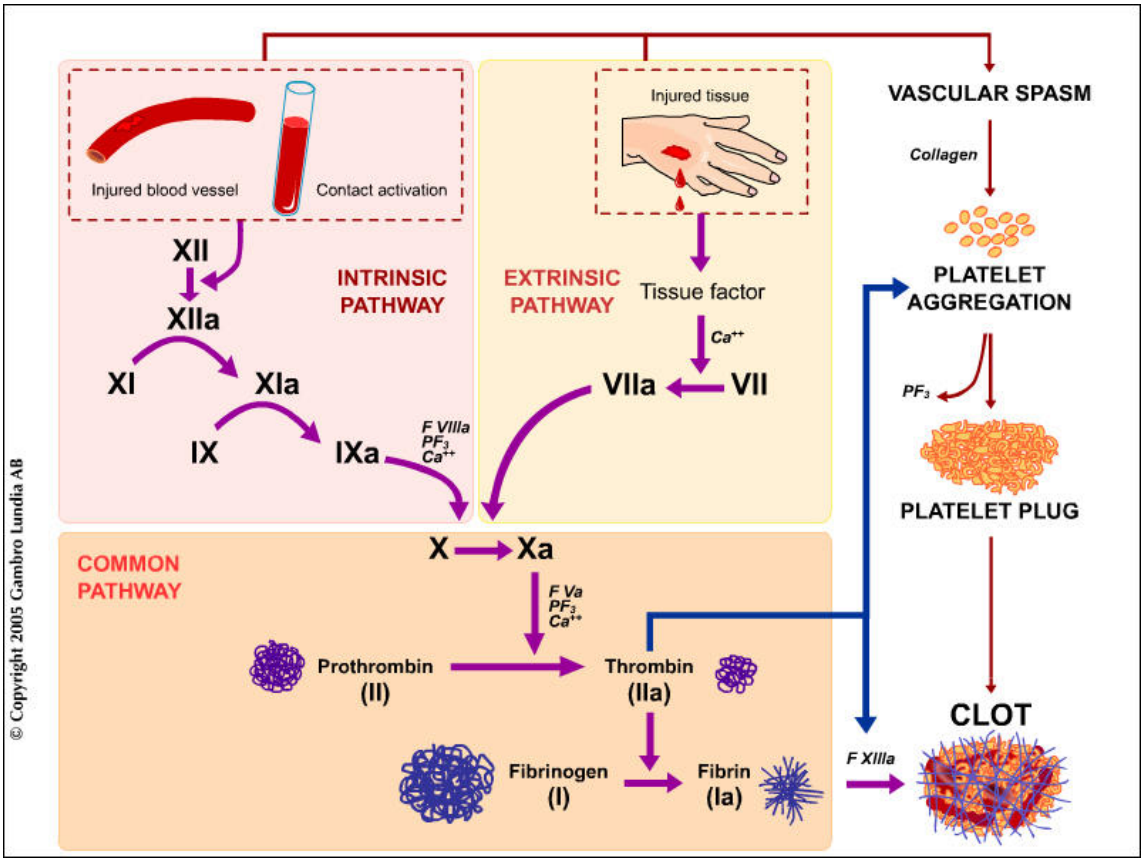
High-flux membrane. Membranes with small pores move the clearance/molecular weight cure to the right.

5.2 Membrane-related problems

5.2.1 Coagulation and complement activation

Blood coagulation occurs through activation of the clotting cascade (complement activation) by chemical mediators known as clotting factors. Some of the steps in the clotting cascade require the presence of plasma calcium and platelet factor 3. Calcium plays an important role in blood coagulation (Factor IV in the clotting cascade) and is one of the factors, which may be altered to achieve adequate anticoagulation of the circuit/hemofilter during CRRT. The phospholipid - platelet factor 3, secreted by the platelet plug, activates factor X (in the clotting cascade), which converts prothrombin into thrombin. Thrombin plays several roles in blood coagulation including the conversion of fibrinogen to fibrin; activation of the factor that stabilizes the fibrin meshwork of the clot; activation of more prothrombin into thrombin; and enhancement of platelet aggregation.

Either the intrinsic pathway or the extrinsic pathway may trigger the clotting cascade. With CRRT, the clotting cascade is triggered when blood comes in contact with foreign material (*i.e.*, hemofilter/dialyzer tubings and vascular access cannulas), thus causing blood to clot via the intrinsic pathway. Because these foreign surfaces initiate blood coagulation to various degrees, effective anticoagulation is essential during CRRT to prevent thrombus formation in the extracorporeal circuit. The extracorporeal circuit consists of all surfaces outside of the body to which the blood is exposed (*i.e.*, hemofilter, circuit tubings and vascular access cannulas) prior to being returned to the body. Effective anticoagulation is essential to treatment optimization (fluid/solute removal and filter longevity), and to minimization of treatment interruptions and blood loss.



Blood coagulation. With CRRT, the clotting cascade is triggered when blood comes in contact with foreign material (i.e., hemofilter/dialyzer tubings and vascular access cannulas), thus causing blood to clot via the intrinsic pathway.

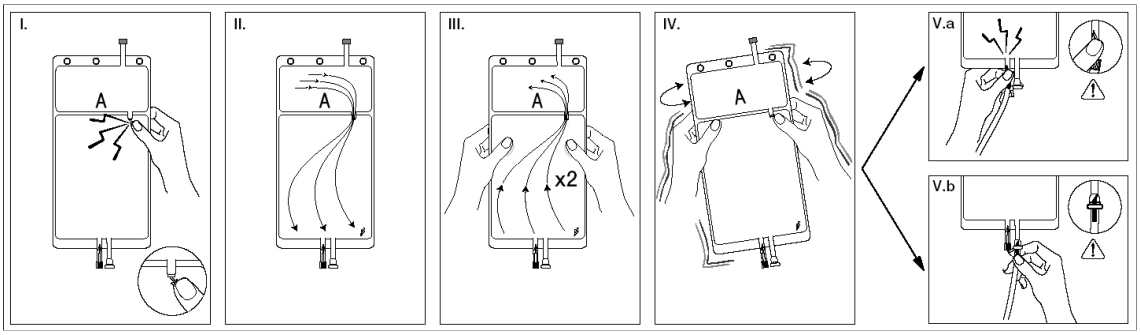
Anticoagulation Therapies used with CRRT:
Unfractionated or standard Heparin - the most common anticoagulant used for dialysis therapy.
Low Molecular Weight Heparin (LMWH)
Danaparoid Sodium
Regional Citrate - Trisodium Citrate most common form used

Prostanoids
Hirudin
Argatroban
Proteinase Inhibitors
Saline Flushes

5.3 Solutions – Dialysate and replacement

5.3.1 Types and characteristic

Although many hospitals prefer to use their own admixtures, commercially available solutions are most frequently used. The replacement solution usually has the same electrolyte additives as the dialysate. The solutions are sterile, and commercially prepared solutions are available in 1 to 5-liter bags. Addition of electrolytes to both commercially prepared and hospital-prepared solutions may be done through the medication injection port on the bags.



Commercially available solutions. In order to obtain an homogeneous mixing, Follow the steps;
(I) to break the frangible pin between the two compartments,
(II) to move solution from top to bottom compartment,
(III) to rinse the upper compartment with fluid from bottom compartment
(IV) to shake the bag.
(Va) to connect the luer lock port to the infusion line and break the frangible pin inside the luer look or
(Vb) to spike the injection port with the spike from the infusion line to connect via the injection port.

The standard commercial solutions contain a lactate, buffer which is not suitable for patients with liver failure or those suffering from severe metabolic acidosis. In these cases, specific hospital admixtures or commercially prepared bicarbonate-buffered solutions should be used instead.

5.3.2 Solution consideration based on anticoagulation

It is important to note that calcium and bicarbonate, when mixed in a solution, may precipitate. Therefore, special consideration should be given to the choice of dialysate and replacement solutions when using regional citrate anticoagulation (Trisodium citrate).

5.4 Vascular access

A veno-venous double lumen hemodialysis catheter or two single lumen venous hemodialysis catheters may be used.

Internal Jugular Vein - This is the primary site of choice due to lower associated risk of complication and simplicity of catheter insertion. This vessel is usually straight and less difficult to landmark.

Femoral Vein - If the patient is immobilized, the femoral vein is optimal and constitutes the easiest site for insertion. However, this site is also associated with the highest incidence of infection. (IJV has a similarly high rate of infection if tracheostomy is in place.)

Subclavian Vein - The least preferred site given its higher risk of pneumo/hemothorax and its association with central venous stenosis.

Choosing the right catheter

The length of the catheter chosen will depend upon the site used (the size of the catheter is important in pediatric population). The following are suggested guidelines for the different sites:

- RIJ = 15 cm French
- LIJ = 20 cm French
- Femoral = 25 cm French

5.5 QUIZ

1. Polysulfone, polyamide and polyacrylonitrile high flux membrane hemofilter/dialyzers are synthetic and biocompatible.
   a) True
   b) False

2. The risk of severe membrane/blood reactions and complement activation are significantly decreased with the use of these biocompatible membranes.
   a) True
   b) False

3. Patients receiving angiotensin converting enzyme (ACE) inhibitor medication may develop symptoms of acute allergic (anaphylactic) reaction within the first few minutes of treatment with the use of the AN69 (polyacrylonitrile) membrane.
   a) True
   b) False

4. Blood coagulation occurs through activation of the clotting cascade by chemical mediators known as clotting factors. With CRRT, the intrinsic pathway triggers the clotting cascade when blood comes into contact with foreign surfaces *(i.e.*, circuit tubings, hemofilter/dialyzer, and venous access cannula).
   a) True
   b) False

5. The types of anticoagulation therapies used in CRRT include: Heparin, Regional Citrate, and Normal Saline Flushes.
   a) True
   b) False

6. The dialysate and replacement solutions usually have the same electrolyte additives.
   a) True
   b) False

7. In CRRT, all solutions used are sterile.
   a) True
   b) False

8. Special consideration should be given, when choosing a solution, for patients with liver failure or severe metabolic acidosis, and for patients receiving regional citrate anticoagulation.
    a) True
    b) False

9. The preferred vascular access site for the hemodialysis veno-venous catheter is the:
    a) Femoral vein
    b) Subclavian vein
    c) Internal jugular vein

10. If the patient is immobilized, the optimal and easiest site for insertion is the:
    a) Internal jugular vein
    b) Femoral vein
    c) Subclavian vein

5.6 ANSWERS to quiz

1. Polysulfone, polyamide and polyacrylonitrile high flux membrane hemofilter/dialyzers are synthetic and biocompatible.
   a) True
   b) False

   Polysulfone, polyamide, and polyacrylonitrile high flux membrane hemofilters/dialyzers are synthetic and biocompatible.

2. The risk of severe membrane/blood reactions and complement activation are significantly decreased with the use of these biocompatible membranes.
   a) True
   b) False

   Use of biocompatible membranes presents lower risks of severe membrane/blood reactions and complement activation.

3. Patients receiving angiotensin converting enzyme (ACE) inhibitor medication may develop symptoms of acute allergic (anaphylactic) reaction within the first few minutes of treatment with the use of the AN69 (polyacrylonitrile) membrane.
   a) True
   b) False

   Patients receiving ACE inhibitors may develop symptoms of acute (anaphylactic) reactions within the first several minutes of treatment with the use of the AN69 membrane.

4. Blood coagulation occurs through activation of the clotting cascade by chemical mediators known as clotting factors. With CRRT, the intrinsic pathway triggers the clotting cascade when blood comes into contact with foreign surfaces (*i.e.*, circuit tubings, hemofilter/dialyzer, and venous access cannula).
   a) True
   b) False

   During CRRT, the clotting cascade is triggered by the intrinsic pathway when blood comes into contact with foreign surfaces.

5. The types of anticoagulation therapies used in CRRT include: Heparin, Regional Citrate, and Normal Saline Flushes.
   a) True
   b) False

   Anticoagulation therapies include: Heparin, Regional Citrate (Trisodium Citrate) and Normal Saline Flushes.

6. The dialysate and replacement solutions usually have the same electrolyte additives.
   a) True
   b) False

   Dialysate and replacement solutions usually have the same electrolyte additives.

7. In CRRT, all solutions used are sterile.
   a) True
   b) False

   All solutions used for CRRT are sterile.

8. Special consideration should be given, when choosing a solution, for patients with liver failure or severe metabolic acidosis, and for patients receiving regional citrate anticoagulation.
   a) True
   b) False

   The choice of solution for patients with liver failure or severe metabolic acidosis and for patients receiving regional citrate anticoagulation therapy must be given special consideration.

9. The preferred vascular access site for the hemodialysis veno-venous catheter is the:
   a) Femoral vein
   b) Subclavian vein
   c) Internal jugular vein

   The internal jugular vein is the preferred site for insertion of a hemodialysis vascular access catheter due to the ease of insertion and lower risk of complications associated with it.

10. If the patient is immobilized, the optimal and easiest site for insertion is the:
    a) Internal jugular vein
    b) Femoral vein
    c) Subclavian vein

    If the patient is immobilized, the optimal and easiest site of insertion of a hemodialysis vascular access catheter is the femoral vein.

6. Complications related to CRRT

Both patient-related and technical problems can be associated with CRRT treatment. The following are potential complications related to CRRT:

(a) Infection related to contamination of access or equipment.

(b) Vascular access complications related to vascular spasm (initial BFR too high), movement of catheter against vessel wall or improper length of hemodialysis catheter inserted.

(c) Fluid volume deficit (dehydration) related to excessive fluid removal without appropriate fluid replenishment.

(d) Hypotension related to excessive intravascular volume depletion, underlying cardiac dysfunction, or vasoplegic state.

(e) Electrolyte imbalances related to high ultrafiltration rates (high clearances), inadequate replenishment of electrolytes by intravenous infusion, or inadequate replenishment of bicarbonate loss during CRRT.

(f) Acid/Base imbalance related to renal dysfunction and respiratory compromise.

(g) Blood loss (anticoagulation) related to ineffective anticoagulation therapy, clotting of hemofilter, inadvertent disconnection in the CRRT system, hemorrhage due to over-anticoagulation, or blood filter leaks.

(h) Air embolus related to leaks or faulty connections in tubing, cracks (hairline) on hemodialysis catheter, unarmed or malfunctioning air detector, or line separation.

(i) Reaction to AN69 hemofilter related to reaction to ethylene oxide (sterilizing agent), use of ACE inhibitors, or complement activation.

(j) Pyrogenic reactions related to endotoxin leak from membrane, contamination of access or equipment during setup, or contaminated solution.

(k) Cardiac arrest related to profound hypotension/hypertension, hemolysis, air embolism, circulatory overload, or arrythmias.

7. Pre-CRRT Patient Assessment

7.1 ANNA Practice Standards and Guidelines for CRRT (endorsed by AACN)

Prior to initiating CRRT, a comprehensive assessment of the patient is required to establish patient baseline. This assessment should include a complete medical history – past illnesses and current disease process, current medications and relevant lab data. A head-to-toe assessment should also be performed with emphasis on the following parameters:

Central Nervous System

- mentation
- orientation to person, time and place
- ability to communicate
- intracranial pressure/cerebral perfusion pressure (if monitored)
- function of cranial nerves
- deep tendon reflexes of extremities
- mobility/immobility
- bilateral muscle strength
- use of sedative/anesthetic agents, muscle relaxants or paralytic agents

Cardiovascular System

- heart sounds – gallop S4 S3, pericardial friction rub
- blood pressure
- baseline EKG, heart rate and rhythm
- apical/radial pulses and peripheral pulses and strength of pulses bilaterally.
- presence of edema - location and grading (absent, trace, moderate, gross - 0 - 4+)
- hemodynamic parameters – central venous pressure (CVP), pulmonary artery wedge pressure (PAWP), pulmonary artery diastolic pressure (PAD), cardiac output (CO), cardiac index (CI), stroke volume (SV), and ejection fraction (EF)
- core temperature
- current cardiac medications/infusions, vasopressors
- intraaortic balloon pump (IABP)
- temporary or permanent pacemaker
- ventricular assist device
- cardiac reports (*i.e.*, echocardiogram) if applicable.

Respiratory System

- breath sounds and respiratory effort
- CXR – presence/absence of pleural effusions, CHF, ARDS, pneumonia, etc.
- oxygenation status and baseline arterial blood gas
- continuous monitoring of oxygen saturation
- oxygen delivery system – nasal prongs, face mask, rebreathe/non-rebreathe mask, bipap (positive pressure ventilation), intubated and ventilated.
- if ventilated – ventilation mode and current settings
- extracorporeal membrane oxygenator (ECMO)
- bronchoscopy report if available

Gastrointestinal System

- bowel sounds in four quadrants
- bowel patterns – presence of diarrhea, incontinence of stool, etc.
- presence of nasogastric, oral gastric or small bore feeding tube
- nutritional status – oral, tube feeds, parenteral nutrition, metabolic cart assessment if available or 24 hour calorie count
- diagnostic reports if available (endoscopy or proctoscopy)

Renal System

- fluid volume status – intake and output
- weight (preadmission and current)
- etiology of renal failure, acute versus chronic renal dysfunction
- urine output patterns – presence of foley catheter
- presence of hemodialysis vascular catheter or fistula
- types and rates of fluids administered
- types and amount of fluid loss from alternate sources (*i.e.*, chest tubes, nasogastric tube, wound drains, foley catheter, stool, insensible losses)
- mucous membranes
- electrolyte and acid-base balances
- diagnostic renal studies (*i.e.*, ultrasound)

Dermatologic

- presence of surgical or trauma wounds, scars
- skin integrity – presence of ulcers, rashes, ecchymosis, hematomas, induration, erythema
- skin color, temperature and turgor.
- presence and patency of indwelling intravenous and/or intraarterial catheters.

Hematological/Immunological

- presence of known HIV, VRE, MRSA, Hep A, B, or C.
- diagnostic cultures/lab reports
- presence of fever or hypothermia
- current antibiotic administration

Psychosocial

- patient/family understanding of current illness and past medical illness
- available support systems, religious affiliations
- patient/family past effective coping mechanisms
- patient/family teaching of CRRT therapy

7.2 QUIZ

1. Pre-CRRT patient assessment should include a medical history (past and present), current medications, and relevant lab data.
   a) True
   b) False

2. A thorough head-to-toe assessment of the patient is not required prior to initiating CRRT therapy.
   a) True
   b) False

3. As this is a dialytic therapy, only assessment of renal status is required.
   a) True
   b) False

4. Assessment of cardiovascular status would include (but is not limited to): hemodynamic parameters, blood pressure, heart rate and rhythm, core temperature, heart sounds and current cardiac medications.
   a) True
   b) False

5. Assessment of use of sedation/anesthetic/paralytic agents and muscle relaxants should be included in the central nervous system assessment.
   a) True
   b) False

6. Respiratory system assessment should include (but not be limited to): breath sounds, respiratory effort, CXR, oxygenation/ABG, continuous oxygen saturation, oxygen delivery system and, if ventilated, current ventilator mode and settings.
   a) True
   b) False

7. The patient's nutritional status, bowel patterns, presence/absence of bowel sounds are not relevant to treatment.
   a) True
   b) False

8. Fluid volume status, weight, etiology of renal failure, amount/type/source of fluid loss, acid-base status and types and amounts of fluid administration, etc., are significant factors in assessing renal status.
   a) True
   b) False

9. Assessment of dermatologic, hematological and immunological systems should also be included in the head-to-toe assessment.
   a) True
   b) False

10. It is important to assess both the patient's and the family's understanding of the disease process, coping mechanisms and supports. Open communication and education of both patient and family regarding the patient's therapy and treatment goals should be done prior to initiation of therapy.
   a) True
   b) False

7.3 ANSWERS to quiz

1. Pre-CRRT patient assessment should include a medical history (past and present), current medications, and relevant lab data.
   a) True
   b) False

   The pre-CRRT patient assessment should include a medical history, current medications and relevant lab data.

2. A thorough head-to-toe assessment of the patient is not required prior to initiating CRRT therapy.
   a) True
   b) False

   A thorough head-to-toe assessment prior to establishing CRRT is important in establishing baselines.

3. As this is a dialytic therapy, only assessment of renal status is required.
   a) True
   b) False

   Although this is a dialytic therapy, all systems may be affected. Therefore a total system assessment is necessary.

4. Assessment of cardiovascular status would include (but is not limited to): hemodynamic parameters, blood pressure, heart rate and rhythm, core temperature, heart sounds and current cardiac medications.
   a) True
   b) False

   These parameters, as well as others, would be included in the cardiovascular assessment of the patient.

5. Assessment of use of sedation/anesthetic/paralytic agents and muscle relaxants should be included in the central nervous system assessment.
   a) True
   b) False

   It is important to note the use of sedation/anesthetic agents, paralytic agents and muscle relaxants as part of the central nervous system assessment.

6. Respiratory system assessment should include (but not be limited to): breath sounds, respiratory effort, CXR, oxygenation/ABG, continuous oxygen saturation, oxygen delivery system and, if ventilated, current ventilator mode and settings.
   a) True
   b) False

   The respiratory system assessment should include these parameters.

7. The patient's nutritional status, bowel patterns, presence/absence of bowel sounds are not relevant to treatment.
   a) True
   b) False

   It is important to note the patient's current nutritional status and bowel patterns. If the patient is experiencing diarrhea or incontinence of stool, these factors could affect the hemodialysis catheter site selection.

8. Fluid volume status, weight, etiology of renal failure, amount/type/source of fluid loss, acid-base status and types and amounts of fluid administration, etc., are significant factors in assessing renal status.
   a) True
   b) False

   Fluid volume status, weight (previous and current), etc., are all significant factors in renal assessment.

9. Assessment of dermatologic, hematological and immunological systems should also be included in the head-to-toe assessment.
   a) True
   b) False

   Dermatologic, hematological and immunological data should be included in the assessment.

10. It is important to assess both the patient's and the family's understanding of the disease process, coping mechanisms and supports. Open communication and education of both patient and family regarding the patient's therapy and treatment goals should be done prior to initiation of therapy.
    a) True
    b) False

    It is important to assess both the patient's and the family's knowledge and support systems. Education regarding CRRT treatment and treatment goals should be discussed with patient/family prior to initiation of therapy.

8. Initiation of Therapy

8.1 ANNA Guidelines and Standards for CRRT

- Using universal precautions as recommended by the Centers for Disease Control, assess vascular access(es) insertion site for problems.

- Assess and record the patient's vital signs and hemodynamic parameters prior to initiation of therapy.

- Review physician's orders and relevant lab data.

- Prepare vascular access(es) using sterile technique according to established protocols prior to initiation of therapy.

- Connect blood tubing (access and return) to appropriate vascular access ports to establish the veno-venous extracorporeal circuit.

- If using pump-assisted technique (CRRT system set-up and primed according to system instructions prior to initiation), set blood flow rate. Start blood flow rate at 50 ml/min and increase as prescribed (or as patient tolerates). Depending upon therapy chosen, set fluid removal, dialysate and replacement solution flow rates as prescribed.

- Ensure all lines are secure.

- Administer anticoagulant and initiate infusion if applicable.

- Document the patient's hemodynamic stability with initiation of therapy.

9. Intratherapy Monitoring

9.1 ANNA Standards and Guidelines for CRRT

The critical care nurse must continuously monitor the following parameters while the patient is undergoing CRRT:

- blood pressure, heart rate, cardiac rhythm, temperature
- hemodynamic stability
- level of consciousness, mentation
- fluid volume status
- oxygenation and respiratory status (acid/base balance)
- electrolyte balance
- coagulation and hematologic status
- nutritional status/hyperglycemia
- infection
- air embolus
- security and patency of extracorporeal circuit by established protocols
- anticoagulent delivery and effectiveness
- blood flow rate and ultrafiltration flow rate
- dialysate flow rate and replacement flow rate (if applicable)
- pressure monitor information
- alarms and response
- color of ultrafiltrate/filter blood leak
- color and temperature of CRRT circuit

10. Termination of Therapy

The decision to terminate CRRT treatment is made by a nephrologist or an intensivist based on the patient's renal recovery or the patient's status – recovery from acute illness or futility of further treatment –, or by the informed decision of the patient (or family if the patient is incapacitated). Once the decision is made to terminate CRRT treatment, CRRT will be discontinued following established protocols, using universal precautions as prescribed by the Centers for Disease Control.

- Extracorporeal circuit will be discontinued as per established protocol.
- Hemodialysis vascular catheter care will be administered as per established protocol.
- The process will be documented.

10.1 Post-therapy patient assessment (ANNA Standards and Guidelines)

- patient/family education related to discontinuation of CRRT
- emotional status and support systems
- cognitive function
- coping mechanisms
- behaviour
- symptoms of stress or perceived degree of stress
- perceived quality of life, alteration of lifestyle

10.2 Evaluation of therapy

- complications
- duration and type of renal replacement therapy
- number of days in ICU, length of hospitalization
- operative procedures
- medical condition
- probability of improvement

10.3 QUIZ

1. Continuous monitoring of the patient and CRRT system is not required.
   a) True
   b) False

2. The decision to discontinue CRRT is made by a nephrologist, an intensivist or the patient/family.
   a) True
   b) False

3. CRRT should be discontinued following established protocols and universal precautions.
   a) True
   b) False

4. Once CRRT has been discontinued, a psycho/social assessment of the patient should be included as part of the documentation of the process and evaluation of therapy.
   a) True
   b) False

5. Assessment of effectiveness of therapy, complications, duration and type of renal replacement therapy, medical status and probability of improvement does not require evaluation.
   a) True
   b) False

6. Ongoing education of patient/family regarding renal replacement therapy, the disease process (possibility of short or long term IHD therapy), possible alteration in lifestyle, and quality of life issues must be addressed and documented as part of the evaluation following discontinuation of CRRT.
   a) True
   b) False

10.4 ANSWERS to quiz

1. Continuous monitoring of the patient and CRRT system is not required.
   a) True
   b) False

   Continuous monitoring of both patient and CRRT system is required once CRRT treatment is initiated.

2. The decision to discontinue CRRT is made by a nephrologist, an intensivist or the patient/family.
   a) True
   b) False

   The decision to discontinue CRRT is made by either a nephrologist, an intensivist or the patient/family.

3. CRRT should be discontinued following established protocols and universal precautions.
   a) True
   b) False

   CRRT should be discontinued using established protocols and universal precautions.

4. Once CRRT has been discontinued, a psycho/social assessment of the patient should be included as part of the documentation of the process and evaluation of therapy.
   a) True
   b) False

   Once CRRT has been discontinued, a psycho/social assessment of the patient should be included as part of the documentation of the process and evaluation of therapy.

5. Assessment of effectiveness of therapy, complications, duration and type of renal replacement therapy, medical status and probability of improvement does not require evaluation.
   a) True
   b) False

   Assessment of effectiveness of therapy, complications, duration and type of renal replacement therapy, medical status and probability of improvement is an important part of the evaluation process.

6. Ongoing education of patient/family regarding renal replacement therapy, the disease process (possibility of short or long term IHD therapy), possible alteration in lifestyle, and quality of life issues must be addressed and documented as part of the evaluation following discontinuation of CRRT.
   a) True
   b) False

   Ongoing education of the patient and their family is always required. These issues must be discussed with the patient/family and documented within the patient's chart.

SUMMARY

Continuous renal replacement therapy is a therapy option that is gaining greater acceptance and is becoming more widely used for the treatment of both renal and non-renal illnesses. Acuity levels of patients in critical care are often high due to their disease process and hemodynamic instability. In many situations, CRRT is the only treatment option available that the critical care patient population may tolerate. The critical care nurse plays a prominent role in the success of continuous renal replacement therapy through critical thinking and problem solving, an extensive knowledge base, advanced assessment skills, continuous monitoring, identification of problems (potential or actual) and early intervention.

REFERENCES

American Nephrology Nurses' Association ANNA), Core Curriculum for Nephrology Nursing 3rd Edition, 1995. Continuous Renal Replacement Therapy, pp.325-345.

American Nephrology Nurses' Association (ANNA), Guideline and Standards of Clinical Practice for Nephrology Nursing. Continuous Renal Replacement Therapy, pg. 1-12.

Bellomo R., Et al., International Journal of Artificial Organs. CRRT (CVVHDF) is associated with improved control of azotemia over IHD. 1999, Mar 23:3, pp145-150.

Bellomo R., and Ronco C., Critical Care Medicine, October 2000. ATN seems to be compounded by recurrent hyoptension. Vol. 4 No. 6 pp. 339-345.

Clark W.R., Mueller B.A., Krause M.A., Marcias W.L., Advances in CRRT, April 1997. Dialysate Prescription and Kinetics in Acute Renal Failure. Vol.4, No. 2, Suppl. 1;
pp. 64-71.

Gambro Renal Products, 2003. PRISMA System. CRRT Advantage and Product Advantage. St. Leonard, Canada.

Gambro Renal Products, 2003. Anticoagulation for Continuous Renal Replacement Therapy. St. Leonard, Canada.

Gambro Renal Products, 2002. PRISMA Continuous Fluid Management System. St. Leonard, Canada.

Herman Hospitals, SLE(E)D, ppt. JC, USA. Lakewood, Denver.

Lemiere, Van Biesen, Et.al, Kidney International 1998, 53, Suppl 66, pp. S110-149.

Manns M, Et al., Nephrology Dialysis Transplant, 1997, 12: pp. 870-872.

Marshall M.R., Et.al., Kidney International 2001, 20: pp 777-785.

Marshall M.R., Golper T.A., Shaver M.J., Chatoth D.K., Hybrid Dialysis for the Critically Ill, 2001; 20: pp 253-257.

Mehta R.L., Blood Purification 1999. Fourth Annual International Conference on CRRT, 17: pp 19-50.

Mehta R.L., Critical Care Nephrology. Anticoagulation for Continuous Renal Replacement Therapy, pp. 1199-1211.

Meyer M., Critical Care Clin. 2000. Renal Replacement Therapy. Vol 16 (1) pp.29.

Monson & Mehta R.L., CRRT. Nutrition Considerations in CRRT, pp. 152-160.

Schetz, Kidney International, 1999; 56; 72.88-94.

Schlaeper C., Amerling R., Manns M., Levin N.W., Kidney International, 1999. High clearance continuous renal replacement therapy with a modified dialysis machine. Vol. 56, Suppl. 72, pp. S20-23.

Troyonov S., Cardinal J., Geadah D., Parent D., Courteau, S., Caron S., Leblanc, M. Nephrology Dialysis Transplant, 2003. Solute clearances during continuous venovenous haemofiltration at various ultrafiltration flow rates using Multiflow-100 and HF 1000 filters. Vol. 18: pp961-966.