

FOR CRITICAL CARE NURSES

Continuous Renal Replacement Therapy

An Education Package

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The Continuous Renal Replacement Therapy Education Package

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Introduction

Since its conception in 1977, Continuous Renal Replacement Therapies have been increasingly accepted as the chosen form of renal treatment for critically ill and haemodynamically unstable patients in the intensive care unit. This is despite CRRT modes having largely unproven advantages over traditional intermittent haemodialysis techniques. This is due to the lack of enough evidence coming from blinded randomised trials that can truly compare the outcomes between them (Cho, Himmelfarb, Paganini, Ikizler, Soroko, & Mehta, 2006). However, in Australian intensive care units, critical care nurses have embraced the management of patients receiving CRRT treatments which has expanded upon their essential skills and knowledge required to practice safely within the critical care field. Thus the purpose of this education package is to enable new nurses to the critical care environment to effectively manage patients receiving CRRT by imparting a baseline for knowledge, skills and procedures required to do so. As nursing knowledge and skills are continually changing and evolving, the information presented in this package is based purely on the evidence available at this time and it is important that nurses see this knowledge as a starting point, so they can expand, develop and improve on it to increase their personal knowledge as their experience through practice continues.

This education package will cover the following aspects of Continuous Renal Replacement Therapy:

- The kidneys and their normal function
- A brief history of haemodialysis and the conception of CRRT
- Principles used in CRRT
- CRRT compared to normal kidney function.
- Indications and Contraindications for CRRT
- Scope of CRRT
- Differing modalities of CRRT
- Set up and management of CRRT
- Nepean Intensive Care Unit's CRRT accreditation.

The Kidney

The kidney is an essential organ for the healthy functioning of human beings and is the functional organ in the urinary system. Each person normally has two functioning kidneys which are positioned on the posterior abdominal wall on either side of the vertebral column generally from T12 – L3 and lie outside of the peritoneal cavity. They are a bean shaped organ about 11 cm in length, 5 to 6 cm wide and 3 to 4 cm thick. The kidneys are protected and kept in place by a tight fitting capsule (renal capsule) and by layers of fat which cushions them from blunt trauma. The kidneys receive blood from the renal arteries which branch off the abdominal aorta and return blood via the renal vein to the inferior vena cava. These vessels, the ureters and nerves all enter and exit each kidney via an indentation toward the vertebral column called the hilum. The kidney has two layers, the outer layer is called the cortex and the medulla is the inner layer (Huether and McCance, 2006).

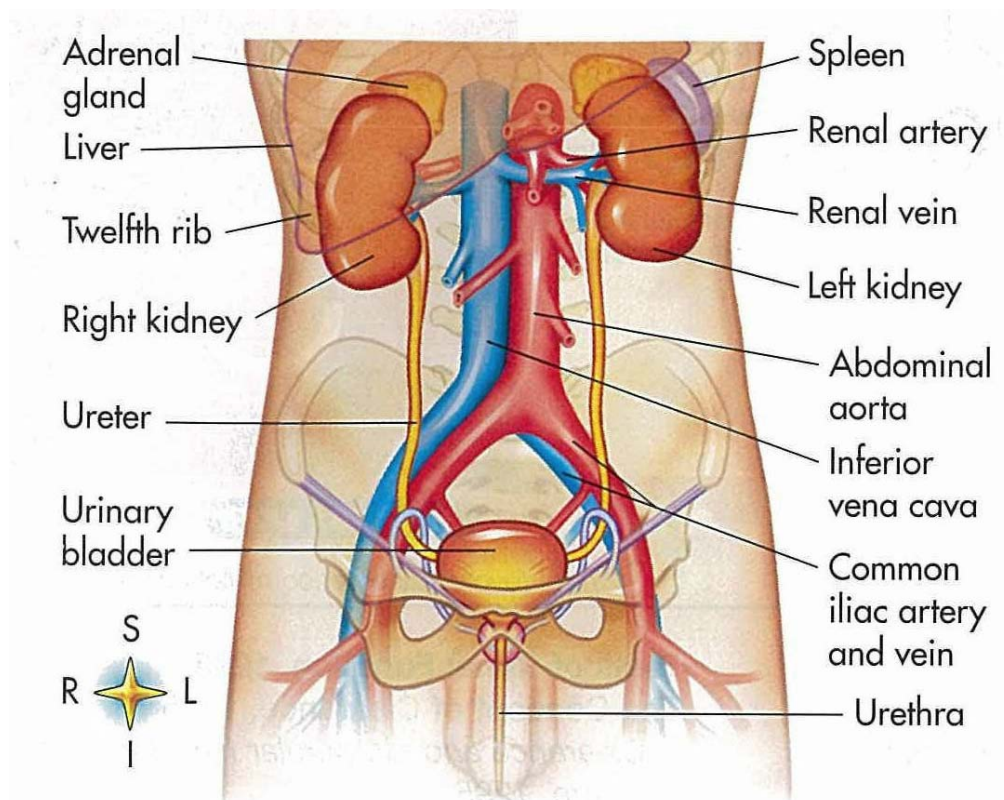


Figure 1: Organs of the urinary system (Huether & McCance, 2006)

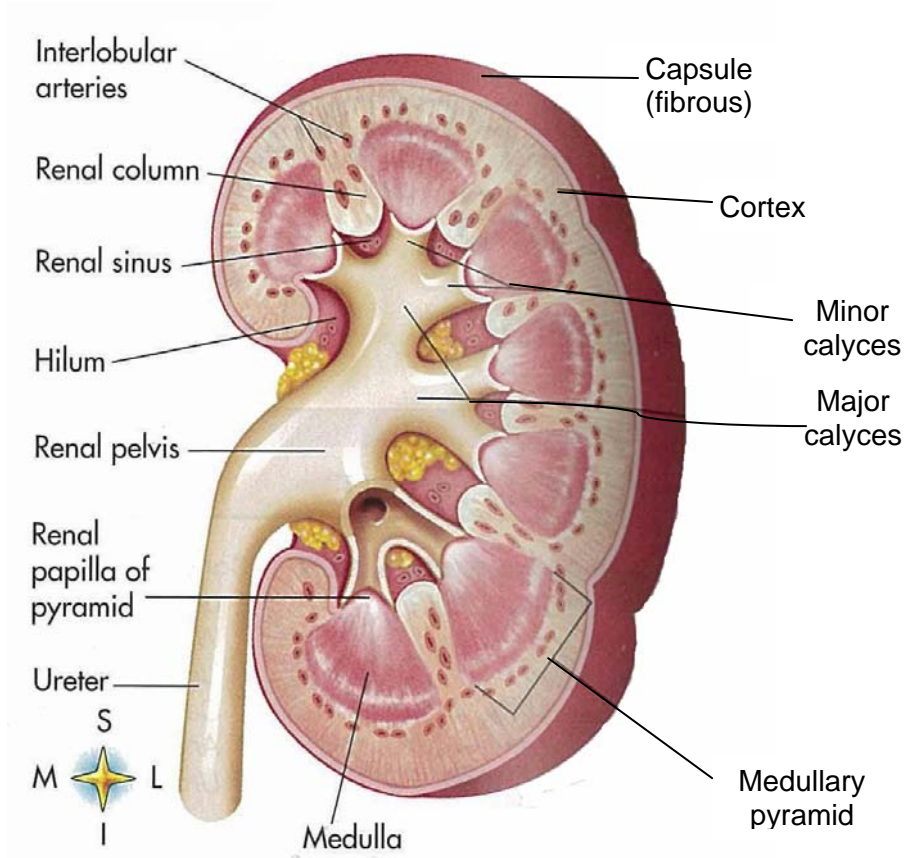


Figure 2: The Kidney (Huether and McCance, 2006)

The functional part of the kidney is called the nephron and each kidney initially has over one million nephrons. The nephron consists of a glomerulus, Bowman's capsule and a tubular system that has a proximal convoluted tubule, Loop of Henle and the distal convoluted tubule. The renal cortex contains the glomerulus, Bowman's capsule, proximal and distal convoluted tubules while the medulla contains the Loop of Henle and the collecting ducts. The distal convoluted tubule empties into the collecting ducts in the renal pyramid and empties into a minor calyx via the point of the pyramids called the papilla. The medulla contains several pyramids that drain the urine formed by the kidneys. These minor calyces connect with other minor calyces, expand and empty into a funnel shaped sac called the renal pelvis. Urine is then drained via the ureters into the bladder for storage (Huether and McCance, 2006).

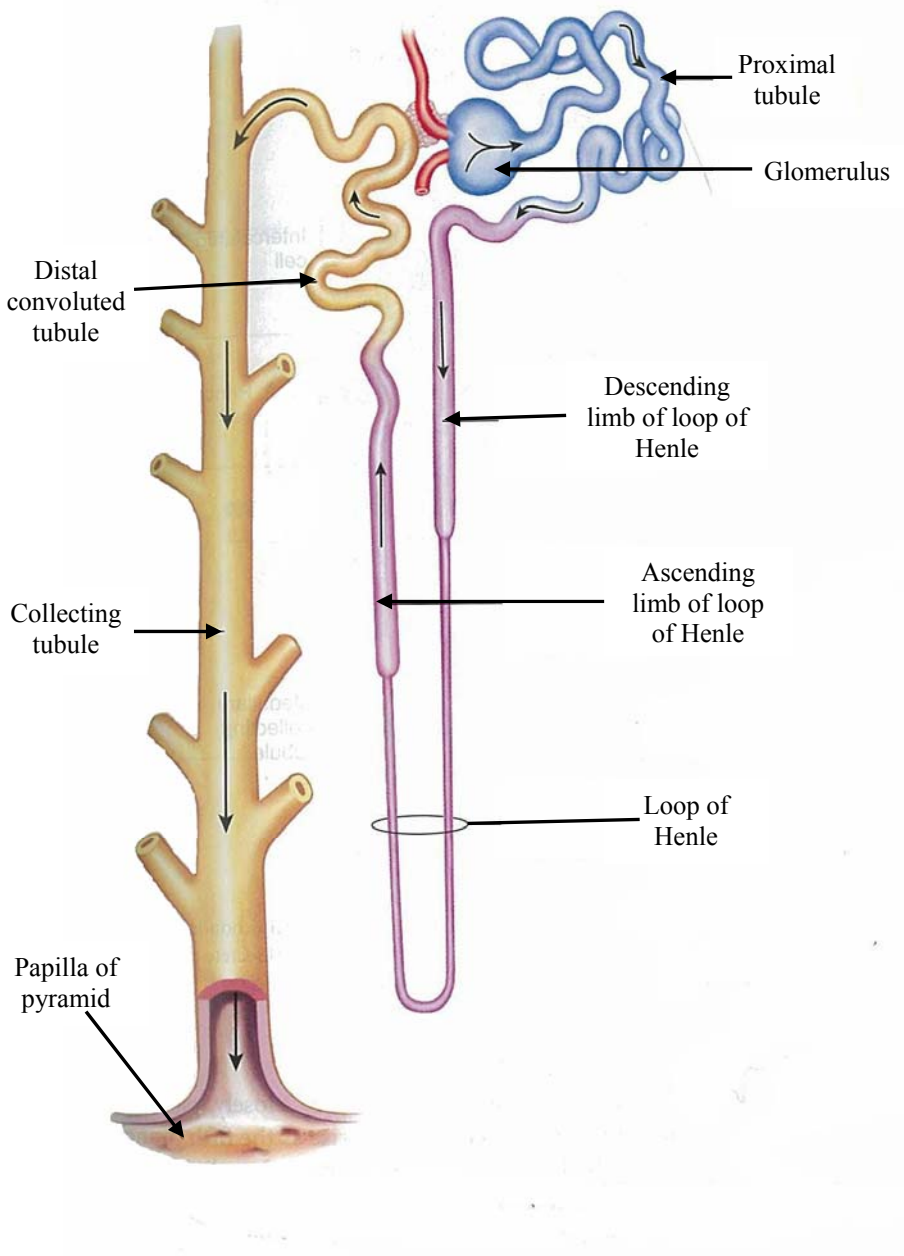


Figure 3: Components of the nephron (Huether and McCance, 2006)

The kidneys receive from 1000 to 1200 mls of blood every minute which is about 20 % of the cardiac output. Blood enters the kidney via the renal artery in the hilum it splits into anterior and posterior branches and then to lobular arteries which supply the three thirds of the kidney. These arteries split into a large system of capillaries which further break down into tiny vessels called afferent arterioles which enter the glomerulus and form four to eight capillaries in loops which are called the glomerular capillaries. The glomerular capillaries then join again in the efferent arteriole

which closely follows the tubular system (for re-absorption and secretion) and then empties into the arcuate vein which will join with other veins and exit the kidney via the renal vein (Huether & McCance, 2006).

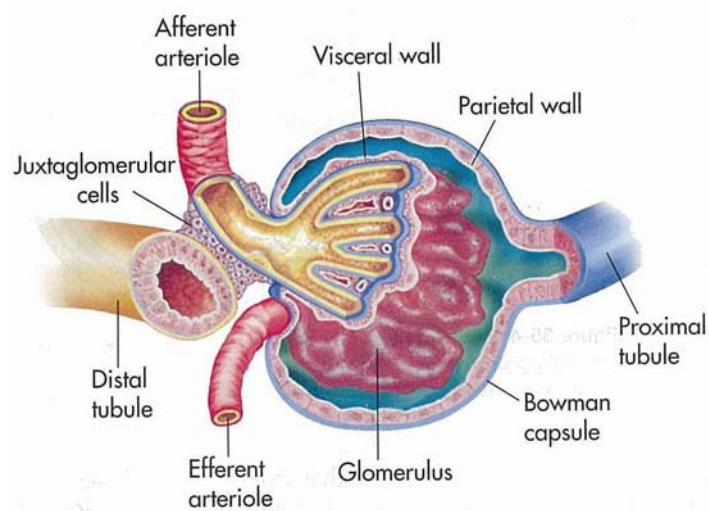


Figure 4: The Glomerulus in the nephron (Huether and McCance, 2006)

What does the kidney do?

The kidney has two main functions in the body; the regulation of the volume and composition of extra cellular fluid and the removal of waste products from the body in the form of urine. However, it also has other essential endocrine functions which are very important to body homeostasis. These include blood pressure control, erythropoietin production, activation of vitamin D, and acid-base regulation (Huether and McCance, 2006).

How does the kidney do this?

In order to complete its main functions, the kidneys perform complex processes within the nephron. This includes glomerular filtration, tubular secretion and tubular re-absorption of water, electrolytes and metabolic waste (Lewis, Heitkemper & Dirksen, 2004).

Glomerular filtration is the primary process of the nephron and as the name suggests occurs within the glomerulus and Bowman's capsule. The blood passing through the capillaries in the glomerulus is filtered by the capillary membranes which allow the majority of molecules to pass through into the Bowman's capsule. The composition of the filtrate is similar to that of blood however it does not contain larger molecules like blood cells and proteins that are retained in the capillaries (Lewis,

Heitkemper & Dirksen, 2004). The glomerular filtration rate relies predominantly on the hydrostatic pressure differences between the capillaries and the bowman's space which in turn relies on good blood flow from the heart. This is considered to be a mean arterial pressure above 60 mmHg (Huether and McCance, 2007). On average a normal glomerular filtration rate is 125 mls per minute (Elliot, Aitken et al. 2007).

As the filtration occurring in the glomerulus is primarily done by the size of the molecules, the majority of the blood volume becomes the filtrate so in the next parts of the nephron extensive secretion of non-essential molecules and re-absorption of essential molecules is done to maintain normal levels in the body (Huether & McCance, 2006). Re-absorption is the movement of molecules from the tubules (containing the filtrate) to the nearby capillaries and secretion is movement of molecules out of the capillaries (containing blood) into the tubules. These processes occur in specific parts of the tubular system depending on the different concentrations of molecules in the blood (Lewis, Heitkemper & Dirksen, 2004).

Filtrate will constantly drain out of the bowman's space and into the proximal tubule. When the filtrate enters the proximal tubule active re-absorption of all the glucose, small proteins and amino acids, with 80% of electrolytes (Sodium Chloride, Potassium ions, Bicarbonate and Phosphate) occurs (Lewis, Heitkemper & Dirksen, 2004). Some molecules are also secreted into the filtrate; including hydrogen ions, foreign substances and creatinine (Huether and McCance, 2006).

In the Loop of Henle the concentration of the filtrate occurs. In the descending loop water is reabsorbed that causes sodium chloride to diffuse back into the blood while urea is being secreted (Huether & McCance, 2006). In the ascending loop chloride ions are reabsorbed via active transport which passively brings across more sodium ions. Thus the filtrate becomes more concentrated (Huether and McCance, 2006).

The distal convoluted tubule is important in final water and acid-base balances (Lewis, Heitkemper & Dirksen, 2004). Here the tubule is affected by several substances to regulate what is excreted or retained. The extra re-absorption of water is reliant on the presence of Anti-Diuretic Hormone (ADH). ADH makes the tubules and collecting ducts permeable to water. It is released from the posterior pituitary gland in reaction to high serum osmolarity or decreased blood volume and relates to the hydration status of the patient. If ADH is not present, water is excreted with the urine (Lewis, Heitkemper & Dirksen, 2004). Aldosterone also affects the re-absorption of sodium and water. It is excreted from the adrenal cortex based upon blood volume and the plasma concentrations of sodium

and potassium and acts on the distal convoluted tubule. Aldosterone causes re-absorption of sodium ions while excreting potassium ions in a process where they literally swap places (Lewis, Heitkemper and Dirksen, 2004).

Acid-base regulation is related to blood pH and the kidney will manage this by re-absorption of bicarbonate (base) and the excretion of hydrogen ions (acid) to maintain pH between 7.35 – 7.45. This forms the metabolic management of acid-base reactions and is generally slower to take effect than respiratory measures.

Blood pressure is maintained by the kidney via the instigation of several systems.

Atrial natriuretic factor (ANF) is a hormone secreted to help manage blood volume and blood pressure (high blood pressures) by inhibiting the effects of ADH on the distal tubule. This causes greater diuresis and thus loss of blood volume. It is monitored by receptor cells (monocytes) in the right atrium. These monocytes measure the blood pressure within the atrium and secrete this hormone if it is too high (Huether and McCance, 2006).

The kidney is integral in the all-important Renin-angiotensin-aldosterone system; the effect of aldosterone on the kidney has already been discussed however the initiation of this system also begins in the kidney. Renin is the trigger for this system, produced and released from the juxtaglomerular apparatus which is connected to the afferent arteriole next to the glomerulus. The juxtaglomerular apparatus monitors the sodium levels in the blood passing through it. Renin acts on Angiotensinogen which is constantly present in the blood and converts it to angiotensin I that is converted to angiotensin II by the presence of Angiotensin Converting Enzyme (ACE). Angiotensin II is a powerful vasoconstrictor that acts on the kidney to reabsorb more sodium and water and increases blood flow to the kidney by raising the blood pressure. This system forms an important part of the sodium and water balancing of the body when blood pressure is high or low. Angiotensin II also stimulates the release of aldosterone from the adrenal cortex (Huether and McCance, 2006).

The last hormone that acts on the distal tubule is parathyroid hormone. This hormone causes the re-absorption of calcium and a decrease in absorption of phosphate ions related to the measured calcium levels in the Parathyroid gland.

After all these processes, the resulting filtrate - which is approximately 1% of the initial volume - is excreted as urine (Elliot, Aitken et al. 2007).

Other functions of the kidney:

The kidney also has two important functions as an endocrine organ. It is essential in the production of new red blood cells in the bone marrow as it is able to recognise a decrease in oxygen carrying capacity and in response releases erythropoietin that acts on the bone marrow to produce further red blood cells. The kidney's other endocrine function is the synthesis of Vitamin D to its active form which has been produced by skin cells exposed to UV radiation (Huether and McCance, 2006).

Renal Failure

Renal failure is the partial or complete reduction of the normal kidney function described above. This is characterized by the inability to remove excess water and metabolic wastes from the body. This subsequently has haemodynamic effects on other systems including blood pressure, blood volume and the blood content (Lewis, Heitkemper, & Dirksen, 2004). Renal failure is classed in two different forms depending on the rate of onset and the cause. The first is Acute Renal Failure (ARF); the second is Chronic Renal Failure (CRF).

Acute Renal Failure

Acute renal failure is usually rapid in onset and is potentially reversible depending on the initial cause and how long it remains untreated (Huether and McCance, 2006). ARF is a common complication of critical illness and the predominant reason why patients require Continuous Renal Replacement Therapies in the intensive care unit (Kellum, Mehta, Angus, Palevskey, & Ronco, 2002). Mortality due to ARF still remains high with over 50% of diagnosed patients dying (Kellum, Mehta, Angus, Palevskey, & Ronco, 2002). This condition is characterised by azotaemia which is the increased levels of nitrogenous wastes in the blood such as urea, creatinine and potassium, and oliguria (urine output less than 400 mls per day). Acute Renal Failure is classed into three different types depending on the causes; pre-renal, intra-renal and post-renal (Lewis, Heitkemper, & Dirksen, 2004).

Pre-renal causes of Acute Renal Failure are the most common, forming approximately 55 – 60% of all ARF cases and are also the most readily reversible. They are related to the reduction of blood flow to the kidneys which reduces the glomerular filtration rate due to decreased glomerular perfusion (and decreased glomerular pressure). Failure to recognise and treat prerenal failure can initiate intra-renal causes such as Acute Tubular Necrosis which is the most common (Huether &

McCance, 2006). Pre-renal Acute renal failure has a number of causes. These are summarised in the following table:

Pre-renal Causes	Intra-renal Causes	Post-renal Causes
<p><i>Hypo-volaemia</i></p> <ul style="list-style-type: none"> • Dehydration • Haemorrhage • Gastro-intestinal losses • Excessive diuresis • Hypoalbuminaemia • Burns 	<p><i>Longstanding Pre-renal ischemia</i></p>	<p><i>Prostatic hyperplasia</i></p>
<p><i>Decreased cardiac output</i></p> <ul style="list-style-type: none"> • Cardiac arrhythmias • Cardiogenic shock • Congestive heart failure • Myocardial infarction • Pericardial tamponade • Pulmonary oedema • Valvular Heart Disease 	<p><i>Injury to the kidney cells</i></p> <ul style="list-style-type: none"> • Certain drugs like gentamycin, amphotericin B • Contrast agents • Haemolytic blood transfusion reactions • Crush injuries • Exposure to lead, arsenic or ethylene glycol. 	<p><i>Bladder cancer</i></p>
<p><i>Decreased peripheral vascular resistance</i></p> <ul style="list-style-type: none"> • Anaphylaxis • Antihypertensive drugs • Neurologic injury • Septic shock 	<p><i>Acute Tubular Necrosis (ATN)</i> <i>Acute glomerulonephritis</i></p>	<p><i>Bladder calculi formation</i></p>
<p><i>Low renal vessel blood flow</i></p> <ul style="list-style-type: none"> • Renal artery or vein thrombosis • Embolism • Heparto-renal syndrome 	<p><i>Thrombosis of kidney vessels</i></p>	<p><i>Neuromuscular disorders</i></p>
	<p><i>Long standing hypertension</i></p>	<p><i>Prostate cancer</i></p>

	<i>Allergies to drugs</i> <ul style="list-style-type: none"> • NSAIDS • Some antibiotics • ACE inhibitors 	<i>Spinal cord disease</i>
	<i>Infections</i>	<i>Strictures</i>
		<i>Trauma to the urethra, ureters or bladder</i>

(Lewis, Heitkemper, & Dirksen, 2004)

Intra-renal acute renal failure is caused by actual permanent damage occurring to the kidney and kidney structures (Huether & McCance, 2006). Acute Tubular Necrosis is the most common cause which can be started from a number of other causes including ischemic events, nephro-toxic chemicals and drugs, surgery, sepsis, burns and trauma. Once damage has occurred it is generally irreversible. However, human kidneys are able to achieve satisfactory clearance of solutes with decreased numbers of functioning nephrons.

Post-renal acute renal failure is the least common cause of ARF and occurs when there is urinary tract obstruction affecting both kidneys at the same time. This produces an increased intra-tubular pressure in the kidneys. Backflow from the occlusion causes the glomerulus and the Bowman’s capsule to lose their hydrostatic difference and thus filtration, secretion and re-absorption will not occur properly. This form of ARF is shown with a slow decrease in glomerular filtration rate (Huether & McCance, 2006).

Chronic Renal Failure

Chronic Renal Failure is usually associated with a slower onset of damage to kidney cellular tissue. This is irreversible and will eventually lead to End-stage Renal Disease with the need for a kidney transplant. The kidneys display incredible adaptive abilities when operating with high solute levels in the blood for long periods of time. To increase kidney life, a careful diet, monitoring and treatment of blood pressure, and regular renal replacement therapies are introduced (Huether & McCance, 2006). The most common causes of chronic renal failure are hypertension and diabetes mellitus (Huether & McCance, 2006).

When the kidneys fail - either through acute or chronic means - they require treatment to support their important functions in the body. With the improvement in technology and monitoring the kidney’s fluid and solute functions can be effectively managed with haemodialysis techniques.

Haemodialysis and history of CRRT

- Haemodialysis

Haemodialysis is defined as “any procedure in which impurities and wastes are removed from the blood.” It is used in renal failure and other toxic conditions. The patient’s blood is shunted from the body in an extracorporeal circuit through a membrane where it undergoes diffusion and ultra-filtration before being returned to the body.” (Mosby, 1994). The current gold-standard in haemodialysis is Intermittent Haemodialysis (IHD) which is usually performed as required over 3 to 4 hours via appropriate access every couple of days. It is able to manage molecules and solutes within the blood stream to close to normal values (Ponikvar, 2003) and is usually managed in specialised units with trained nurses and medical staff. However intermittent hemodialysis also causes significant side effects which has gross effects on already critically ill patients.

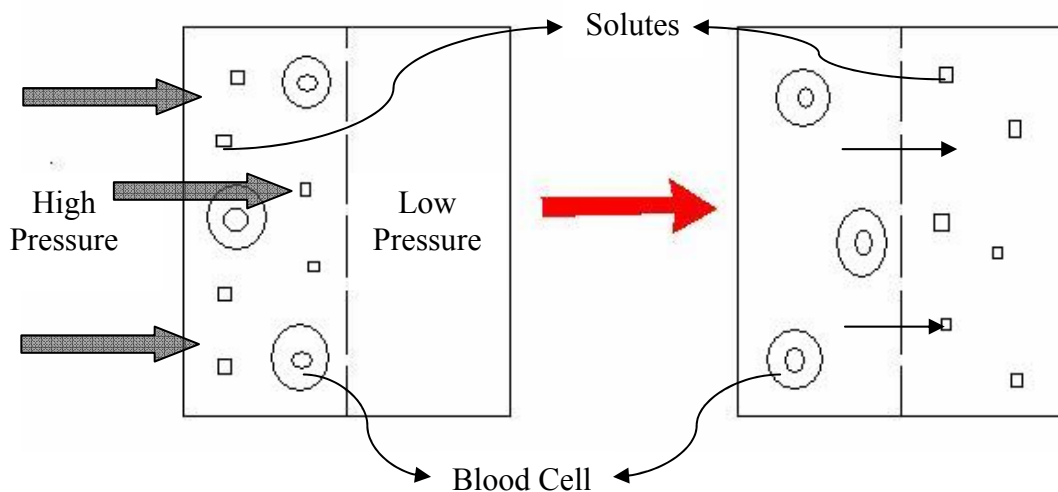
- CRRT history

Continuous Renal Replacement Therapies are also a type of haemodialysis that were born out of frustration on the part of intensive care medical practitioners due to the restrictions of peritoneal dialysis and the delays to the commencement of IHD. Peritoneal Dialysis has been shown to have restricted clearance of wastes and fluids, the risk of the introduction of infections, limiting respiratory and cardiac function as well as making blood glucose levels difficult to manage (Elliot, Aitken, & Chaboyer, 2007; Cho, Himmelfarb, Paganini, Ikizler, Soroko, & Mehta, 2006). Therefore peritoneal dialysis is not recommended for treating adults in the intensive care unit (Ronco, Bellemo, & Ricci, 2001). Normal IHD treatment consisted of 4 hours of treatment every second day and due to haemodialysis machines requiring specialised staff, that meant patients would need transporting to a dialysis unit for treatment. This increased risks to the critically ill patient as well as delaying necessary treatment. IHD was also shown to affect the condition of the critically ill patient adversely in a couple of main areas. These included the increased haemodynamic instability, the fluctuations in uraemic and fluid control and decreased metabolic control (Ronco, Bellemo, & Ricci, 2001).

In 1977 Peter Kramer developed the first of many Continuous Renal Replacement Therapies (Elliot, Aitken, & Chaboyer, 2007). By inserting a catheter into the patient’s femoral artery, blood was directed using an extracorporeal circuit through a semi-permeable membrane and then returned to the catheterised femoral vein. This technique was able to remove plasma water and dissolved solutes at a rate of 200-600 ml an hour via passive drainage using the principles that are now known

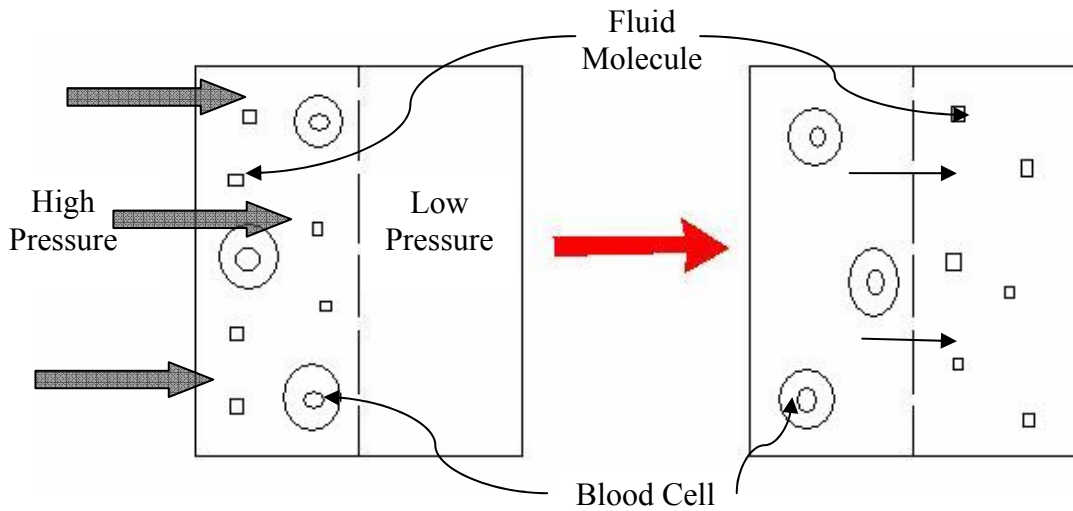
as ultra-filtration and convection (Elliot, Aitken, & Chaboyer, 2007). This was seen to have good therapeutic potential and since then increasing numbers of patients in the intensive care unit require renal replacement therapies (Elliot, Aitken, & Chaboyer, 2007). It was clear at this early stage that CRRT might have some important advantages over IHD including the haemodynamic stability, control of circulating volume, nutritional support and the ability to manage it fully within the intensive care unit (Ronco, Bellemo, & Ricci, 2001). However there were also some shortcomings including the need to catheterise an artery and the limited solute clearance. This prompted the development of further modes, access and machines to allow treatment to be more effective and easier to manage (Elliot, Aitken, & Chaboyer, 2007; Ronco, Bellemo, & Ricci, 2001). With the added advantages of having user friendly machines, access as well as the better solute removal found through the development of more efficient modes, CRRT has become ideally suited for the renal treatment of critically ill patients (Ronco, Bellemo, & Ricci, 2001). Over time however CRRT has not been able to prove itself better than IHD with both having similar morbidity and mortality rates, but this is also due to the lack of well founded studies comparing them (Vinsonneau, et al., 2006).

Different principles involved in CRRT

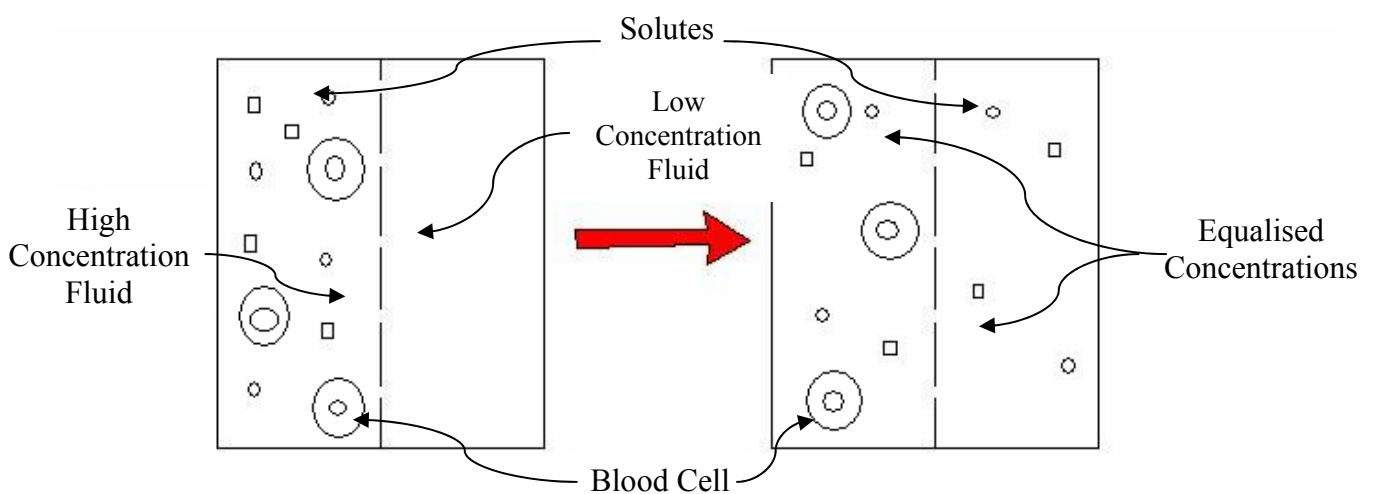


- **Convection:** Convection and ultra-filtration are very similar when it comes to the movement of fluid and solutes. Convection in particular refers to the movement of dissolved solutes/molecules which are in the plasma water across the semi-permeable membrane. It is based upon the movement of fluid from an area of high pressure to an area of low pressure and the size of the molecules which move across are related to the size of the pores in the filter (Palevsky, Bunchman, & Tetta, 2002).

This is similar to the function of the glomerulus in the kidney however instead of using re-absorption and secretion to balance fluids and electrolytes the filtered fluid is discarded and replaced by chemically similar replacement fluid.



- Ultra-filtration:** Is based upon the similar principle to convection as in it is the movement of fluid volume from an area of high pressure to an area of low pressure across a semi-permeable membrane. The difference between ultrafiltration and convection is the first is related to the movement of fluids while the second is related to the movement of dissolved molecules. As large amounts of fluid can be removed during ultra-filtration, replacement fluids are essential reducing the risk of hypovolaemia.



- Diffusion:** Occurs across a semi-permeable membrane along a concentration gradient, where the fluid on one side of the membrane has higher concentrations of a

solute than the other liquid, thus the solute will be drawn across the membrane to the area of low concentration until they have equalised. In CRRT this is done by passing a dialysate fluid reflecting normal blood chemistry counter-current to the blood flow on the other side of the membrane. This means that excess wastes in the blood will diffuse out, plus replacement electrolytes and molecules will diffuse in if necessary.

Both solute removing principles, convection and diffusion, are as efficient as each other when clearing low molecules weight solutes from the blood with middle to high molecular weight solutes being removed more effectively by convective techniques (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002).

Differing modes and treatments of CRRT

With much development and alterations over the years CRRT has become quite versatile in an effort for it to more accurately meet treatment goals in a timely manner. In general CRRT can be defined as an extracorporeal blood purification therapy which is able to treat impaired renal function over extended periods of time with treatment able to run 24 hours a day (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002). CRRT modes have been developed by combining the different principles seen in haemodialysis treatments. Each of the different modes offered by the Aquarius dialysis machine is able to achieve different outcomes through the selective removal of solutes and fluids which will be most beneficial to the patient.

The next section will outline the modes of CRRT dialysis used, and the main principles these modalities adopt in order to remove certain solutes and fluids.

- **SCUF – Slow Continuous Ultra filtration**

This mode of CRRF uses the principle of ultra filtration purely to remove excess fluid from the body and therefore is used to safely treat fluid overload. For this reason fluids removed are generally not replaced. It works by pumping the patient's blood through a filter which separates the fluid and molecules according to the size of the filter pores. These are generally very small in this mode so as not to lose different solutes. Convection does also occur in this mode, however is restricted by the filter pore size and as it is generally not the aim of the therapy this is not important.

- **CVVH – Continuous Veno Venous Haemofiltration.**

This mode of CRRF uses the same principles as SCUF; that is ultra-filtration. However the filter used in CVVH is different from that used in SCUF as convection to remove solutes is more important, so the size of the pores in the filter is increased thus allowing further molecules to pass into the ultra-filtrate. The fluid that is filtered from the blood is then replaced by a suitable fluid with chemistry similar to normal blood which is applied in either pre or post dilution. As this mode uses convection it is useful in removing molecules of all sizes depending on the size of the filter pores. Fluid balance can be managed depending on the amount of replacement fluid infused.

- **CVVHD – Continuous Veno Venous Haemodialysis**

This mode of CRRF uses totally different principles to the previous ones. This mode is driven by diffusion of molecules across a semi-permeable membrane along a concentration gradient. A dialysate with similar chemistry to normal blood is pumped counter-current to the blood through the filter. Any molecules that are in greater concentration in the blood are drawn across into the dialysate and removed from the body. Molecules which are low in the blood are also replaced by the normal levels in the dialysate. Generally diffusive principles are more effective for removing small sized molecules (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002). In this mode replacement fluids are not administered.

- **CVVHDF – Continuous Veno Venous Haemodiafiltration.**

This mode of CRRT is able to combine ultra filtration, convection and diffusion to enable the ultimate removal and replacement of solutes and fluids within the blood. Combined to the fluids and molecules removed via convection and ultrafiltration the filter has a dialysate running counter current to blood flow to increase diffusive clearance. Ultra-filtration and convection also help with fluid and solute removal with fluids being either partially or fully replaced (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002).

- **TPE – Therapeutic Plasma Exchange**

This mode is designed to separate the plasma from the other formed parts of the blood through a special filter membrane. The plasma is then replaced by a mixture of fresh frozen plasma and albumin (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002). Plasma exchange has shown good results in removing harmful cytokines in conditions like myasthenia gravis, Guillian-Barre Syndrome, Good pasture syndrome and thrombotic thrombocytopenic purpura (TTP) (Ponikvar,

2003). There are also theoretical benefits in the treatment of severe sepsis however the beneficial effects have yet to be proven with randomised trials (Ponikvar, 2003).

- **Haemoperfusion**

Is an extracorporeal treatment that passes the patient’s blood through a filter impregnated with an absorptive substance, for example, charcoal. This is able to bind to certain toxins in the blood stream which removes them, returning the cleaned blood to the patient (Kellum, Mehta, Angus, Palevskey, & Ronco, 2002). It has been shown to be effective against drugs like digoxin, glutethimide, phenobarbital theophiline and paraquat among others, and allowed patients to maintain normal levels of essential molecules (Ponikvar, 2003).

- **Dialysate fluids; the differences.**

There are currently two different types of dialysate fluid used in CRRT in most intensive care units, one being a lactate based solution and the other a bicarbonate based fluid. In CRRT modes these fluids are pre-prepared and packaged ready to use typically in 5 litre bags which are hung below the machine (Elliot, Aitken, & Chaboyer, 2007). Dialysate fluids are designed to mimic normal blood chemistry as closely as possible so as to encourage the correct amount of diffusion in the system if that technique is being used, but also to ensure that as a replacement fluid it does not cause imbalance in the blood chemistry. Therefore to create the correct therapeutic action the chemistry of dialysate fluid does not differ all that much apart from the buffer agent used (Kellum, Mehta, Angus, Palevskey, & Ronco, 2002). As the names suggests one uses lactate and the other uses bicarbonate. The table below shows a summary of the chemical differences:

Component	Bicarbonate-based solution (mmol/L)	Lactate-based solution (mmol/L)
Buffer	25.00	45.00
Potassium	0.00	1.00
Sodium	140.00	140.00
Glucose	0.00	10.00
Calcium	1.63	1.63
Magnesium	0.75	0.75
Chloride	100.75	100.75

(Elliot, Aitken, & Chaboyer, 2007)

There has been research completed into which replacement fluid produced better outcomes as there was concern that lactate-buffered fluids would reduce heart performance. It has been found that lactate based solutions are not recommended for patients with cardiac or liver failure, as in a healthy liver the lactate would be converted into bicarbonate. However people with liver dysfunction find that too much lactate remains causing increased acidaemia (Elliot, Aitken, & Chaboyer, 2007). Even though bicarbonate solutions have shown this advantage over lactate based solutions in critical care, the lactate based solutions are cheaper and more stable in solution than bicarbonate ones and are generally used unless the patient has cardiac or liver issues (Elliot, Aitken, & Chaboyer, 2007; Kellum, Mehta, Angus, Palevsky, & Ronco, 2002).

Complications of CRRT

Patients who undergo Continuous Renal Replacement Therapies are vulnerable to many complications especially when they are critically ill.

The first major complication of CRRT is hypotension. Even though CRRT is gentler on a patient's haemodynamic status, it can cause a drop in blood pressure. This is usually easily compensated for by the patient but in some cases inotropic support may be required to maintain effective mean arterial pressures.

The second major complication of CRRT is the risk associated with anticoagulation therapies including bleeding and coagulopathy (Vanholder, Van Biesen, & Lameire, 2001). Although the patient's coagulation status is carefully monitored it is important to look for other signs of bleeding such as a decrease in haemoglobin levels or drop in blood pressure. Blood can also be lost in other ways too if the membrane ruptures or the patient's blood was unable to be returned (Lewis, Heitkemper, & Dirksen, 2004).

Another complication of CRRT is the introduction of infection through poor aseptic technique when handling the CRRT circuit, filter and vascath. It can also develop when a vascath has been in the patient for an extended period of time, particularly in a femoral site, as these vascath lines have a shorter life span (Lewis, Heitkemper, & Dirksen, 2004). Nurses should always be monitoring for signs of infection like redness, swelling and heat at the site, increased temperature and increased white blood cells (Lewis, Heitkemper, & Dirksen, 2004). Due to the cooling effect of drawing blood outside the body, nurses should also ensure the patient is not too cold either.

CRRT can cause electrolyte and acid-base imbalances if not managed correctly, so nurses must be constantly monitoring the patient for the signs and symptoms and looking at blood results (Lewis, Heitkemper, & Dirksen, 2004).

Indications for CRRT (conditions requiring CRRT)

The predominant indication for CRRT in intensive care is the diagnosis of Acute Renal Failure where the patient is haemodynamically unstable however; CRRT has also proven beneficial in cases of drug toxicity. Proposed criteria for commencing a critically ill patient on CRRT treatments include:

- Oliguria (200ml in 12 hours)
- Anuria (less than 50ml in 12 hours)
- Hyperkalaemia (Potassium >6.5 mmol/L)
- Severe acidaemia (pH <7.1)
- Azotaemia (urea >30 mmol/L)
- Significant organ oedema (lung or heart overload)
- Uraemic encephalopathy
- Uraemic pericarditis
- Uraemic neuropathy/myopathy
- Severe dysnatraemia (Sodium >160 or <115 mmol/L)
- Hyperthermia
- Drug overdose with dialysable toxin.

(Elliot, Aitken, & Chaboyer, 2007)

It is still controversial in clinical benefit but it has also been found that certain inflammatory markers and infecting organisms can be effectively removed using CRRT techniques. This could be helpful in treating patients with severe sepsis as well as auto-immune diseases; however this is yet to be proved in a reliable study (Vanholder, Van Biesen, & Lameire, 2001)

Contraindications for CRRT

The main contraindication for CRRT is the necessity to have treatment outcomes reached quicker than the CRRT treatment is able (Lewis, Heitkemper, & Dirksen, 2004).

Management of CRRT

Access

As the access required for CRRT is generally only temporary for the treatment of ARF the access of choice in intensive care currently is a dual-lumen centrally placed venous catheter (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002). Venous catheters also provide better solute and fluid clearance than arterial powered methods due to the use of pumps to maintain pressures and fluid movement (Kellum, Mehta, Angus, Palevsky, & Ronco, 2002).

Vascaths

Vascular catheters are placed by a medical practitioner during a sterile procedure into either the internal jugular, sub-clavian or femoral veins and are secured by a suture like a normal central line. Before the vascath can be accessed an x-ray must be performed and checked by the medical practitioner to ensure correct placement in the vessel as well as checking for any complications associated with central line insertion, including pneumothorax. The doctor may also take a blood sample tested on the gas machine to ensure that it is from a venous vessel. Once the position of the catheter is confirmed it is ready to use. Vascaths usually have a lifespan of 7 – 10 days when they are placed in the sub-clavian or internal jugular veins and up to 5 days when placed in the femoral vein. As nurses it is our job to try and extend the lifespan of the vascath as long as possible. This is done by attending to some simple cares which help reduce the possible complications. The main complications of vascaths are the introduction of infectious organisms and the clotting of the lumens.

Infections are decreased by always maintaining good hand washing and aseptic techniques when coming in contact with the vascath. A vascath site needs to always have an intact occlusive clear (IV 3000) dressing over the top so that there is less chance for infections to be introduced. But also that signs of infection like redness, swelling, pain and discharge can be witnessed if present around the insertion site. Dressings are routinely changed every Monday and Thursday using aseptic technique with chlorhexidine and alcohol solution. When not in use the ends of the blue and red lumens of the

vascath need to be kept sterile and so should always have the red luer-lock caps in place. Generally if there are any signs of infection around the site the vascath will need removing as soon as possible with the tip sending to pathology for culturing.

Clotting occurs naturally when something alien is introduced into the body. This will occur more when blood is static in the lumen which happens when the vascath is not in use. So to prolong the life of a vascath when it is not going to be used for over four hours, an anticoagulant is flushed into the dead space of each lumen to help prevent clotting at the local vascath level, without affecting the systemic coagulation status (Elliot, Aitken, & Chaboyer, 2007). The Anti-coagulant of choice is generally heparin and is done in a procedure called “heparin locking”. Heparin locking should be done as soon as possible once a treatment has concluded but also removed and replaced every two days if the vascath has not been used.

For the equipment and procedure involved in heparin locking a vascath see the section in procedure for ceasing treatment.

AV fistulas

When it is seen that renal replacement therapy will be required for longer than a temporary treatment especially in chronic renal failure patients then formation of an AV fistula in the patients forearm will be considered. This involves a surgical procedure which joins an artery and a vein together in the forearm to produce a vascular access point which is accessed with large bore needles. Patients who have these procedures done are on long term treatment with Intermittent Haemodialysis and are usually managed by specialist dialysis staff (Elliot, Aitken, & Chaboyer, 2007).

The Set up for Connection


The CRRT order form

In intensive care units medical staff will order continuous renal replacement therapies on a specialised form which will outline the necessary parameters and treatment goals. The order form must include the following:

- Patient’s name, medical record number, address, date of birth and sex for identification purposes.

- The patient's pre treatment weight (you may need to take one if not done)
- The prescribed fluid balance for the patient which will either be negative a certain volume or neutral.
- The type of replacement fluid (Dialysate): Lactate or Bicarbonate based fluid.
- Type of anticoagulation for the circuit: Heparin, Regional heparinisation, citrate or no anticoagulant. (This will be related to the patients current coagulation blood results and so should be checked prior to commencing treatment)
- If heparin is selected then the hourly rate in units/kilogram/hour and a heparin bolus (usually 2500 units).
- The Machine settings: Effluent rate 25 ml/kg/hr or 40 ml/kg/hr, a Dialysate rate in ml/hr and postdilution replacement rate in ml/hr which will usually be set at the same speed.
- The type of filter: Either a GAMBRO filter or an EDWARDS filter which has two different sizes according to surface area; the 1.2 or the 1.9.
- The order form also has some standing orders according to electrolyte replacement which are: If the patient's serum potassium level drops below 4.0 mmol/L then add 15 mmol of Potassium Chloride to each 5 litre bag of replacement fluid. If the patient's serum phosphate level drops below 1.0mmol/L then KH_2PO_4 will need to be prescribed for replacement.
- The order form finally requires a doctor's signature with a date and time.

- This is an example order for Continuous Veno Venous Haemodiafiltration:

 Wentworth Area Health Service	MRN: <u>04-35-69</u>
	NAME: <u>JOHN CITIZEN</u>
RENAL study no: <u>N/A.</u>	ADDRESS: <u>45 GEORGE STREET</u>
Patient weight = <u>80</u> kg	<u>SYDNEY 2000</u>
	DOB: <u>2/9/1953</u> SEX: <u>M</u>
	(affix sticky label here)

NEPEAN INTENSIVE CARE HAEMODIAFILTRATION DAILY ORDERS

1. HOURLY PATIENT FLUID BALANCE: Neutral or negative 100 ml/h
(Please see back page for definitions)

2. LIST FLUID BOLUSES NOT INCLUDED-IN PATIENT INPUT -

3. REPLACEMENT FLUID:

Lactate (HRF) or Bicarbonate (Hemosol) or RENAL study (Hemosol)

4. ANTICOAGULATION: No anticoagulant or Heparin or Regional heparinisation
or Citrate or Other

Commence heparin infusion at 10 units/kg/hr or _____ units/kg/hr

5. HEPARIN BOLUS at patient connection (2500 units) Yes or No

6. MACHINE SETTINGS: Effluent default 25 ml/kg/hr or 40ml/kg/hr

Dialysate rate 1000 ml/hr Post-filter replacement rate 1000 ml/hr

7. FILTER: RENAL study (GAMBRO Nephral) Edwards 1.2 or Edwards 1.9

8. STANDARD ADDITIVES: If patient's serum K < 4.0mmol, add 15 mmol KCl to each 5 litre bag of replacement fluid. Prescribe additional KH₂PO₄ on the flow chart if patient's serum phosphate is < 1.0mmol/L (may need 60mmol/daily if patient is on high dose RENAL).

MO's SIGNATURE:  Date/Time: 5/11/2008 0800 hrs

MEDICAL ORDER CHANGES			
DATE	TIME	CHANGES	SIGNATURE

In this example order these are the set parameters:

- The CRRT mode ordered is CVVHDF.
- Fluid balance: negative 100 ml an hour
- Replacement fluid: Bicarbonate (Hemosol)
- Anticoagulation: Heparin at 10 units per kilogram per hour
 - Heparin bolus of 2500 units
- Effluent rate at 25ml/kg/hr
- Dialysate rate and post- filter replacement rate at 1000 ml/hr.
- Filter chosen was the 1.2 Edwards filter.

Calculating parameters (Especially fluid status)

Using the order shown before, here is an example of how to calculate the required fluid removed per hour set in the Aquarius to meet the order. To calculate this number you need to know all of the patient's regular fluid inputs including intravenous infusions, enteral feeding and fluid boluses.

The Calculations:

Hourly input = ((Hourly fluid intake × 24) + fluids received in 24 hours) ÷ 24 hours

Hourly balance = hourly input – hourly average output

Set Aquarius fluid balance = hourly balance + prescribed fluid removed

For the sake of this example, John Citizen has a central venous catheter which has 10 mls of normal saline an hour, a fentanyl infusion (2000mcg in 100ml of normal saline) running at 5 ml/hr, a midazolam infusion (100mg in 100ml of normal saline) running at 5 ml/hr and a nor-adrenaline infusion (6mg in 100ml of normal saline) running at 5ml/hr. Enteral feeds are running at 80 ml/hr and the patient receives an average of 200 mls of liquid boluses for medication administration during a 24 hour period. There is no current output but usually you would include drains catheters and suction canisters.

$$\begin{aligned}\text{Hourly input} &= (((10 + 5 + 5 + 5 + 80) \times 24) + 200) \div 24 \\ &= (((105) \times 24) + 200) \div 24 \\ &= (2520 + 200) \div 24 \\ &= 2720 \div 24 \\ &= 113 \text{ ml/hr}\end{aligned}$$

$$\begin{aligned}\text{Hourly balance} &= 113 - 0 \\ &= 113 \text{ ml/hr}\end{aligned}$$

$$\begin{aligned}\text{Aquarius Set fluid balance} &= 113 \text{ ml/hr} + 100 \text{ ml/hr} \\ &= 213 \text{ ml off an hour}\end{aligned}$$

Calculating rate of heparin infusion and bolus:

$$\begin{aligned}\text{Heparin infusion rate} &= (\text{Ordered heparin dose} \times \text{patient's weight}) \div (\text{infusion strength} \div \text{infusion volume}) \\ &= (10 \text{ units per hour} \times 80 \text{ kg}) \div (25000 \text{ units} \div 50 \text{ ml}) \\ &= 800 \text{ units per hour} \div 500 \text{ units/ml} \\ &= 1.6 \text{ ml/hour}\end{aligned}$$

$$\begin{aligned}\text{Heparin Bolus} &= \text{Units required} \div (\text{infusion strength} \div \text{infusion volume}) \\ &= 2500 \text{ units} \div (25000 \text{ units} \div 50 \text{ ml}) \\ &= 2500 \text{ units} \div 500 \text{ units/ml} \\ &= 5 \text{ ml}\end{aligned}$$

Equipment required and setting up circuit correctly

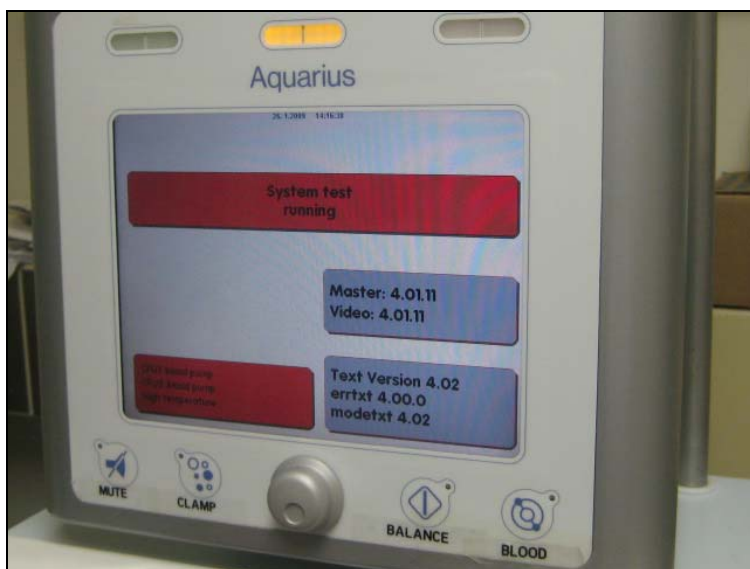
Equipment:

- 2 × 1000 mls 0.9% Sodium Chloride
- 45,000 units of heparin (9 ampoules of 5000 units in 1 ml) or citrate as ordered.
- 1 × 500mls of 0.9% Sodium Chloride
- 1 × standard IV giving set
- 1 × 50 ml BD syringe
- 5 × 10 ml poly ampoules of 0.9% Sodium Chloride
- Dressing pack
- Sterile gloves
- 70 % Chlorhexidine solution (Pink tinted)
- 5 × 10ml syringes
- 2 × 19 gauge needles (sharp)
- 4 × additive labels
- Potassium Chloride poly ampoules (if ordered)
- Dialysate solution (Either Lactate or Bicarbonate 5 litre bags)
- The Aquarius haemodialysis circuit
- Dialysis filter (size and type as per order)
- 3 IV spikes.

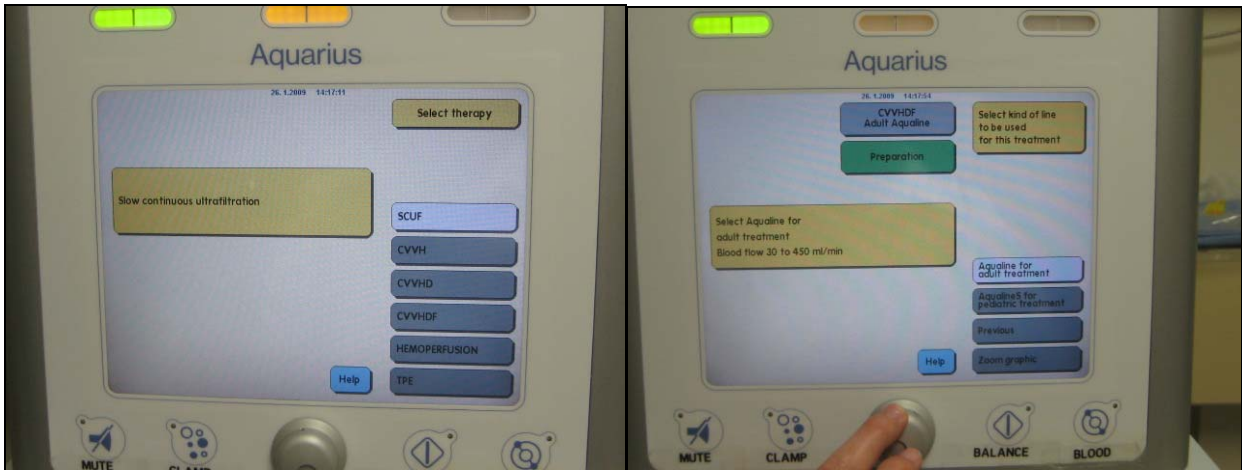
Setting up the circuit:

General:

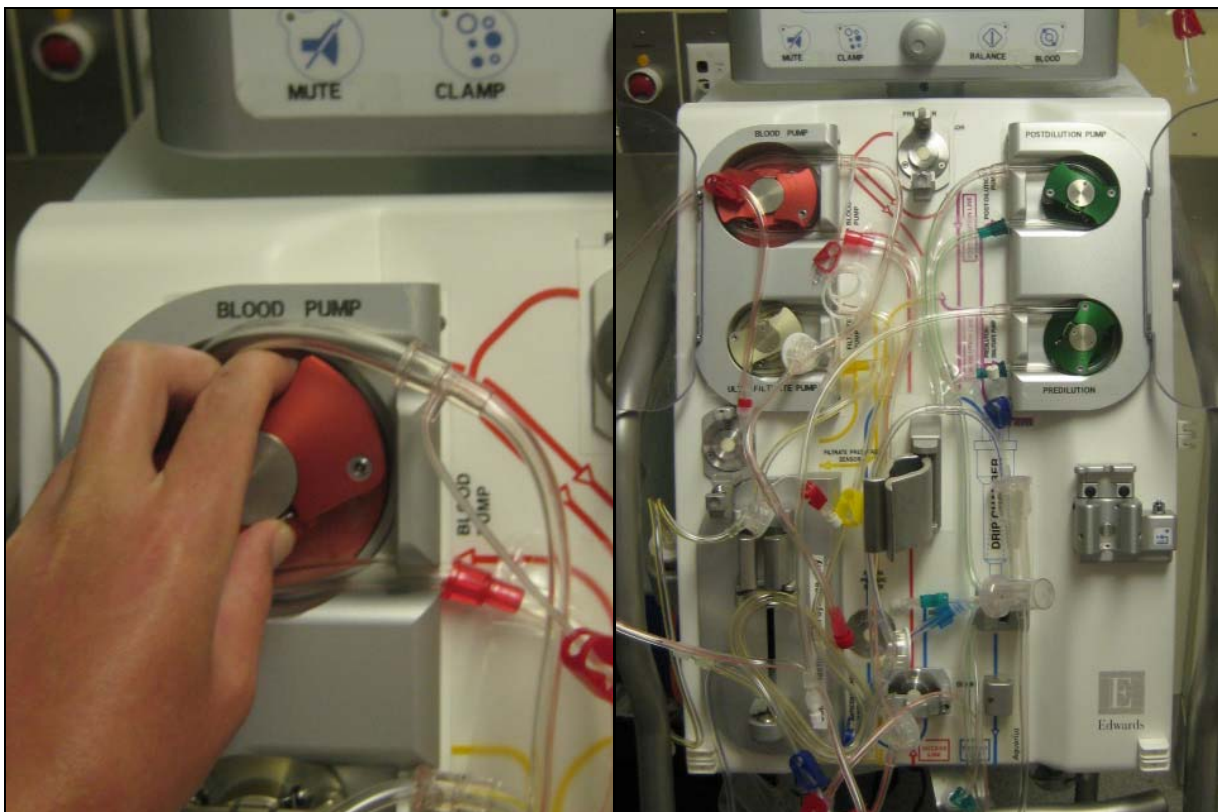
1. Bring Aquarius machine to the bedside, plug into the wall and switch on. The machine will do a brief self test.



2. Prepare the priming solutions which will be the two one litre bags of normal saline and add 10000 units (2 ampoules of 5000 units) of heparin in each bag if that is the chosen anticoagulant. Affix the additive labels.
3. Prepare the heparin infusion (if ordered) in the 50ml syringe by drawing up 25000 units of heparin (5 ampoules of 5000 units) and top up to 50 ml with normal saline poly-ampoules. End concentration should be 500 units per ml. Affix additive label and keep clean by putting a blunt cannular on the end.
4. Once the Aquarius machine has finished its self-test: Select the ordered therapy: (SCUF, CVVH, CVVHD, CVVHDF, TPE or Haemoperfusion)



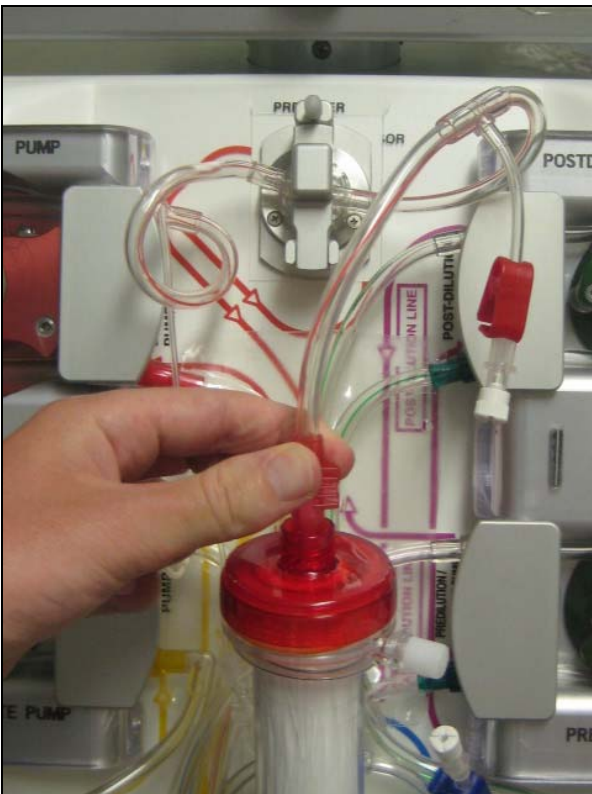
5. On the Aquarius machine screen will be displayed the set up procedure step by step with detailed diagrams to help you. If in doubt always use these to guide you.
6. Open the Aquarius circuit up and clamp all the lines.
7. Pick up the clear plastic centre sheet and place in the middle of the Aquarius machines front panel in between the four pumps.
8. Thread the four pump loops through the four pumps.



- Open filter and place in the filter clamp in the middle of the machine with the arterial (red) end facing up.



- Connect the red end of the circuit coming out of the blood pump to the red end of the filter.

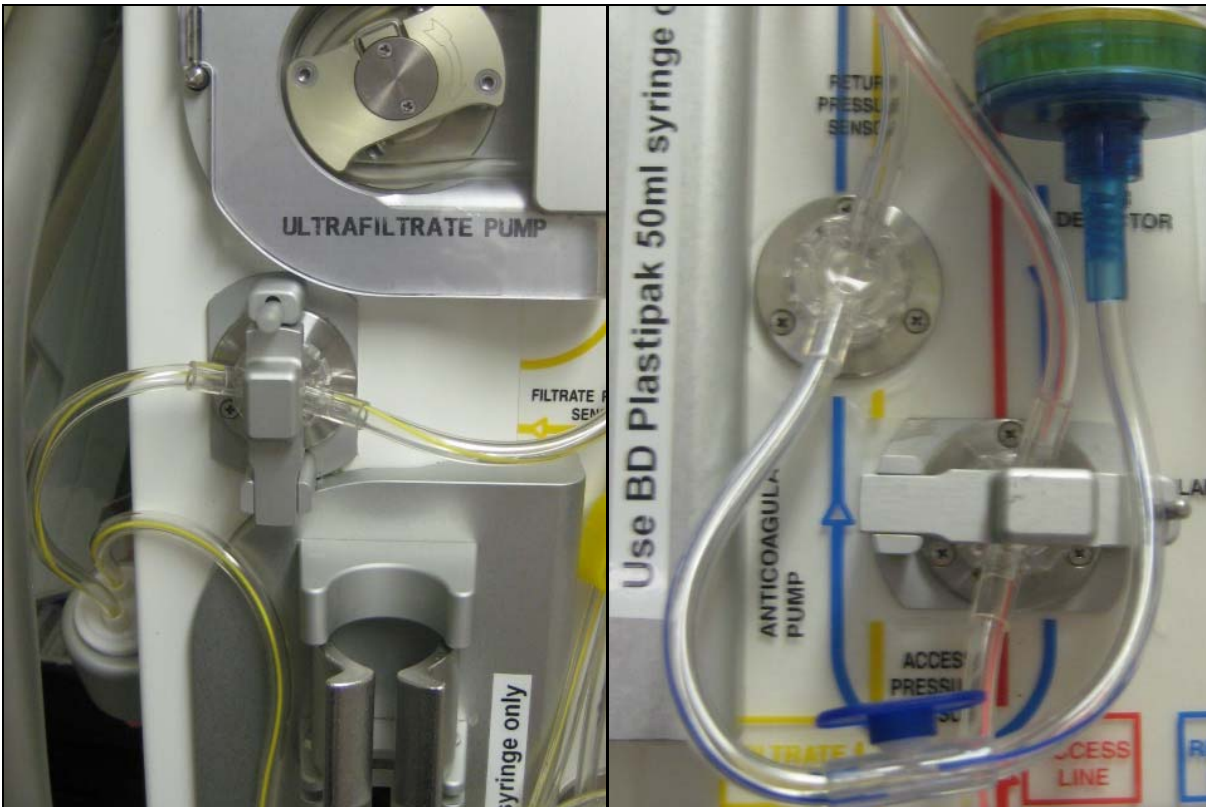


11. Connect the blue end of the circuit to the blue end of the filter.

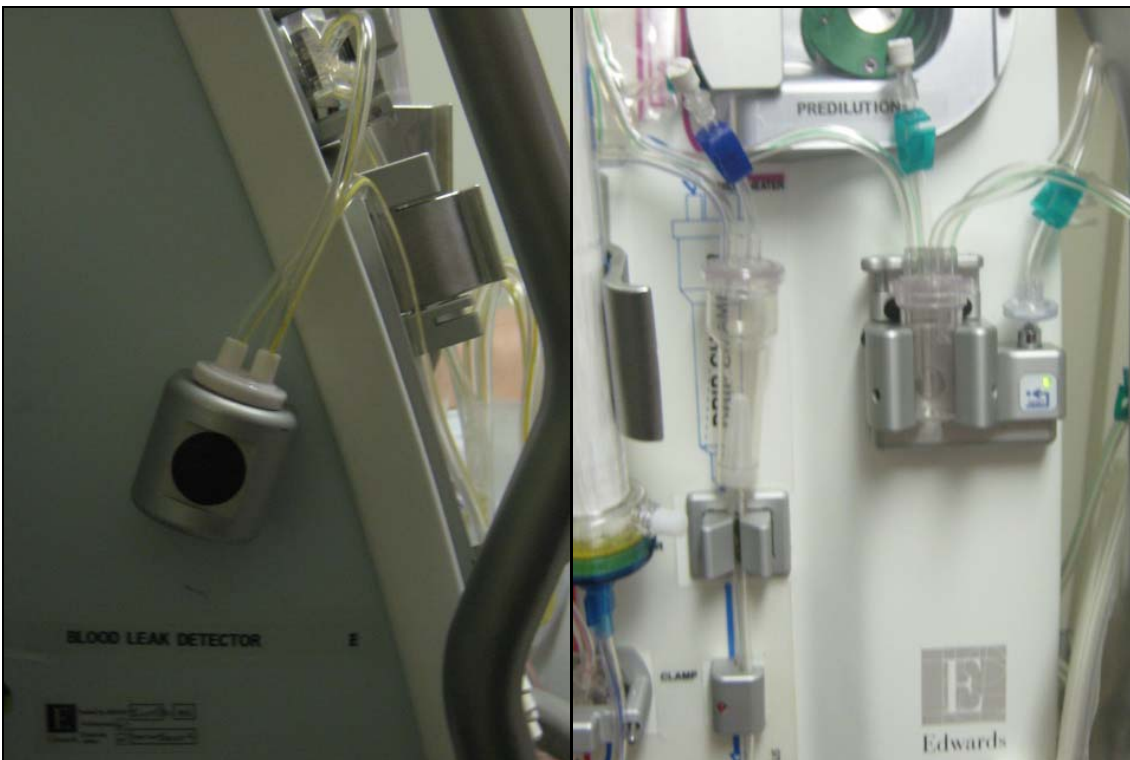


12. Remove the covers on all the pressure sensor caps and clip them in place on their appropriate housing.





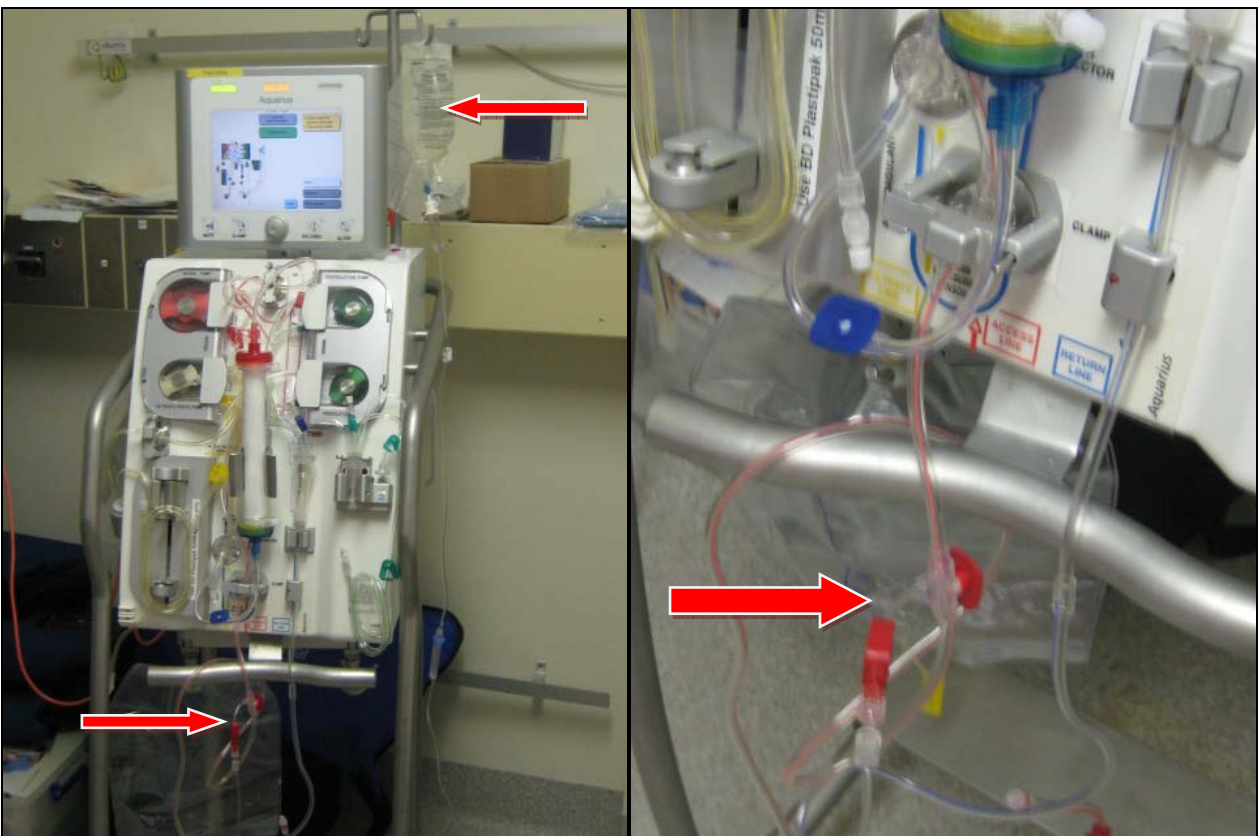
13. Place blood detection chamber, venous bubble trap and degassing chambers in appropriate places. Make sure you thread the venous line into the air detector clamp and screw the side port of the degassing chamber into the bung on the machine.



14. Open door on right side of machine and place the heating coil inside shutting the door afterward.



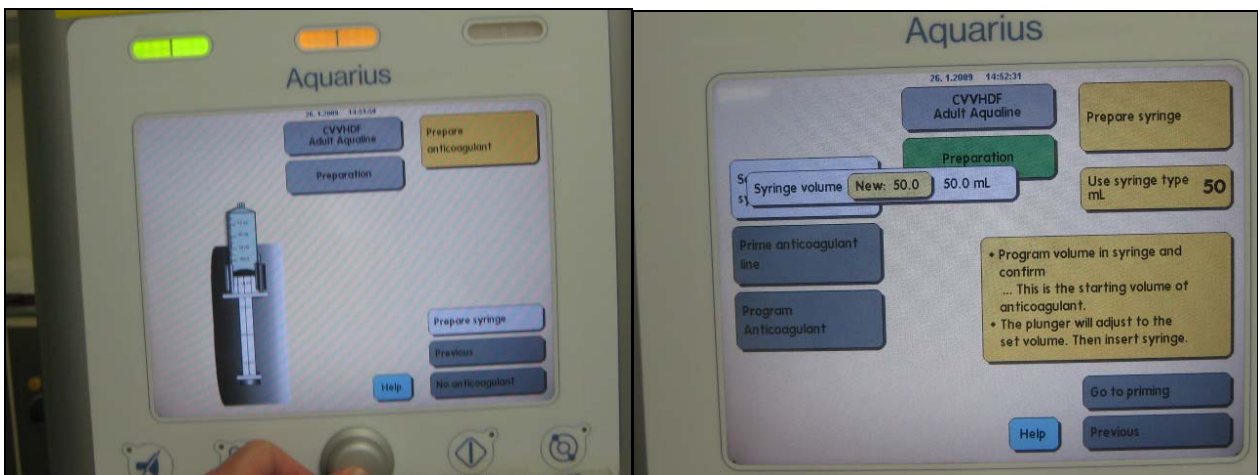
15. Prime IV line with the 500ml of normal saline as your “rescue line” and connect to the access line port. Make sure line and port are clamped.

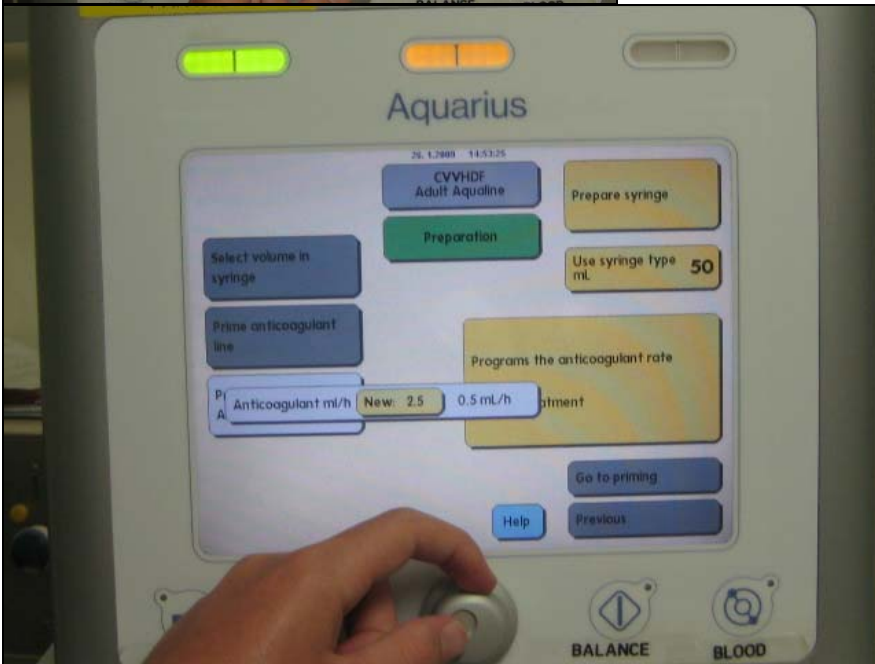
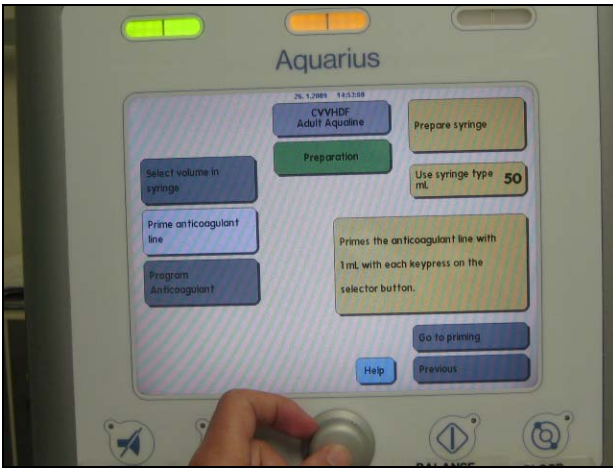


- Depending on the mode of treatment will depend where the post dilution and pre-dilution lines which come out of the pre and post dilution pumps are to be connected in the circuit and so you should follow the instructions on the Aquarius carefully.

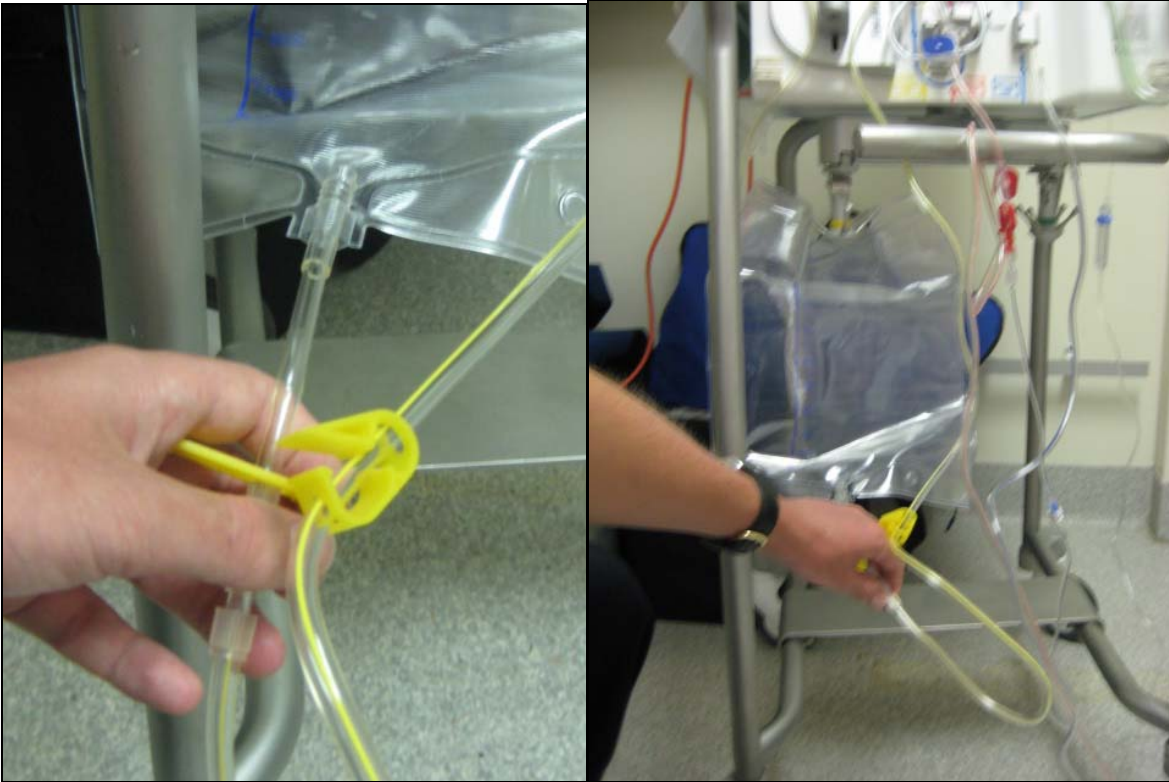


- If heparin anticoagulation is ordered get the prepared 50 ml syringe with heparin and connect to the heparin line which enters the circuit just after the blood pump. Place the syringe in the syringe driver and select prime anticoagulant on the Aquarius machine. The machine will automatically prime the line to the main circuit.





18. Connect an empty effluent bag to the end of the yellow effluent line and hang it on the left side of the balancing scales (under the machine).



19. Connect a five litre bag of the prescribed haemoreplacement fluid to the green dialysate line and hang it on the right side of the balancing scales.



20. Connect the empty bag found in the CRRT circuit to the red access line and hang it on the pole to the right hand side of the screen.



21. Connect first bag of priming solution to the blue return line (with clean spike) and hang on the same pole.



22. Ensure all clamps are now undone and commence priming by selecting it on the Aquarius menu. (This will become an option after you scroll through the set up process.) The Aquarius machine will prime the circuit automatically but you should watch and ensure that the priming solution perfuses all areas of the circuit, especially the filter, removing all air bubbles. To assist the perfusion of the filter rolling it gently around and lightly tapping it can be helpful however being too rough can cause the membrane to rupture. Other area to watch is the fluid level in the bubble traps. If necessary remove extra air from the trap using a 10 ml syringe from the ports at the top. You may also need to use the second bag of priming solution.



23. After the circuit is satisfactorily primed, connect the access and return lines to two lumen spike and connect to the same bag of priming solution. Allow machine to perform the clamp and pressure test.



24. Once finished, select the “recirculation” option from the Aquarius menu and turn up the blood pump speed to at least 150 ml/min. Allow to recirculate for 15 minutes if time is available.

Setting the parameters

When the circuit is recirculating the parameters for the treatment can now be entered into the Aquarius. These parameters are either part of the order or calculated as was shown in the example. You enter these parameters by scrolling to and selecting the Programming tab. The essential parameters to enter include: fluid loss rate (ml/hr), total fluid loss (ml), pre-dilution rate (ml/hr), post dilution rate (ml/hr), anticoagulant rate (ml/hr) and temperature.

Connection

1. Wash hands and prepare trolley by wiping with neutral detergent then open dressing pack.
2. Open out the gauze, four 10 ml syringes onto the field.
3. Pour enough chlorhexidine into one of the pots on the sterile field to soak the gauze.
4. Place two 10 ml normal saline polyamps beside the field ready to be drawn up.
5. Prepare another level surface with alcohol wipes and open sterile gloves onto it.
6. Ask another nurse to assist you with the connection.
7. Select double connection on the Aquarius machine (this will prevent loss of circulating volume at commencement of treatment).
8. Aseptically wash hands and apply sterile gloves.
9. Prepare gauze in sterile field by soaking up the chlorhexidine and squeezing out the excess.
10. With the other nurse to assist you draw up 10ml of normal saline into two of your 10 ml syringes
11. With one hand lift the two vascular catheter lumens with sterile forceps and place sterile towel from dressing pack underneath them. Discard forceps.

12. Using some of the gauze pick up and clean the lumens of the vascular catheter placing them back on the towel and discarding the gauze.
13. Ensuring the vascular catheter is clamped, remove and discard the red cap on the end of the red (access) lumen and connect an empty 10 ml syringe. Unclamping the vascular catheter, aspirate 10 mls of blood assessing the ease at which the blood is removed. Clamp vascular catheter and discard syringe with blood. Connect syringe with 10ml of normal saline; unclamp vascular catheter and flush, again assessing the ease at which you are able to push the fluid in. Again clamp the vascular catheter and ask the assisting nurse to pass the red access line which you hold with a piece of gauze and using non-touch technique connect the red lumen.
14. Repeat this same process for the blue lumen, connecting the blue return line to the blue lumen.
15. Ensure that the luerlock connections on the vascular catheter are secure and tightened.

Commencing treatment

1. Confirm all the treatment settings against the order with the assisting nurse.
2. Record some baseline observations prior to treatment.
3. Make sure the clamps on the vascular catheter, access and return lines as well as the clamps on the effluent (yellow) and dialysate/replacement fluid (green) lines are all open.
4. Press the blood pump button to start the blood pump.
5. Slowly increase the blood pump speed carefully monitoring the access pressures of the circuit but also the blood pressure and heart rate of the patient, till it reaches an optimal level of 200 ml/min. The blood pump speed has to be run according to the tolerance of the patient and can be reduced if the patient is not coping with the speed however bear in mind the loss of clearance efficacy and higher clotting risk.
6. Once the blood reaches the air detector the Aquarius machine will alarm and you can press the balance button to commence treatment.

During treatment:

Observations:

General:

As the patient in intensive care remains critically ill and as commencement of CRRT can cause major affects to their baseline observations, it is important to maintain regular observations (at least hourly) on their:

- cardiac rhythm, heart rate, Central venous pressure, peripheral pulses, skin turgor, capillary return, blood pressure, temperature and blood sugar level.
- neurological status,
- Peripheral saturations, respiratory rate and respiratory support the patient is receiving.

These are all recorded on the patient's flow chart. Not recorded but equally important is your visual observation of the overall patient condition and appearance looking for any changes.

Aquarius:

Every hour after commencement of treatment it is essential to take certain observations from the Aquarius machine and are recorded in the HRF observation form, these include:

- Fluid loss Total
- Hourly fluid loss (fluid loss total for last hour subtracted from this hour)
- Post-dilution rate (ml/hr)
- Dialysate rate (ml/hr)
- Heparin infusion rate (ml/hr) if used
- Pre-filter pressure
- Blood pump rate

These values can be found either on the main Aquarius screen or if you key into the "More" tab.

On the next page is an example observation chart:

Date: _____

Date/Time Filter started _____

AQUARIUS MACHINE

Time	Aquarius		Post-dilution rate (ml/hr)	Dialysate rate (ml/hr)	Heparin ml/hr (1ml=500 U)	Patient APPT 4-8/24	Pre-filter pressure	Blood Pump Rate
	Fluid loss Total	Hourly fluid loss						
0700								
0800								
0900								
1000								
1100								
1200								
1300								
1400								
1500								
1600								
1700								
1800								
1900								
2000								
2100								
2200								
2300								
2400								
0100								
0200								
0300								
0400								
0500								
0600								

Example

VASCATH SITE/length: _____

DATE OF VASCATH INSERTION: _____

Blood results:

Nepean hospital policy on CRRT states that blood needs taking before treatment is commenced and every 4-6 hours during Continuous Renal Replacement Therapies to check the effective clearance of solutes, their blood and coagulation status as well as their electrolyte levels. As most intensive care patients will have an arterial or central line available, formal bloods including EUC, FBC, COAGs and electrolytes can be taken. Also taking regular arterial blood gases can give a picture of the patient's acid-base balance as well as the levels of some of their electrolytes, particularly potassium. If an ABG shows a blood variable which is out of normal ranges then it is always good to send formal bloods too.

Positioning:

Positioning of the patient can be very important during CRRT and is based upon the protection of patency of the vascular access. Therefore it is advisable to keep the patient in their bed during treatment either on their back or turned slightly with the assistance of pillows on to one of their lateral sides. It is important to complete at least 4th hourly turns and pressure area cares during this time to maintain skin integrity and manage development of bed sores. However if the access patency is fragile, shown by increasing access and return pressures, it is a priority to support the continuation of treatment despite limited movements.

Hypothermia

It is often normal to see the patient's temperature drop when treatment is commenced as we are exposing their blood to cooler room temperatures as well as infusing cold intravenous fluids. Therefore this can be managed with the use of blankets, warming blankets and warm IV fluids (using separate fluid warmers and through the Aquarius machine warming fluids).

- Nursing cares whilst on CRRT

Most nursing cares can be maintained while receiving CRRT however extra care needs to be taken for the patency of the vascath and it may be better to leave more involved procedures

till when the patient is disconnected from the circuit (Vanholder, Van Biesen, & Lameire, 2001).

Troubleshooting

Alarms

Low Access Pressures

Causes:

1. Vascath lumen is sucking against a vessel wall
2. Vascath lumen is clotted
3. Lumen or line is kinked, clamped or misaligned.

Troubleshooting:

1. Try to reposition the vascath with a little external manipulation to maintain alignment, try swapping the access and return lumens. Try reducing the blood pump speed down a little.
2. Clamp off lines and lumen, try to aspirate lumen with 5 or 10 ml syringe to remove clot. If clot comes out with good access restored then flush with normal saline and reconnect line and undo the clamps. If clot does not come out and you cannot withdraw any blood, you may need to cease the treatment, return the blood and get the vascath resited.
3. Make sure all the lumens and lines are straight and unclamped

Press the blood pump and balance keys to recommence treatment.

High Return Pressures

Causes:

1. Vascath lumen is clotted
2. Lumen or line is kinked, clamped or misaligned.

Troubleshooting:

1. Clamp off lines and lumen, try to aspirate lumen with 5 or 10 ml syringe remove clot. If clot comes out with good access restored then flush with normal saline and reconnect line and undo the clamps. If clot does not come out and you cannot withdraw any blood, you may need to cease the treatment, return the blood and get the vascath resited.
2. Make sure all the lumens and lines are straight and unclamped

Press the blood pump and balance keys to recommence treatment.

Low return pressures

Causes:

1. Low blood pump speed

Troubleshooting:

1. Increase blood flow rate

Press the blood pump and balance keys to recommence treatment.

High Trans membrane(TMP) pressures

Rapid rise Cause:

1. Filtrate (green) line is occluded by a clamp or kink.

A slow rise Cause:

2. The filter is clotting slowly

High TMP from the beginning of treatment cause:

3. Ratio between the blood and dialysate flows is too high

Troubleshooting:

1. Remove the kink or unclamp the line or bag.
2. Consider increasing pre dilution rates and decreasing post dilution rate. Try flushing out the circuit with the rescue line to see how badly clotted the filter is. If it recovers after flushing then continue treatment but if the filter is too badly clotted it is better to cease treatment so as to not lose blood. Then replace filter and circuit.
3. Increase the blood flow speed or decrease the exchange rate.

Press the blood pump and balance keys to recommence treatment.

Air detected alarm

Causes:

1. Air is present down the return line at the air detector
2. Blood level is too low in bubble trap chamber
3. Return line is not in the air detector clamp correctly

Troubleshooting:

1. Press the release clamp key and remove air with syringe
2. Press the release clamp key and increase height in both the degassing and bubble trap chambers with a syringe
3. Place the line within the air detector clamp.

Press the blood pump and balance keys to recommence treatment.

Blood leak alarm

Causes:

1. The ultra filtrate is coloured, the filter membrane has ruptured causing a leak of blood.
2. Plasma Exchange is being performed
3. Blood detection chamber not in housing
4. Mirror in housing is dirty

Troubleshooting:

1. Cease treatment
2. As plasma is present in the “ultrafiltrate” the blood detection alarm will sound so replace the chamber in the circuit with the dummy chamber filled with water
3. Replace chamber in housing
4. Clean the mirror in housing and replace the chamber.

Press the blood pump and balance keys to recommence treatment.

Fluid Balance Alarm

Causes:

1. Fluid bags moving below machine
2. Fluid bags not connected properly
3. Fluid lines are kinked or clamped
4. Fluid bags need changing.

Troubleshooting:

1. Stop bags from moving
2. Check all the connections are complete and tight between the fluid bags and the lines
3. Ensure all the clamps are undone and lines are not kinked
4. Change effluent and fluid replacement bags for fresh ones, ensuring to clamp off the

lines and the bags, unclamping once new bags are connected. Dispose of the old effluent in the pan room sluice.

Press the balance key to recommence treatment.

(Elliot, Aitken, & Chaboyer, 2007)

Indications for changing the circuit and filter

The main indications for ceasing treatments to change a filter and the circuit relate to the status of the circuit and the vascath access. These are measured by recording the different pressures within the circuit. These are the main indications for ceasing treatment:

1. The pre-filter pressure is consistently above 270 mmHg
2. The trans-membrane pressure is consistently above 250 mmHg
3. The filter is over 72 hours old
4. The patient's blood results start to show poor clearance of solutes even when CRRT is running for example their urea, creatinine or potassium levels start to increase.

If you troubleshoot these indications with no improvement it is better to return the patient's blood from the circuit before total occlusion occurs so as not to inadvertently lose blood volume (Elliot, Aitken, & Chaboyer, 2007).

Process for ceasing treatments

When one of the indications for ceasing treatment is achieved then the nurse can select "End treatment" from the Aquarius menu. The machine will ask for confirm of the decision to end the treatment. Once confirmed the blood must be returned to the patient.

This is done by following the prompts suggested by the Aquarius machine and requires a second nurse.

Disconnection

Equipment:

- 1 × 1000 ml of 0.9% Sodium Chloride
- 2 × 10ml syringe
- 2 × 10ml of 0.9% Sodium Chloride

- 2 × red caps

Process:

1. Clamp the access (red) lumen and line and disconnect the line from the lumen.
2. Pass the line to the assisting nurse who will connect an IV spike to the line and connect it to a 1000 ml bag of normal saline.
3. Meanwhile you can flush the red lumen with 10mls of normal saline and apply a red cap
4. Once the line is connected to the 1000 mls of normal saline the clamp can be undone
5. Press the blood pump button to get blood pump started which will flush the normal saline through the circuit returning all the blood. You can turn up the pump speed if need be.
6. Once all the blood is flushed back to the patient, clamp the blue lumen, disconnect the blue line and pass this to the nurse.
7. Connect the other 10ml of normal saline to the lumen, undo the clamp and flush with saline, clamping the lumen afterward and placing a red cap on the end.
8. Take a final set of Aquarius observations with the total volumes removed and record the reinfusion volume both on the CRRT observation form and the flow chart.
9. The Aquarius machine can now be switched off.
10. Wearing appropriate personal protective attire, remove all the tubing from the pumps and pressure sensors from the caps. Place it all in clinical waste.

Heparin Locking the Vascath

Equipment:

- 2 × 2 ml syringes
- 4 × 10 ml syringes
- 2 × red luer lock caps
- 5000 units of heparin in 1 ml.
- 3 × 10 ml polyampules of 0.9 % Sodium Chloride
- 2 × drawing up needles
- 4 × blunt cannulars

- 2 × sticky labels with “Heparin locked”, date and time written on it

Procedure:

1. Wash hands
2. Check heparin with another nurse and draw up 0.2 ml of heparin into each 2 ml syringe with drawing up needle
3. Dilute the 0.2ml of heparin up to 2 ml of normal saline
4. Remove drawing up needle and place a blunt cannular on each syringe to keep clean, make sure there is no air in the syringe.
5. Draw up 10ml of normal saline into two of the 10 ml syringes
6. Wash hands and apply gloves
7. Using non-touch technique, make sure the clamp is on the red lumen, remove red cap from the end.
8. Place empty 10 ml syringe in lumen and undo clamp
9. Withdraw 10 ml of blood, clamp the lumen and discard assessing ease at which you can withdraw.
10. Using 10ml of normal saline, undo the clamp, flush the lumen, then re-clamp the lumen.
11. Flush in the heparin lock, clamping off the lumen once it is in.
12. Apply one of the sterile red caps
13. Repeat the process for the blue lumen.
14. Label each lumen with a sticky label.

(Elliot, Aitken, & Chaboyer, 2007)

Clinical Certification

AQUARIUS CRRT

Indicator	Performance Criteria	Competent	Not yet competent
Identifies rationale for commencing CRRT	<p>Discuss rationale for type of CRRT/TPE</p> <p>Explains how selected therapy achieves therapeutic goal</p> <p>25. Convection</p> <p>26. Diffusion</p> <p>27. Fluid balance</p> <p>28. Particulate size</p> <p>29. Blood pump speed</p> <p>30. Appropriate size filter</p> <p>31. Volume of exchange</p>		
Identifies and prepares all items required for circuit set-up	<ul style="list-style-type: none"> ● Collect AQUARIUS machine, turn on and allow machine to perform self test ● Prepares IV fluids ● 2x 1000ml bag Normal Saline with 10,000 units Heparin in each bag. (Omit heparin for citrate anticoagulation) ● 1 x 500ml bag Normal Saline. ● 1 x IV giving set ● Heparin infusion as ordered (50 ml saline + 25,000 units Heparin in BD syringe) ● Dressing pack ● Sterile gloves ● 70% Chlorhexidine solution ● 5 x 10ml syringes ● 2 x 19 gauge needles ● 4 x additive stickers ● KCL (if required) ● HRF ● Assembles all lines required for circuit ● Collect circuit, 3 spikes and filter 		

<p>Demonstrates AQUARIUS operation and correct circuit set-up</p>	<ul style="list-style-type: none"> ● Wash hands ● Select CVVH ● Remove lines from package and place on machine ● Wind set through pumps x 4 ● Connect blood lines to arterial and venous end of filter ● Remove covers and place pressure sensor caps over housing x 4 ● Place blood detector cup, venous bubble trap, degassing chamber and replacement fluid lines in appropriate housing. ● Connect ultrafiltrate line to filter and connect replacement fluid, pre-filter to circuit ● Clamp lines, spike HRF, spike priming fluid and hang ultrafiltrate bag and arterial priming bag. ● Connect “rescue line” ● Prepare heparin infusion and place in machine as directed ● Unclamp all lines and commence priming ● Re-prime with second litre of solution if required ● Complete “Clamp and Pressure Test” ● Recirculate circuit for 15mins prior to connection if able ● Set program as ordered. 		
<p>Outlines steps taken to commence filtration</p>	<ol style="list-style-type: none"> 1. Washes hands 2. Opens dressing pack and sets up sterile field 3. Washes hands and dons sterile gloves 4. Clean vascath connections with alcohol 		

	<p>solution</p> <ol style="list-style-type: none"> 5. Aspirate 10ml of blood from each lumen, discard and flush each lumen with 10ml N/Saline 6. Assess patency of vascath. 7. Select double connection and follow machine prompts 8. Connect arterial and venous lines to vascath 9. Start blood pump 10. Wait for blood pump speed to achieve maximum speed (usually 200ml/min) then press balance key and commence treatment 		
<p>Outlines documentation required for operation of AQUARIUS CRRT</p>	<p>Identifies the appropriate medical order form for the therapy</p> <p>Records start time and hourly observations on order form and ICU flow chart</p> <p>Operates AQUARIUS as ordered</p>		
<p>Describes ongoing nursing considerations for CRRT</p>	<ul style="list-style-type: none"> ● Identifies changes in patient condition associated with this treatment ● Describes the routine blood tests done to monitor haemofiltration / anticoagulation effectiveness ● EUC ● FBC ● COAGS ● Electrolytes <ol style="list-style-type: none"> 3. Demonstrates HRF bag change 4. Describes vascath site care. 		

<p>Demonstrates ability to troubleshoot</p>	<ul style="list-style-type: none"> ● Discuss methods for prolonging filter and circuit life <ul style="list-style-type: none"> ○ Predilution ○ Postdilution ○ Heparin infusion ○ Clots ○ Air in circuit ● Discuss problems associated with access and possible solutions ● Navigates through screens and explains significance of measured pressures and values 		
<p>Demonstrates ability to discontinue CRRT</p>	<ul style="list-style-type: none"> ● Select disconnect option and follow machine prompts ● Open flush bag and clamp arterial line ● Flush blood back to patient ● Disconnect circuit from patient ● Cap, flush, heparin lock and label vascath ● Remove lines from AQUARIUS, discard and turn machine off ● Document final total real fluid and reason for discontinuation of treatment. 		

Name	Assessor
Date	Signature

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