

Continuous Renal Replacement Therapy

A quick reference guide to
haemofiltration and renal failure

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Alison Bradshaw

CONTENTS

Page 3...	Acute Renal Failure
Page 4...	Normal Kidney Function
Page 5...	Nephron Function
Page 6...	Definitions of Key Words
Page 7...	Indications for CRRT
Page 8...	TYPES OF CRRT
	SCUF
Page 9...	CVVHF
Page 10...	Predilution or Postdilution?
Page 11...	CVVHD
Page 12...	CVVHDF
Page 13...	Transport of molecules
Page 14...	PRINCIPLES OF DIALYSIS
	Diffusion
Page 15...	Filtration
Page 17...	Convection
Page 18...	Application of Principles
Page 19...	Manipulation of Principles
	Summary of Principles
Page 21...	VASCULAR ACCESS
Page 22...	Dos and Don'ts of Vascular Access
Page 23...	ANTICOAGULATION
Page 24...	The Clotting Cascade
Page 25...	Heparin
Page 26...	Regional Heparinization and Citrate
Page 27...	Saline Flushes and Table of Anticoagulant Options
Page 28...	THE HAEMOFILTER
Page 30...	DIALYSATE COMPOSITION
Page 32...	CARE OF THE PATIENT
Page 36...	NUTRITION
Page 37...	CARE OF THE MACHINE
Page 38...	The BM 25
Page 39...	The Aquarius
Page 40...	Guide to Troubleshooting Alarms – The Aquarius
Page 41...	References

ACUTE RENAL FAILURE

Acute renal failure (ARF) is a common complication of the critically ill patient. Types of ARF include;

PRERENAL FAILURE

INTRARENAL FAILURE

POSTRENAL FAILURE

Prerenal failure; this is the most common type of ARF. It is a result of renal ischaemia caused by a significant decline in renal blood flow. Decline in renal blood flow and a fall in glomerular filtration rate may result from hypovolaemia, a decrease in cardiac output or sepsis. (Dirkes,2000:581)

Intrarenal Failure; indicates injury to the nephrons within the kidney itself, usually caused by nephrotoxins. Some of these potential nephrotoxins are aminoglycosides, heavy metals, contrast dye. Prolonged ischaemia in the kidney will cause intrarenal failure as well. (Dirkes, 2000:581)

Postrenal Failure; occurs when there is an obstruction to the outflow of urine from the kidney. Urinary tract obstruction, including renal stones, tumors and prostatic hypertrophy are common causal factors. (Dirkes, 2000:581)

NORMAL KIDNEY FUNCTION

The kidneys, with their approximate one million nephrons, are responsible for the filtration of blood and the subsequent formation of urine. In addition, they contribute to homeostasis by;

- **Regulating blood ionic composition**
(sodium, potassium, calcium, chloride and phosphate ions)
- **Maintaining blood osmolarity**
(through regulation of water and solute loss in urine)
- **Regulating blood volume**
(conservation or elimination of water)
- **Regulating blood pressure**
(activation of the renin-angiotensin system and renal vasoconstriction)
- **Regulation of blood pH**
(retention of bicarbonate ions $\{HCO_3^-\}$ or excretion of hydrogen ions $\{H^+\}$)

(Tortora and Grabowski, 2000:914-915)

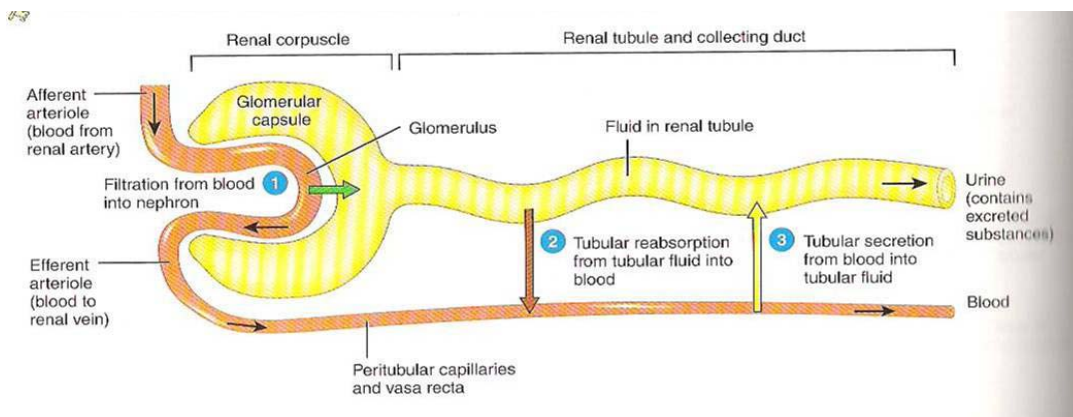
Each Nephron Performs Three basic Functions

Glomerular Filtration; blood flows through the afferent arteriole into the glomerular capsule. It is here that water and most solutes in plasma pass from blood across the wall of the glomerular capillaries into the glomerular capsule. Blood leaves the capsule via the efferent arteriole.

Tubular Reabsorption; this system returns most of the filtered water and many of the filtered solutes back to the blood. In fact about 99% of the approximate 180 liters of filtrate is returned to the blood stream. Solutes that are reabsorbed, both actively and passively include glucose, amino acids, urea and ions such as Na^+ , K^+ , Ca^{2+} , Cl^- , HCO_3^- and phosphate.

Tubular Secretion; as fluid moves along the tubule and through the collecting duct, waste products, (such as excess ions and drugs) are added into the fluid.

(Tortora and Grabowski, 2000:914-915)



Tortora and Grabowski, 2000:924)

DEFINITIONS OF KEY WORDS

SOLUTE; a substance dissolved in a fluid or solvent to form a solution. A solution consists of a solute and a solvent.

(Dorland 2003:1719)

SOLVENT; a substance, usually a liquid, which dissolves, or is capable of dissolving. (Dorland 2003:1721)

SEMI PERMEABLE MEMBRANE; a membrane permitting the passage of water and some small molecules and hindering the passage of larger molecules (Cole, L. Intensive Care Specialist Nepean Hospital 4 June 2004 pers com)

DIALYSATE; During haemodialysis, dialysate is the fluid that passes through the filter countercurrent to blood flow, which then accumulates the solutes and water being removed and is ultimately discarded (Cole, L. June 4 2004 pers com)

REPLACEMENT FLUID; fluid administered to the blood side of the filter during haemfiltration. This may be done before the blood enters the filter (pre-filter) or after the blood leaves the filter (post-filter) (Bellomo, Ronco and Mehta 1996:S6)

ULTRAFILTRATE; The net amount of water and solutes that are removed from the patient through the filter. Ultrafiltrate can be removed during haemodialysis or haemofiltration

(Cole, L. June 4 2004 pers com)

INDICATIONS FOR CRRT

CRRT, or continuous renal replacement therapy, is any extracorporeal blood purification therapy intended to substitute for impaired renal function for an extended period of time, and intended to run over 24 hours a day. (Bellomo, Ronco and Mehta, 1996:S3)

CRRT is indicated for several reasons in the intensive care unit (ICU). Some of these indications are;

Renal Failure, Diuretic-resistant pulmonary oedema, Detoxification, Severe hepatic failure and Sepsis.

Criteria for the initiation of dialytic therapy will depend upon the treating physician, but general criteria include oliguria, anuria, plasma urea concentration $>35\text{mmol/l}$, serum creatinine concentration $>600\mu\text{mol/l}$, hyperkalaemia $>6.5\text{mmol/l}$, pulmonary oedema non-responsive to diuretics, metabolic acidosis ($\text{pH} < 7.2$) and uremic encephalopathy. (Bellomo in Eo, 1998:365)

CRRT allows for;

- Continuous gentle fluid removal; achieving a daily volume of water removal, thus avoiding haemodynamic instability. (Dirkes, 2000:582)
- Removal of toxic wastes; urea, creatinine, drugs.
- Correction of electrolyte and acid base disturbances.

TYPES OF CRRT

SCUF

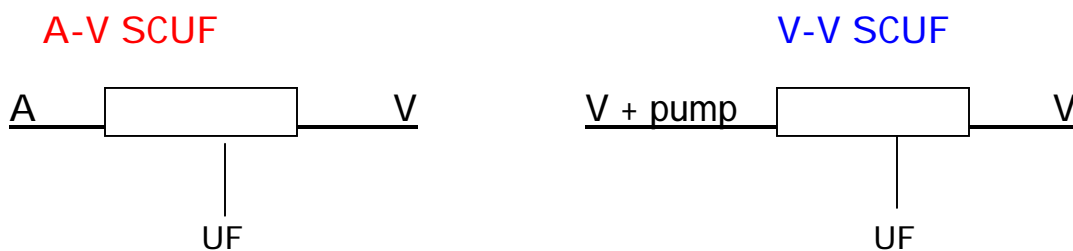
Slow Continuous Ultrafiltration.

SCUF is not associated with fluid replacement and is therefore the simplest form of CRRT. The primary aim of SCUF is to achieve safe and effective management of fluid overload.

SCUF can be either veno-venous (VV) or arterio-venous (AV).

- In V-VSCUF the blood is pumped through a filter by a pump.
- In A-VSCUF the blood is pumped through a filter by the patients own blood pressure.

(Bellomo, Ronco and Mehta, 1996:S3)



A – artery, V – vein, UF – ultra filtrate.

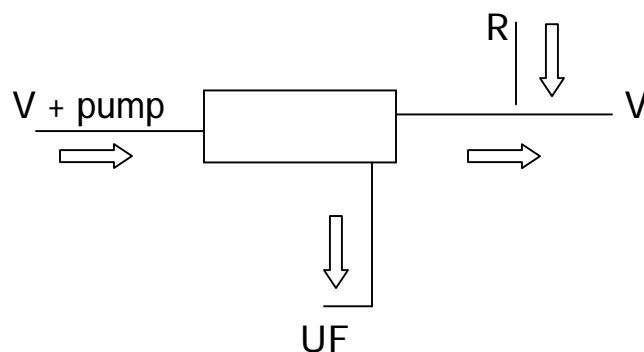
(Bellomo, Ronco and Mehta, 1996:S4)

CVVHF

Continuous Veno-Venous Haemofiltration

Arterial cannulation carries added risks of bleeding, infection and vessel damage. For this reason, the development of pumps to achieve continuous haemofiltration using venous access only, prevails in most ICUs. A double lumen catheter is used to access a central vein, usually femoral, subclavian or jugular.

Blood is driven through a highly permeable membrane (haemofilter) by the peristaltic pump. This is achieved through an extracorporeal circuit, whereby blood is removed through one lumen (called the arterial) and then returned to circulation via the other lumen (called the venous lumen). Ultrafiltrate generated as a result of movement across the membrane is replaced with appropriate fluid to achieve volume control and blood purification. The addition of replacement fluid may be pre-filter (predilution) or post-filter (postdilution). (Bellomo, Ronco and Mehta, 1996:S3) and (Bellomo in Eo, 1998:367).

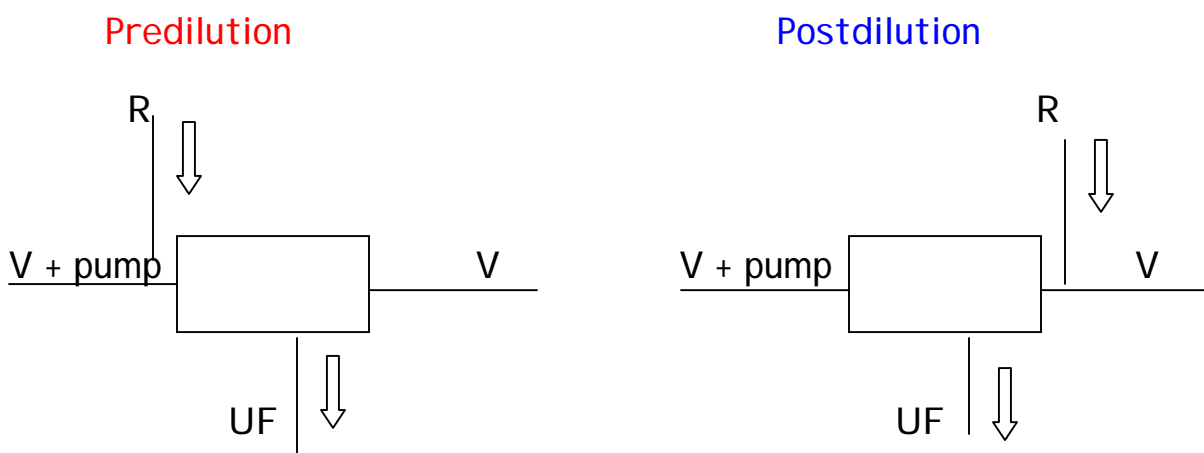


V - vein, R - replacement fluid, UF - ultrafiltrate.

Predilution or Postdilution???

The concept of replacing fluids, whether before or after the haemofilter achieve the same goals - replacing lost volume and replacement of electrolytes. However, predilution provides the added benefit of a continuous flush for the haemofilter, and in effect dilutes the blood flowing through it (Dirkes 2000:585)

This method may reduce the incidence of clotting in the haemofilter but will reduce solute clearance due to haemodilution (Cole, L. June 4 2004).



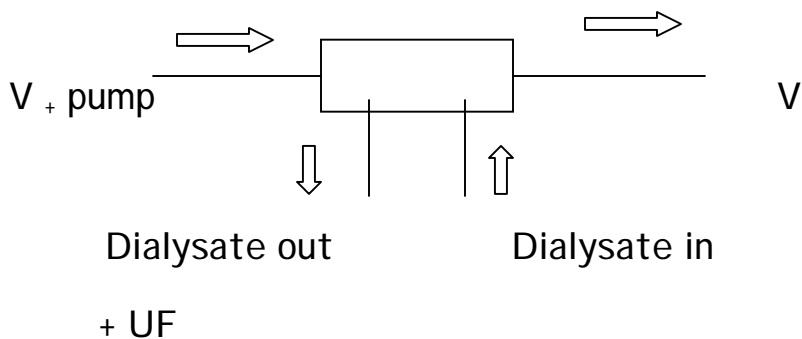
V - vein, R- replacement fluid, UF - ultra filtrate.

CVVHD

Continuous Veno-Venous Haemodialysis

This technique involves a slow countercurrent dialysate flow being added to the haemofilter (through the ultrafiltrate – dialysate compartment of the membrane). Solute clearance is mainly diffusive. Fluid replacement is not routinely added to the circuit.

(Bellomo, Ronco and Mehta, 1996:S5)



V – vein, UF – ultra filtrate

(Bellomo, Ronco and Mehta, 1996:S5)

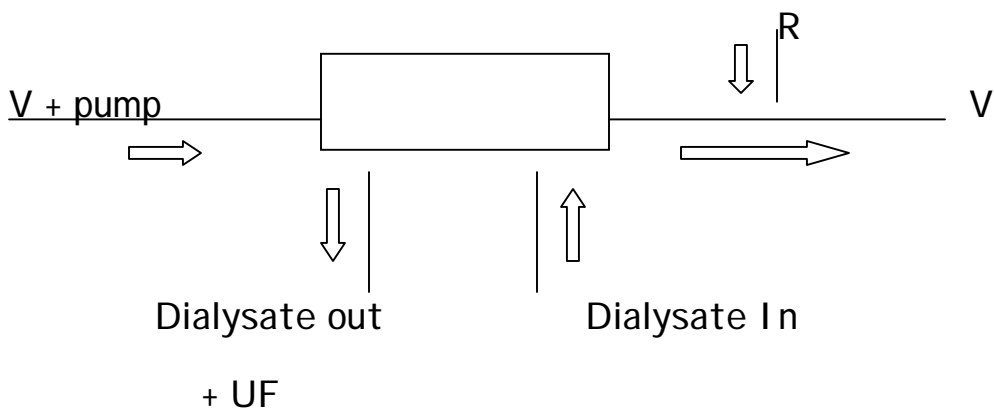
CVVHDF

Continuous Veno-Venous Haemodiafiltration

In this type of CRRT, a slow countercurrent dialysate flow is added to the haemofilter. Solute removal is both diffusive and convective, and is thought to be the most effective method of removal of wastes in CRRT. (Bellomo, Ronco and Mehta, 1996:S4)

Fluid replacement is routinely added, as clinically indicated, to maintain desired fluid balance. This is due to the ultrafiltration rate being greater than the desired patient fluid loss.

(Bellomo, Ronco and Mehta, 1996:S4)



V - vein, R - replacement fluid, UF - ultrafiltrate

Transport of Molecules

Molecules are measured in daltons (Da), which represents their 'size'. The size of the molecule will determine whether that molecule will be moved through the haemofilter membrane.

Diffusion or convection are the mechanisms for transport of the molecules.

Molecule	Molecular Weight
Sodium	33
Calcium	40
Urea	60
Creatinine	113
Uric acid	168
Dextrose	180
Vitamin B12	1352
Myoglobin	17 000
Albumin	68 000
Globulin	150 000

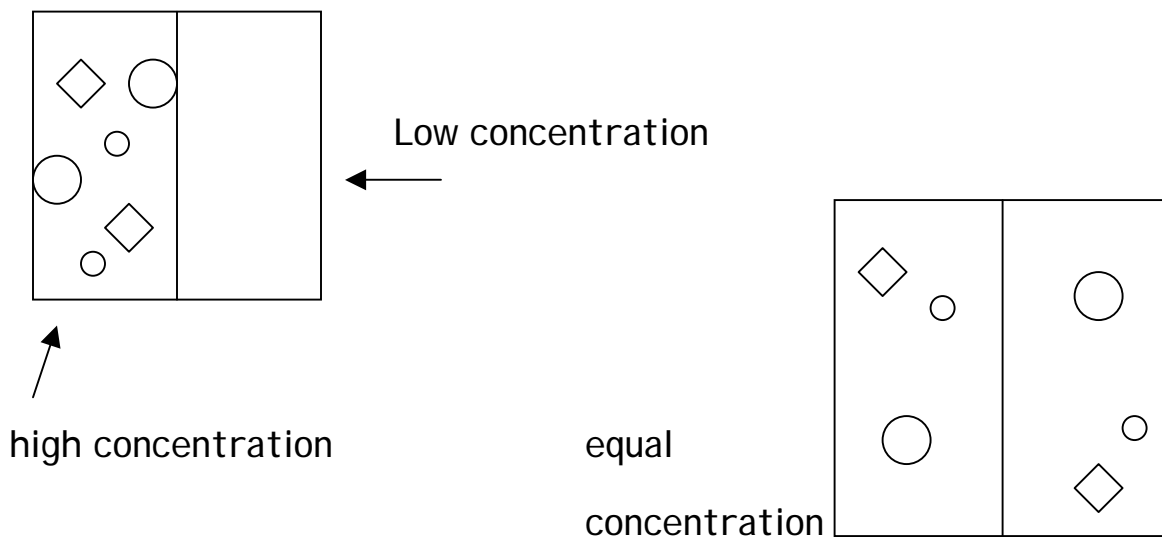
Red blood cells, white blood cells, bacteria and virus' are larger.

Principles of Dialysis

diffusion - filtration - convection

DIFFUSION

Diffusion is defined as the movement of solutes from an area of high solute concentration to an area of low solute concentration across a semipermeable membrane. Ultimately, concentration of the solute will be equal on both sides of the membrane. Diffusion is directly proportional to the concentration gradient, temperature and surface area. Diffusion is inversely proportional to the thickness of the membrane. (Bellomo, Ronco and Mehta, 1996:S6)



The concentration gradient is maintained in filtration because we are continually adding fresh dialysate fluid to the dialysate side.

FILTRATION

Filtration is defined as the movement of water through a permeable membrane caused by a pressure gradient. High molecular weight substances are separated by the membrane according to their size. (Dorland 2003:702)

In renal replacement therapy, it is the process by which plasma water and filterable solutes are separated from whole blood across a semipermeable membrane as a result of transmembrane pressure. (Bellomo, Ronco and Mehta, 1996:S6)



Positive pressure forces solutes through the membrane.

Compare this with your garden hose...think of the tap as the blood pump, and the nozzle as the resistance offered by the return of blood to the patient.

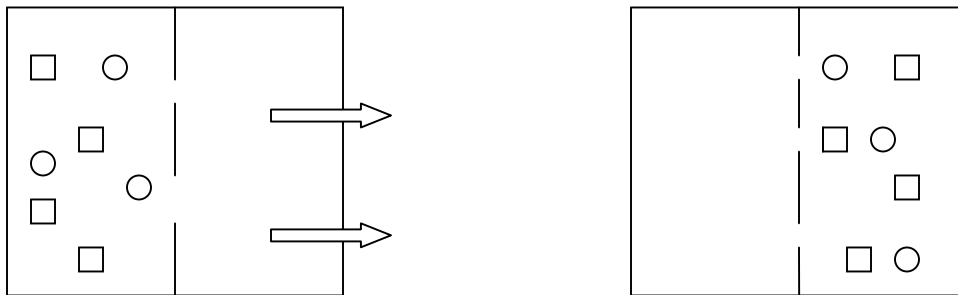
The hose now becomes the membrane, if holes are punched along the surface of the hose pipe. The more you turn the 'tap' on (the blood pump), and /or the more you constrict the nozzle (pts vascular access), the greater the pressure inside the hose. The higher the pressure, the further the water will squirt out of the holes, and the more water you will lose across the membrane.

Analogy

FILTRATION CONTINUED.....

The change in pressure gradient can be either positive as described previously, or it can be a negative pressure.

A vacuum pump, gravity or osmotic pressure gradients can create negative pressure on the dialysate side of the filter.



Filtration can be achieved through either increasing the pressure on the blood side of the filter or increasing the negative pressure on the dialysate side of the filter. (Whitaker in Clochsey et al 1996:936)

Volumetric pumps are used on the dialysate side of the filter to precisely control the negative pressure and therefore the volume of ultrafiltrate produced. (Bellomo, Ronco and Mehta, 1996:s6)

CONVECTION

Convection is defined as a process of 'solvent drag'. Solutes are washed across the semipermeable membrane together with the solvent. This is achieved by the solvent drag or filtration mechanism which occurs as a result of a transmembrane pressure gradient. (Bellomo, Ronco and Mehta, 1996:s6)



The size of the pores in the membrane determines what solutes can be washed to the other side. Small solutes such as amino acids, glucose, vitamins, small plasma proteins, ammonia, urea and electrolytes are able to move through the semipermeable membrane. This is in contrast to the larger molecules such as blood cells, most plasma proteins and platelets, which are too large to cross the membrane. (Tortora and Grabowski 2000:961)

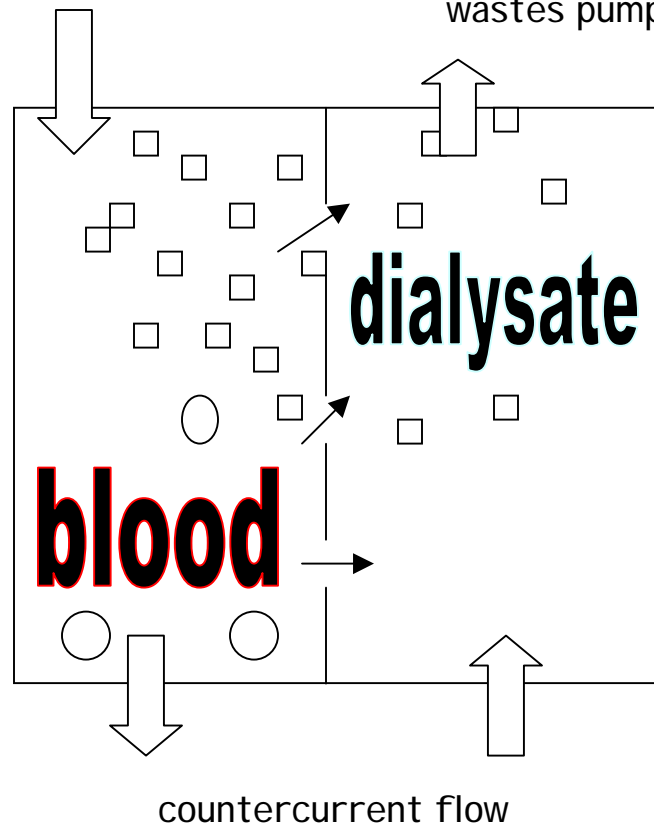
Application of Principles

blood from pt –

at high pressure

negative pressure –

wastes pumped out



- Blood will run at between 50 to 200 mls per hour
- Dialysate will run at between 15 – 30 mls per minute
- Countercurrent is applied in CVVHD and CVVHDF
- Wastes are removed from the blood by diffusion and convection – water is removed by filtration. [Hawkins 2003]

MANIPULATION OF THESE PRINCIPLES

Diffusion is increased by;

- Increasing the rate of the dialysate flow
- Increasing the rate of blood flow
- Using countercurrent flow
- Composition of dialysate fluid to increase the concentration gradient
- Increasing the surface area of the membrane

Diffusion is decreased by;

- Decreasing the rate of the dialysis flow
- Decreasing the rate of blood flow
- Dilution of the blood before the filter (pre-dilution replacement fluid)
- Decreasing the area of the membrane

Ultrafiltration and Convection are increased by;

- An increase in positive pressure on the blood side of the circuit. This can be caused by either an increase in blood flow or an increase in the flow of pre-dilution replacement fluid.
- An increase in negative pressure on the ultrafiltrate side of the membrane.

Ultrafiltration and Convection are decreased by;

- A decrease in the positive pressure on the blood side of the circuit. This can be due to either a decrease in blood flow rate or a decrease in the rate of pre-dilution replacement fluid.
- A decrease in negative pressure on the ultrafiltrate side caused by a decrease in the flow rate of the ultrafiltrate pump. [Hawkins, 2003]

In summary, the following table gives a diagrammatic representation of the changes that occur with manipulation of the principles of CRRT.

	Diffusion Increased	Diffusion Decreased	Convection & Ultrafiltrate Increased	Convection & Ultrafiltrate Decreased
Rate of blood flow	↑	↓	↑	↓
Rate of dialysate or UF flow	↑	↓	↑	↓

Vascular Access

- A double lumen catheter, also known as a 'vascath' is inserted aseptically into either the internal jugular, subclavian or femoral vein. The care of the catheter is a very important aspect of CRRT. [Rodda, 2003]
- With out good quality access, CRRT can prove problematic and ineffective.
- Patents in intensive care are susceptible to infections because of depression of the immune system. With this in mind, all manipulation of the catheter should be done aseptically.
(Ronco and Bellomo 1996:s100)
- Venovenous access allows for blood to be pumped out of the large vein, through the extracorporeal circuit and returned to the same vein. Remembering that cardiac output is 4 – 8 liters a minute, it is not likely that recirculation is a problem.

(College Study Guide, 2004:7-42 and Cole, L. June 4 2004, pers com)

THE DO'S AND DON'T'S OF VASCULAR ACCESS

DO confirm position by x ray, except if it is placed in the femoral vein. X ray will exclude or confirm complications of insertion such as pneumothorax.

DON'T start therapy until position is confirmed.

DO ensure connections are tight, the lines are secured and in view at all times.

DON'T allow the area between the patient and the machine to be too big, this deters people from 'stepping over' the lines.

DO heparin lock both lumens when not in use, and mark on the line that it has been heparin locked.

DON'T flush the heparin lock into the patient; be sure to withdraw the heparin lock prior to recommencing treatment.

DO dressings regularly and aseptically. Use a clear occlusive dressing, the insertion site should be visible at all times.

Anticoagulation

AIM – to prevent the filter and the circuit from clotting, without interfering with the patients' systemic coagulation. With specific patient conditions, no anticoagulation may be adopted.

To comprehensively understand anticoagulation therapies, you must be familiar with the clotting cascade. While detailed explanation is beyond the scope of this manual, a summary of the main points will assist in understanding.

THE CLOTTING CASCADE

Clotting is a complex cascade of reactions involving clotting factors which are activated by each other, in a fixed sequence.

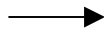
These factors include;

- calcium ions (Ca^{2+})
- several inactive enzymes that are synthesized by the liver and released into the bloodstream
- various molecules - associated with platelets
- or released by damaged tissues

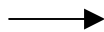
(Tortora and Grabowski 2000:623)

In clotting,
coagulation factors
activate other
factors in sequence,
resulting in a
cascade of reactions.

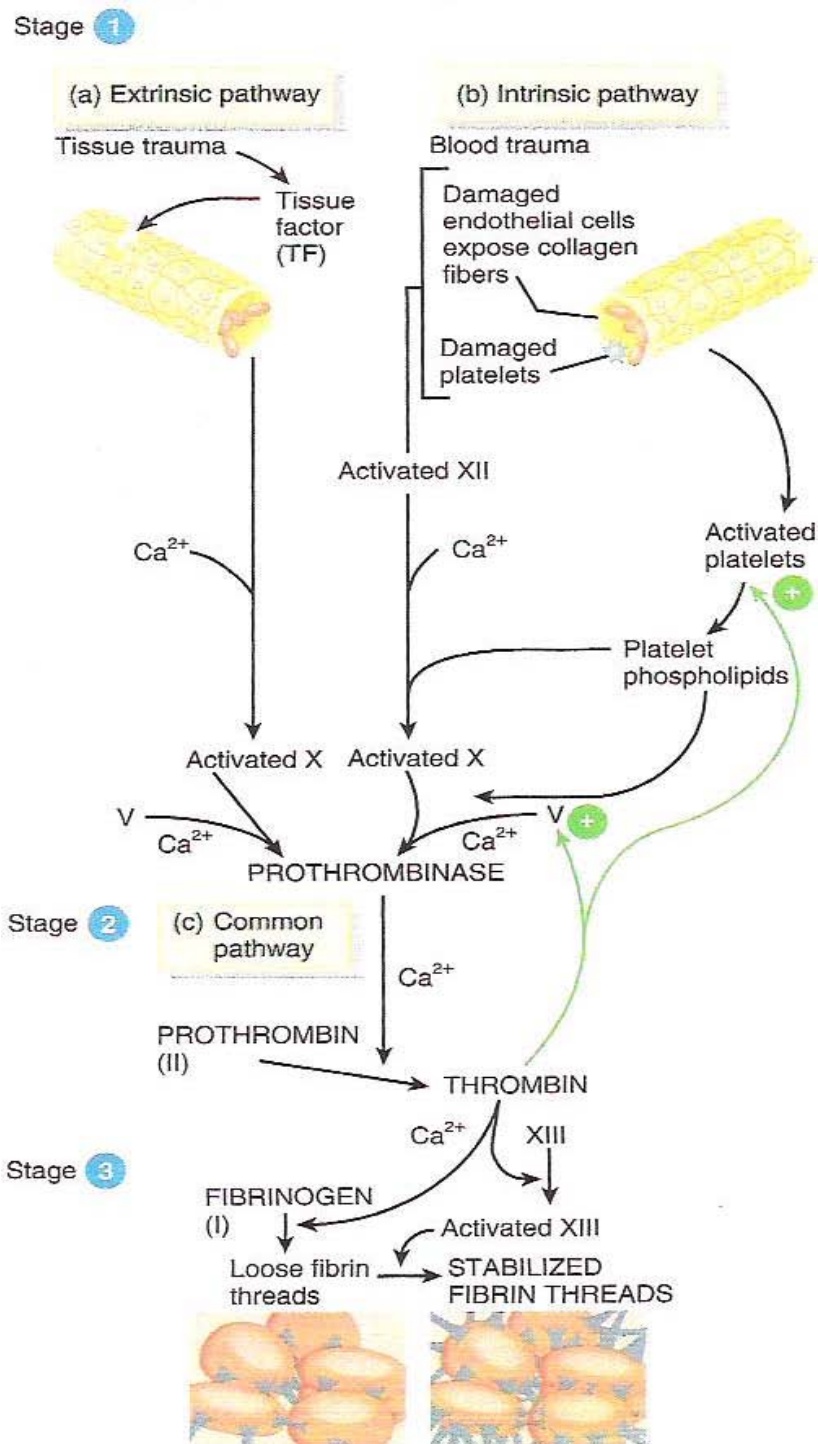
Citrate binds with
ionized calcium



Heparin inhibits
activation of
factor X



NOTE; how calcium
plays a role in all
three stages of the
clotting cascade!



(Tortora and Grabowski 2000:625)

MOST COMMONLY USED ANTICOAGULANT THERAPIES

- * HEPARIN * CITRATE * REGIONAL HEPARINIZATION
- * SALINE FLUSHES * NO ANTICOAGULATION

HEPARIN

- Heparin acts by binding to and greatly enhancing the activity of antithrombin III, and from inhibition of a number of coagulation factors – particularly activated factor X. (Dorland 2003:836).
- Heparin is the most commonly used anticoagulant.
- The extracorporeal circuit is primed with heparinized saline. Depending upon the patients own coagulation, an infusion of heparin is delivered into the circuit prior to the haemofilter.
- Patient coagulation levels should be taken prior to the commencement of CRRT. At 2 hours post commencement draw blood from the blue (venous) port and check machine APTT. This needs to be repeated every 2hours until the machine APTT lies between 60 – 80 seconds. Once stable check 6th hourly. Blood needs to be taken from both the patient and the machine for comparison. Once coagulation is stable within the set limits, bloods are attended 12 hourly.

REGIONAL HEPARINIZATION

- In regional heparinisation, heparin is infused prior to the haemofilter, and its antagonist, protamine, is infused post filter. This effectively reverses the action of any heparin passing through the filter.

(Dirkes 2000:586).

CITRATE

- Regional anticoagulation with sodium citrate is an effective form of anticoagulation for CRRT for patients with contraindications to heparin. It is infused directly into the circuit, pre filter (Macias 1996:S15).
- Citrate prevents clotting by binding to ionized calcium in the blood. Note the clotting cascade.
- Calcium gluconate is infused post filter to prevent systemic anticoagulation and to avoid hypocalcaemia (Bellomo in oh, 1997:368).
- Use of citrate can be complicated with metabolic alkalosis because the citrate returning to the patient is metabolised to bicarbonate (Macias 1996:S15).
- Citrate is contraindicated in patients with hepatic dysfunction.

SALINE FLUSHES

- In patients that are unable to tolerate anticoagulation, routine saline flushes to the circuit can be helpful in keeping the circuit free of clots (Dirkes 2000:586).
- Saline is not an anticoagulant and flushing the circuit can only assist in preventing clots and does not guarantee longevity of the haemofilter (Dirkes 2000:586).

TABLE OF ANICOAGULANT OPTIONS IN CRRT

ANTICOAGULANT	COMMENTS
Heparin	Easy, inexpensive. Potential for systemic bleeding or heparin induced thrombocytopenia
Regional Heparinisation	Heparin infused prefilter and protamine infused post filter.
Citrate	Labor intensive. Requires routine monitoring of blood results to control ionised calcium and magnesium. System requires calcium infusion post filter. Contraindicated in hepatic dysfunction.
Saline Flushes	Not an anticoagulant. Helps flush haemofilter, possibly prolonging filter life.
No Anticoagulation	Success varies. Requires faster rate of blood flow.

Compiled from (Dirkes 2000:586)

The Haemofilter

The haemofilter, otherwise known as 'the kidney', is the 'heart' of the haemofiltration process. It is here that blood is filtered, with the removal of water and dissolved solutes.

There are two types of filters, the parallel plate filter and the hollow fibre filter. The hollow fibre filter is used predominantly in this ICU, and so it will be the feature of this discussion.

These haemofilters are mostly made from polymers, and are constructed of porous hollow fibers. The large pores allow for the passage of larger molecules along with increased volume of fluid

(Dirkes 2000:583)

The fibres are bundled together in a cylindrical tube, and are encapsulated so that they are free at either end of the tube.

This allows blood to enter and exit the hollow lumens, but not to circulate around the outside of the fibres.

As mentioned previously, molecules are measured in Daltons.

Commonly, the average filter pore size is 30, 000 Daltons. The table below represents common molecular weights. Only very small molecules pass freely through the filter.

There is restriction of movement of the medium sized molecules, e.g. Vitamin B12, and very little movement across of large molecules, e.g. albumin.

Molecule	Molecular Weight (daltons)
Sodium	33
Calcium	40
Urea	60
Creatinine	113
Uric acid	168
Dextrose	180
Vitamin B12	1352
Myoglobin	17 000
Albumin	68 000
Globulin	150 000

The fibres within the filter vary in size and composition, with some materials said to be more biocompatible than others and other said to have septic mediator absorption properties.

Another important factor with filters is their size. Filter size is described in square meters. The larger the surface area in square meters, the greater the area of blood contact with the fibres and thus the potential for improved ultrafiltrate formation.

([Rodda 2003])

Dialysate Composition

The ability to modify replacement fluid (for CVVH) and dialysate (for CVVHD) in order to change plasma composition is one of the major advantages of CRRT. For instance, the concentration of ions such as potassium can be manipulated and the concentration of bicarbonate can be varied to correct a metabolic acidosis (Mehta 2002:344).

The composition of the replacement fluid or dialysate is most commonly a standard solution with predetermined concentrations of base (usually lactate) and ions, however, there may be occasions where customising the solutions proves beneficial.

(Mehta 2002:344).

Since high serum potassium is common in acute renal failure, such commercially prepared solutions are low in this ion, and so it may be necessary to add this to the replacement fluid.

Lactate is used as a buffer in prepared solutions, and is stable in this environment. Solutions containing lactate are suitable for use in most patients, but in the critically ill patient who may have difficulty clearing lactate, as with liver failure, a bicarbonate solution may be necessary.

Bicarbonate is unstable in solution, and so should be added just prior to use (Baldwin, Elderkin and Bridge in Bellomo et al 2002:85)

Hospal manufacture a solution with bicarbonate in a separate compartment, which is mixed with the larger compartment prior to treatment. After mixing of the two compartments, composition of the fluid is represented in the table below;

Calcium Ca ²⁺	1.75 mmol/L
Magnesium Mg ²⁺	0.5mmol/L
Sodium Na ⁺	140mmol/L
Chloride Cl ⁻	109.5mmol/L
Lactate	3mmol/L
Bicarbonate HCO ₃	32mmol/L

Composition of standard replacement or dialysate fluid;

	Blood Mmol/l	Semipermeable membrane	Dialysate / replacement fluid
Sodium	134 -146	↔	140
Potassium	3.4 – 5.0	→	1
Calcium	1.15 - 1.30	↔	1.63
Magnesium	0.7 – 1.1	↔	0.75
Chloride	98 – 108	↔	100
Lactate	< 2.0	←	45
Glucose	3.9 – 6.2	←	10
Urea	3.0 – 8.0	→	0
Creatinine	0.08 – 0.12	→	0

Care of the Patient

The patient who requires CRRT is already ill, may or may not be mechanically ventilated and will have the stressors of hospitalisation well and truly evident. Electrolyte imbalances, as well as uremic states have the potential to cloud or even change the way people would normally behave. Reassurance and explanation of the process of CRRT may help to bring calm to your patient, and their family. Remember, the person in your care knows nothing of the process of CRRT.

The first stage is the insertion of the catheter, (the care of vascular access has been covered previously). Remember, if vascular access is subclavian or jugular, your patient will have their head covered with the sterile drape during insertion of the line. Be there for comfort and reassurance.

Once catheter position has been confirmed, with the circuit primed and filtration orders established it is important that the patient has an adequate blood pressure prior to connection.

BASELINE OBSERVATIONS to establish interventional changes are imperative. This should include blood pressure, heart rate, temperature, respiration rate and CVP (if available).

The flow rate has the potential to change blood pressure, since it is drawing volume from the patients' intravascular space. To overcome this, turn flow rates up according to tolerance, remembering that the faster the flow rate, the more efficient the solute clearance and the potential of clotting in the filter is reduced. Flow rates are usually set at 200mls per minute.

Heart rate may increase due to the initial fall in blood pressure and the body interpreting this as hypovolaemia. This is in response to a decrease in cardiac output, monitored by baroreceptors in the arch of the aorta and the carotid sinus.

(Tortora and Grabowski 2000:688)

Temperature will fall, with the blood in the extracorporeal circuit being exposed to room temperatures. Warming devices are located on the machine to warm replacement fluid, and in some cases the temperature may be maneuvered to suit individuals. If patient temperature continues to fall, the use of blankets, warming blanket or aluminium foil around the circuit can be utilised (Smith, 1999:299)

Respiratory rate may or may not change, but will be influenced by acid – base balance. It is worthwhile to observe respiratory function in conjunction with other haemodynamic parameters.

Central venous pressure monitoring is used as a guide to right ventricular filling. Dynamic changes in CVP corresponding with fluid loading or loss indicate the patients' intravascular volume status. CVP changes with the use of positive end expiratory pressure in mechanical ventilation. (Gomersall and Oh, in Oh 1997:832)

Continuous cardiac monitoring allows for alarm limits to be set on haemodynamic parameters, as well as continuous observation of heart rhythm and rate. ECG changes can be seen in the patient with electrolyte imbalances, peaked T waves may indicate hyperkalaemia. (Porterfield 2002:51)

Blood tests for electrolytes, urea, creatinine, liver function, coagulation and full blood count are required not only to compare with bloods during and after CRRT, but also to formulate treatment regimes. The importance of coagulation studies has been discussed previously. Frequent blood sugar levels are necessary if dextrose is a component of the CRRT fluid

(Cole, L. June 4 004, pers com)

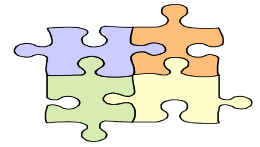
**NORMAL
BLOOD
VALUES**

Na	135 – 145 mmol/L
K+	3.5 – 5.0 mmol/L
HCO ₃	23 – 29 mmol/L
Urea	2.5 – 7.0 mmol/L
Creatinine	60 – 120 μ mol/L

Haemorrhage is a very real possibility for the patient connected to CRRT. The importance of having all lines visible and well secured has been stressed previously. The addition of anticoagulation to the circuit adds to this possible problem, as does an underlying coagulopathy in the patient.

Air Embolus can pose a life threatening situation. Ensuring that all connections are luer locked, and lines secured to the patient will help protect against such an event. However, if an air embolus occurs, your patient will be observed to have difficulty breathing, have pain in the mid chest and shoulder, be pale, nauseated and light headed (Hadaway 2002:104).

Prompt action is required. Place the patient on their left side and in the Trendelenburg position. Administer 100% oxygen and notify the medical staff immediately. This action moves the air embolus away from the pulmonary valve, and the oxygen causes the nitrogen in the air bubble to dissolve (Hadaway 2002:104).



NUTRITION

Recognition of the link between illness, nutrition and recovery is not a new idea. The need for calories to maintain basal metabolism, support growth and repair and for physical activity is imperative in the critically ill. These patients have an increased demand for both calories and protein which is a result of inadequate use of available nutrients (Holmes 1993:28) and (Terrill 2002:31).

The hallmark of metabolic alterations in ARF is accelerated protein breakdown as well as an increase in gluconeogenesis (the building of glucose from new sources) and amino acid release from cells. The process of gluconeogenesis converts amino acids, lactate and glycerol into glucose. Protein synthesis and amino acid uptake by muscle tissue is decreased. (Druml 1998:47)

Haemofiltration, itself can contribute to the loss of amino acids and water soluble vitamins, since they are easily lost through the haemofilter. Replacement of lost nutrients will need to be supplemented (Terrill, 2002:31).

High levels of insulin antagonistic hormones are present in ARF, resulting in high levels of circulating insulin and carbohydrate intolerance. (Terrill, 2002:31)

Care of the Machine

While machines involved in CRRT differ in make and model, the concepts of CRRT do not change. An understanding of the goal will allow for nurses to adapt to the management of different CRRT devices.

Despite the particular make and model, some characteristics are common place. Circuitry, warming devices, alarms and programming are universal.

Circuitry is clear and consists of;

- a venous access line; usually colour indicated blue
- an 'arterial' access line; colour indicated red
- a bubble trap for 'catching' air that may be in the line before its return to the patient
- an area of tubing compliant to a warming device
- thickened areas of clear tubing which are manipulated by the peristaltic action of the machine pumps

The Warming device is responsible for controlling the temperature of the replacement fluid prior to its entry into the circuit. The importance of temperature control has been previously discussed in the care of the patient and observations.

Care of the Machine continued...

Alarms are a key component to not only the safety of the patient, but also to the longevity of the circuit and the filter. Any alarm related to blood flow should be rectified immediately.

A trouble shooting guide to alarms will follow.

The BM25

Manufactured by *Edwards Life Sciences*, the BM25, while effective, is not as 'user friendly' as the Aquarius. There are adult and pediatric circuits available, and blood and dialysate flow ranges are variable. This system offers two scales and three pumps, but a heparin pump is not included. The fluid handling capacity is around 16litres (Ronco et al in Ronco, Bellomo and Greca 2001:326)

While this machine has some advantages, such as ability for high volume CVVH and low cost, it has some disadvantages. There is no screen leading to limited diagnostic ability, the priming procedure is time consuming and trouble shooting can be somewhat difficult.

(Baldwin in Bellomo, Baldwin, Ronco and Golper, 2002:24)

The Aquarius

Manufactured by *Edwards Life Sciences*, the Aquarius is the latest machine to appear on the market for CRRT. The machine comprises of four pumps and two scales and is capable of performing all of the four previously mentioned CRRT techniques. The blood flow rate ranges from 0 to 450ml/minute while the dialysate flow rate can be manipulated 0 and 165ml/minute.

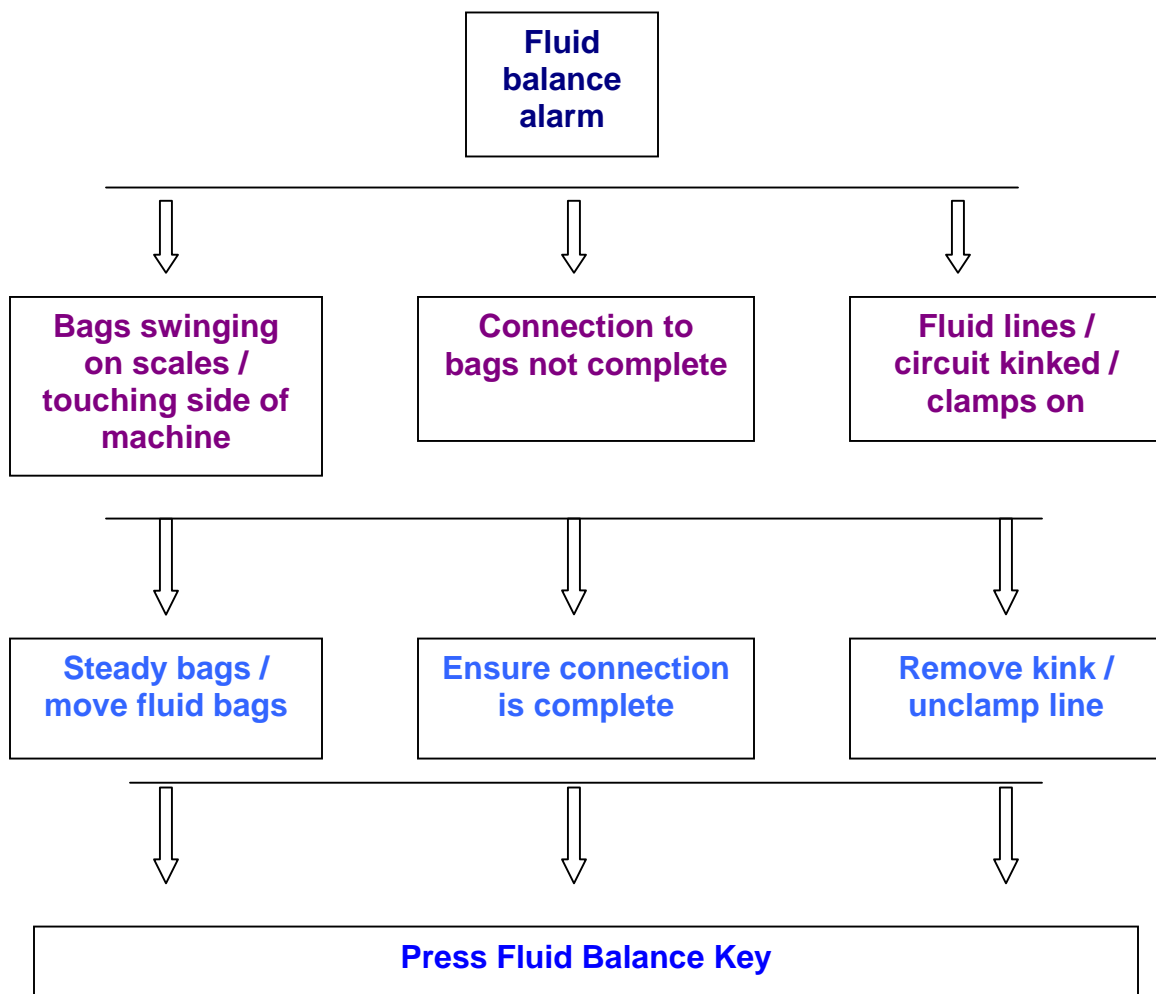
The circuitry is preassembled and colour coded for easy set up. A large colour screen, with a user-friendly interface and an automatic priming procedure make this machine easy to use.

The machine has a built in fluid warmer as well as a heparin pump. Two independent scales are used to accurately calculate continuous fluid balancing, while four pressure sensors assist with extracorporeal circuit function. Both pre and post dilution modes can be utilized as well as a simultaneous pre and post dilution mode (Ronco, Brendolan, Dan, Piccinni and Bellomo in Ronco, Bellomo and Greca 2001:326)

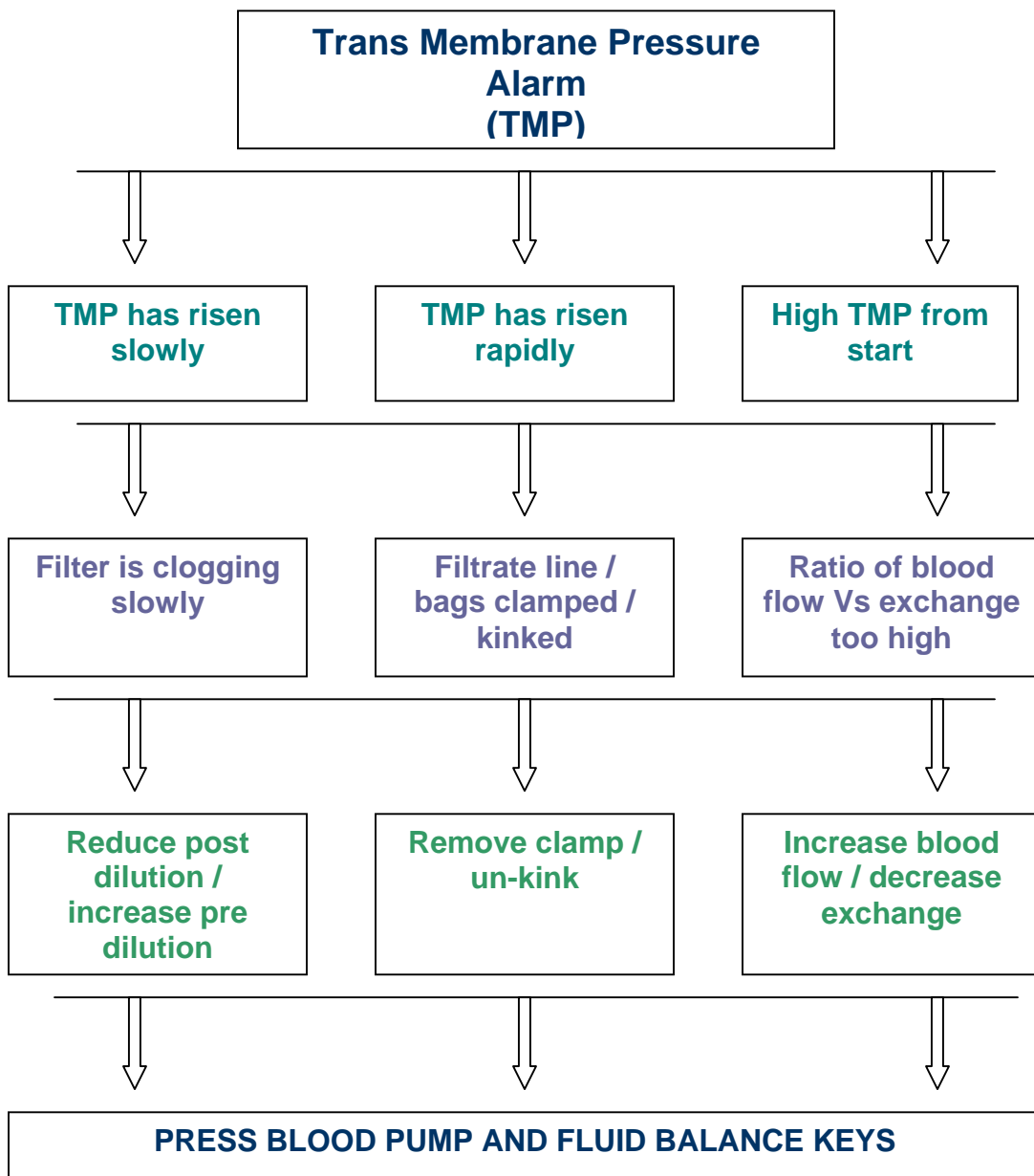
GUIDE TO TROUBLESHOOTING ALARMS...

THE AQUARIUS

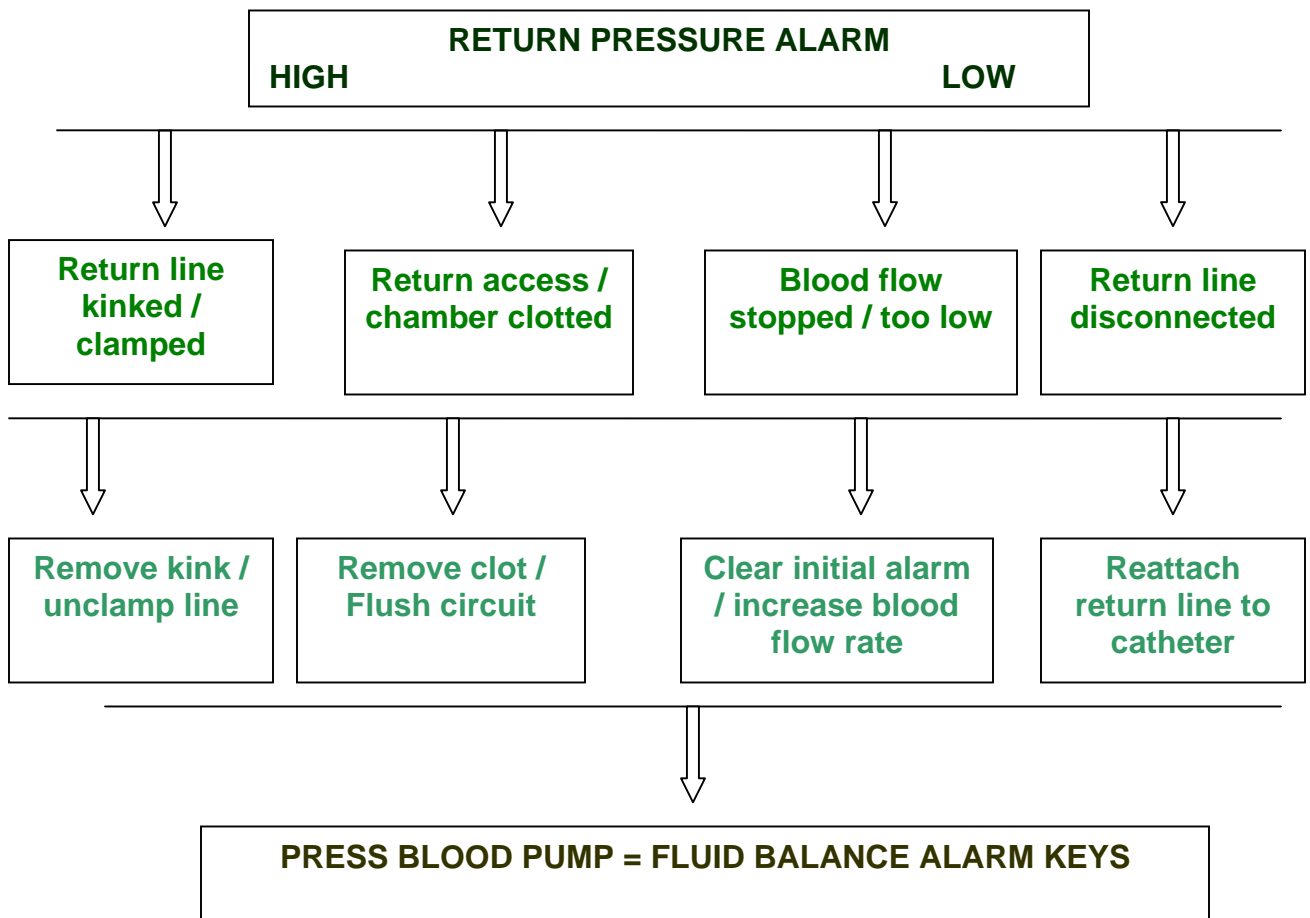
FLUID BALANCE ALARM



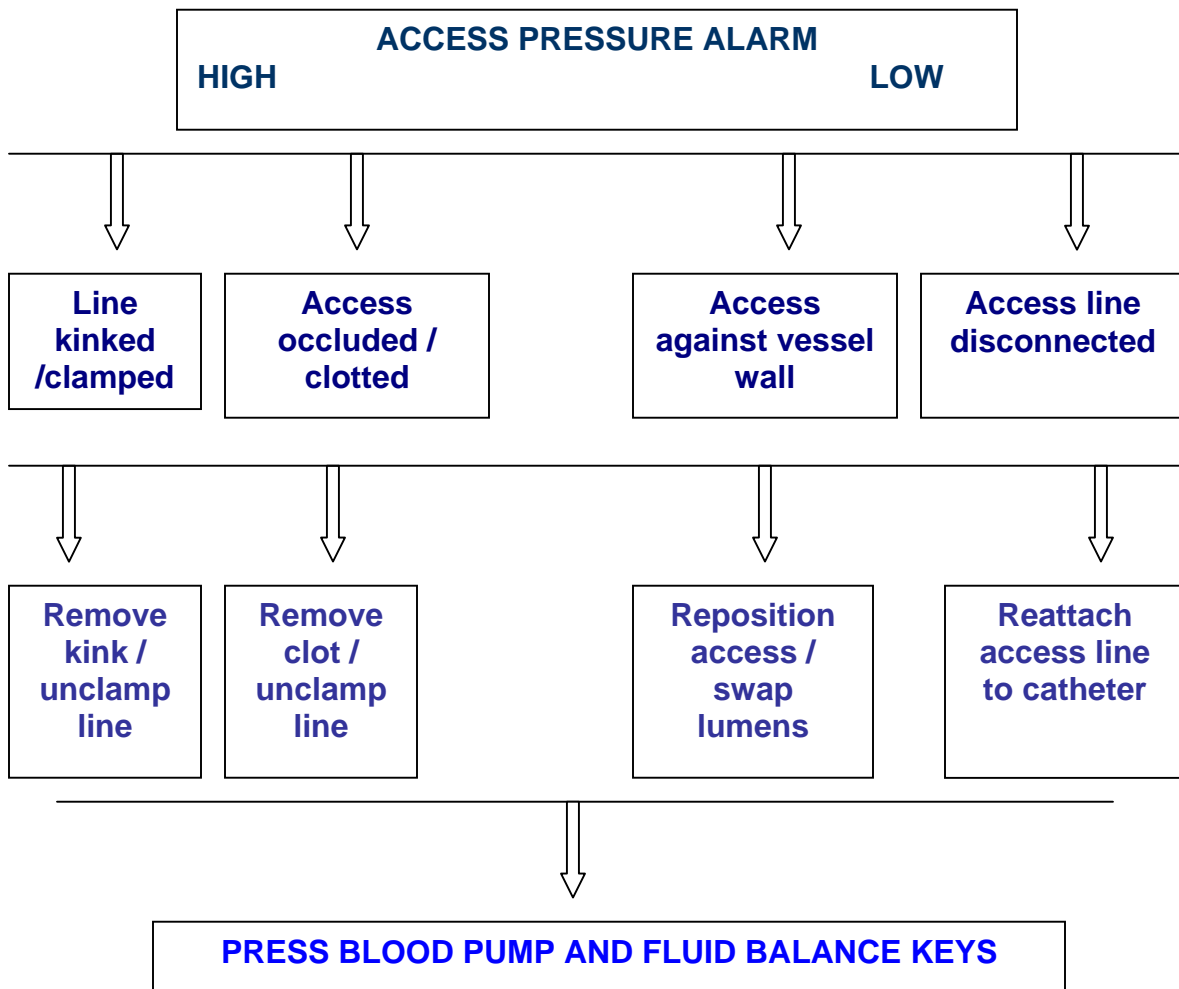
TRANSMEMBRANE PRESSURE ALARM



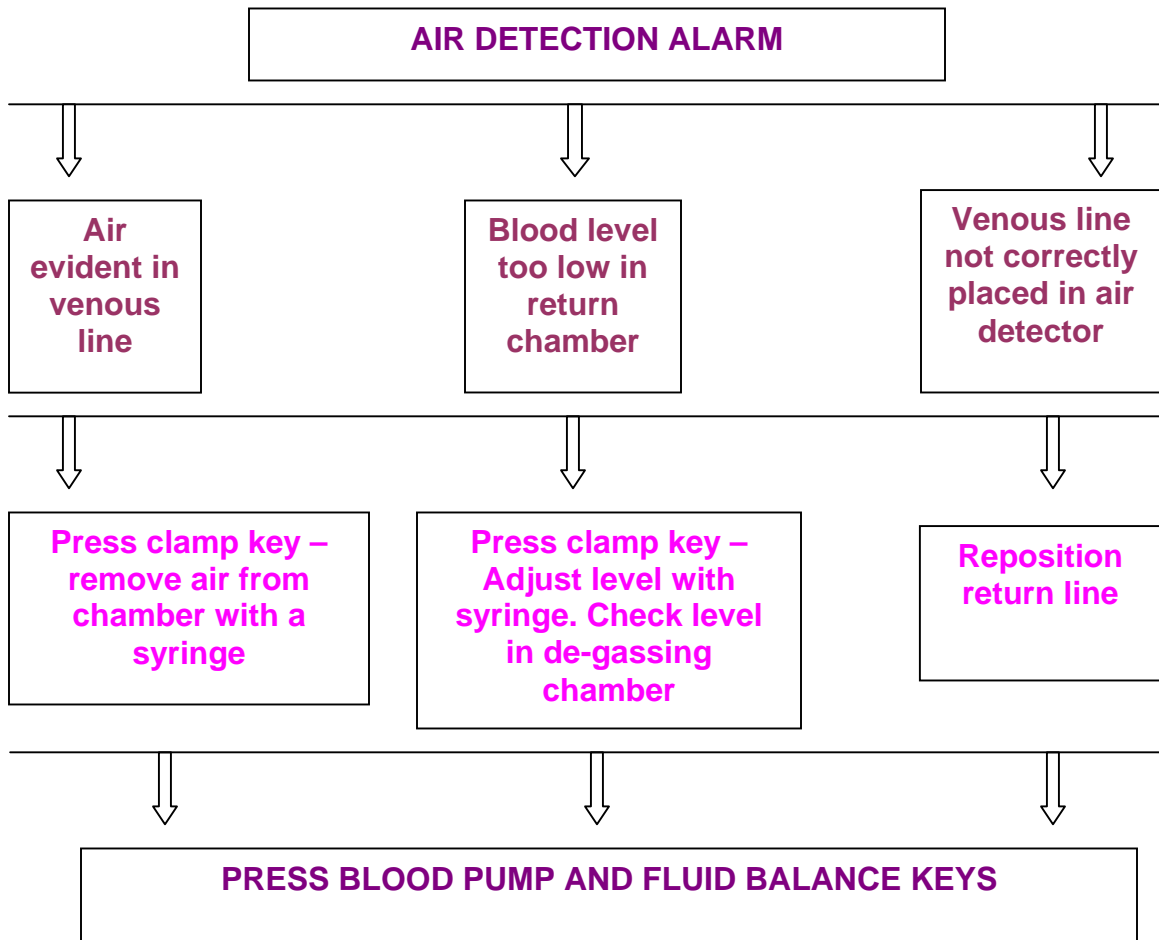
RETURN PRESSURE ALARM



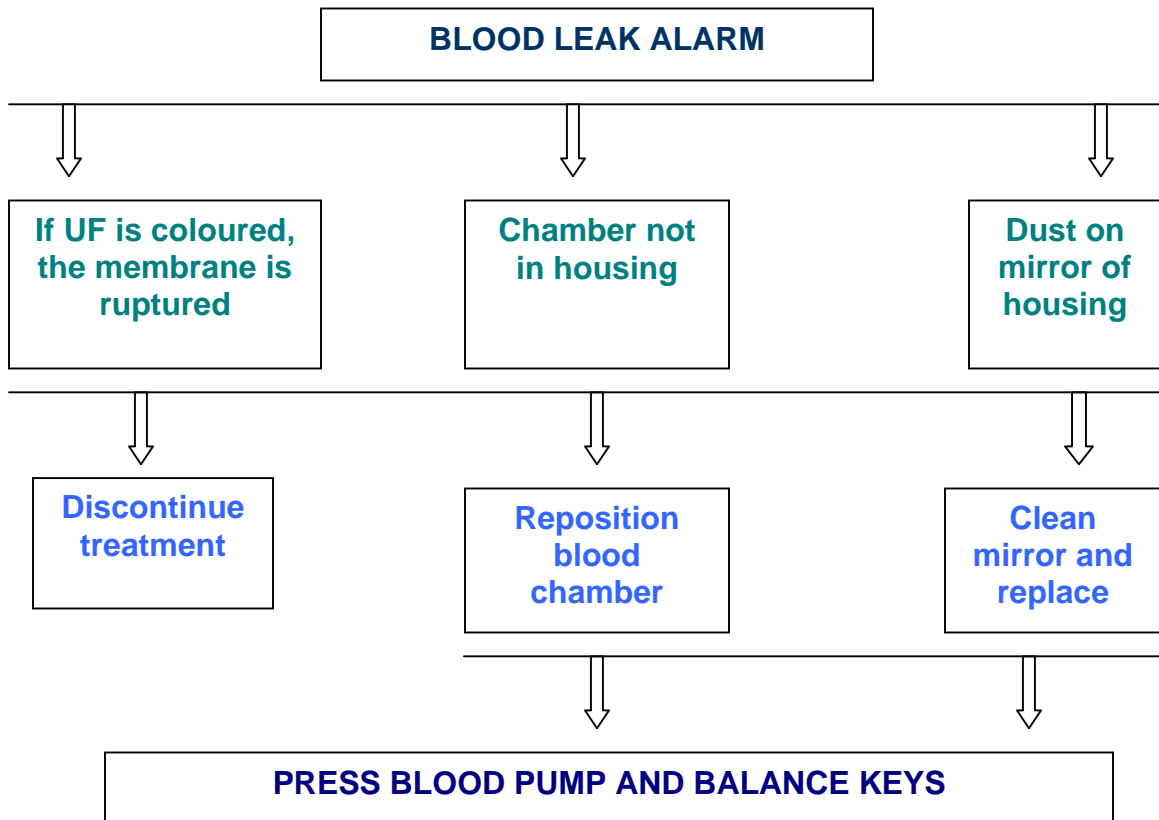
ACCESS PRESSURE ALARM



AIR DETECTION ALARM



BLOOD LEAK ALARM



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