RENAL DIALYSIS

Renal Dialysis is a process of artificial duplication of the kidney function for separating **crystalloid** and **colloid** substances from the blood using a **semi- permeable membrane.**

Terms you will become familiar with in this module

renal dialysis	conductivity meter
electrolyte	ureter
colloid	semi-permeable membrane
crystalloid	urea
permeable	creatinine
diffusion	extra-corporeal circuit
convection	vascular access
solute	graft fistula
osmosis	catheter
nephron	lumen
Bowman's capsule	cannula
tubule	outlet/inlet port
ultra-filtration	congenital
retro-peritoneal space	hereditary
thoracic vertebrae	systemic
lumbar vertebrae	glomerulo-nephritis
electrolytes	analgesic
haemodialysis	nephritis
peritoneal dialysis	insult
dialysate	bio-burden
non-uraemic	bleaching
anticoagulation	venturi effect
effluent	asepsis
	bleaching

Introduction

The kidneys purify the blood by filtering it and then selectively reabsorbing water and useful molecules. Each kidney is made up of about one million microscopic filter units and acts independently of the other. Waste products from the filtering process are flushed through the **ureters** to the **bladder** and excreted as **urine.**

For clients whose kidneys are diseased or no longer perform their normal function without assistance, the **Renal Dialysis** process performs two functions, it:

- removes metabolic waste products
- temporarily restores imbalances in body water and **electrolyte** concentration

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The processes of **diffusion** [transfer from high to lower concentrations] and **convection** [movement from high to lower pressure region] are used for **solute** removal, and a combination of **osmosis** and **ultrafiltration** are used to normalise **body water**.

Anatomy and Physiology

The kidneys of an adult are two fist sized, bean shaped organs located in the **retro-peritoneal space** between the 12th **thoracic** and 3rd **lumbar vertebrae**. The kidneys perform a variety of functions which include the removal of microscopic metabolic waste products and the regulation of body water and **electrolytes**.

The filtration transfer unit in the kidney [the **renal corpuscle**] consists of a cup shaped structure [**Bowman's capsule**] and a clump of extremely fine and specialised blood vessels [capillaries [glomerulus] which deliver blood to the nephron. Higher pressure in the glomerulus pumps water, ions and dissolved molecules through microscopic spaces in the cells forming the glomerular capillary wall . Because the concentration of electrolytes and useful molecules is now greater in the tubule than in the surrounding capillaries, selective reabsorbtion of water [**osmosis**] occurs in the **tubules** which flow from Bowman's capsule.

Although the kidneys perform other functions, these are the only two renal functions which can be replicated by **haemodialysis** [pronounced heem - oh - die -allusis].

Activities

Use the diagram below to label the parts of the kidney listed in the key

renal artery
renal vein
ureter
cortex
medulla
calyx

Renal failure can be classified as **acute**, when full function is expected to return over time, or **chronic** when the loss of function is permanent. In either case, and in most situations, the client's survival depends on successful replacement of the renal function.

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The replacement of renal function can be achieved by dialysis alone [in acute failure] or dialysis and/or transplantation for chronic failure. Other forms of therapy are available but are beyond the scope of this section.

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Dialysis is a medical prescription involving both specialised equipment and a health care team. Administration and maintenance of the prescription is supported by nursing and technical staff involved with the client. The further expertise of biochemists , engineers and microbiologists in maintaining constant and sufficient pure water supplies is increasingly important as dialytic therapies become more complex.

The **dialytic therapies** that are available are **peritoneal dialysis**, where the semi permeable nature of the peritoneal [abdominal] membrane is used to achieve the normalisation of body fluids, and **haemodialysis**, where an **artificial kidney** or dialyser is used.

Of the major types of **peritoneal dialysis.** manual dialysis involves the client using a bag of dialysis fluid which may be warmed to maintain blood temperature. The dialysis takes place over a whole day at regular intervals between dialysis and normal activity.
A second type of peritoneal dialysis is automated and usually takes place in single overnight sessions. In this case, cyclers may need to be maintained and the apparatus has inbuilt alarms to protect the client from damage to the membrane.

Because haemodialysis is the therapy that most frequently involves equipment requiring technical support, it is the focus of this module. Peritoneal dialysis is not explored though an understanding of the physiology involved is useful to help understand the difference between the two forms of therapy.

In large medical centres, dialysis equipment may be maintained by technical service groups within departments of nephrology so that routine service and maintenance protocols can be established and adhered to.

Activities

Use reference sources to identify the main differences between the physiology of peritoneal and haemolytic dialysis.
In discussion with nursing and medical staff, explore reasons for the widespread use of haemodialysis when peritoneal dialysis is also freely available. [A useful resource published by the Renal Resource Centre is referenced at the end of this module]

What Type of Clients Use This Equipment?

Clients with both acute and chronic renal failure may need to rely on haemodialysis. Adults are more likely clients but children can also require dialysis. Indigenous populations are disproportionately represented in rates of renal dysfunction in most developed countries – including Australia.

Questions

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Renal disease is more common among some cultural groups than others. Who are the most common groups suffering long term renal disease in Australia? Suggest why a knowledge of the cultural background of the client may be important in defining your role as a member of the health care team managing the case. Is gender a significant pointer towards the likelihood of chronic renal disease in Australia? Some commonly used prescription drugs such as analgesics can affect renal function. Identify the common pain killers which can interfere with normal renal function. Is there any evidence to suggest a relation between gender and use of analgesics?

Once chronic renal failure has progressed to the point where dialysis or transplantation is required for survival, it is termed **end stage renal disease** [**ESRD**]. Some clients elect not to be treated. They allow the disease to take its natural course. Most choose to receive treatment. At present there are approximately 4,500 dialysis dependent persons in Australia. About two thirds of these rely on haemodialysis. As a result, technical expertise in renal dialysis has become an established need among biomedical technologists and engineers in Australia. As a result, specialised technical teams attached to nephrology units have become more common in larger medical centres.

Each client receives four to five hours of dialysis three times each week. Many of these people dialyse in a major medical centre but, **ideally, treatment is undertaken at home**, after the client and a 'helper' have completed an appropriate learning program.

For other clients, **treatment may be received in satellite centres** where a small number of machines are grouped in a community setting or small hospital with a trained nurse who can assist a number of clients. Some of these clients are able to manage many aspects of their treatment, needing minimal assistance. Others need full support.

What Disease Processes are Involved?

ESRD can result from a range of diseases affecting both males and females, children and adults though the major causes do differ between adults and children. Many children who are on dialysis programs have renal diseases that result from **congenital** or **hereditary** disorders. Adults are more likely to suffer a **primary disease** which originates in the kidney, or to develop renal disease as part of a **systemic disease** which affects some other part of the body.

For adults in Australia, the most common causes of renal disease are:

1. **Glomerulonephritis** [pronounced glom–uh–you–loh–neff–right–uss]: inflammation of the kidney [caused by a variety of conditions].

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2. **Diabetes**: an inability to correctly utilise the hormone **insulin** [pronounced inn-shoe-lin].
3. **Hypertension**: high blood pressure.
4. **Analgesic Nephropathy** [pronounced annal-gee-zik neff-rop-uh-thee]: disease caused by the prolonged use of specific analgesics [pain killers].

Kidney function declines as part of the normal aging process. As a result, many older people are less tolerant to **insults** to the kidney that might not cause serious difficulty for younger people.

Haemodialysis: a Replacement for Renal Function

Haemodialysis is commonly prescribed for 3 times per week and each session lasts from 4-5 hours. Each client receives between 12 and 15 hours of Haemodialysis each week.

Haemodialysis involves passing blood through a **dialyser** to remove substances normally excreted by the kidneys. The dialyser is usually cylindrical in shape and approximately 25-30 centimetres [ten to twelve inches] long (for an adult). In simplified form, it is made up of two compartments separated by a fabric [membrane] which allows the transfer of microscopically fine particles but not larger particles [**semi-permeable membrane]**. The compartment containing the client's blood is called the **blood compartment**. The second or **dialysate compartment** contains the **dialysate** solution which is comparable to the body fluids of a person with normally functioning kidneys [**non-uraemic**]. [see fig 1]

The dialysis machine

The machine performs two primary functions:
- production and monitoring of dialysate
- pumping and monitoring of blood through the extra-corporeal circuit.

Modern dialysis equipment monitors fluid flow in and out of the dialyser and very accurately controls the weight loss required by the client to meet the prescription demand.

The dialysate

Dialysate passes through the dialysate compartment at the rate of 500ml/minute. As a result, 30 litres/hour are required for each 4-5 hour session. The used dialysate is *not* recyclable with most machines. Commonly, 600 litres per week of dialysate is required. To maintain these volumes economically for the client , a mixture of concentrated electrolyte solution is diluted with purified water using the machine at the site of the dialysis.

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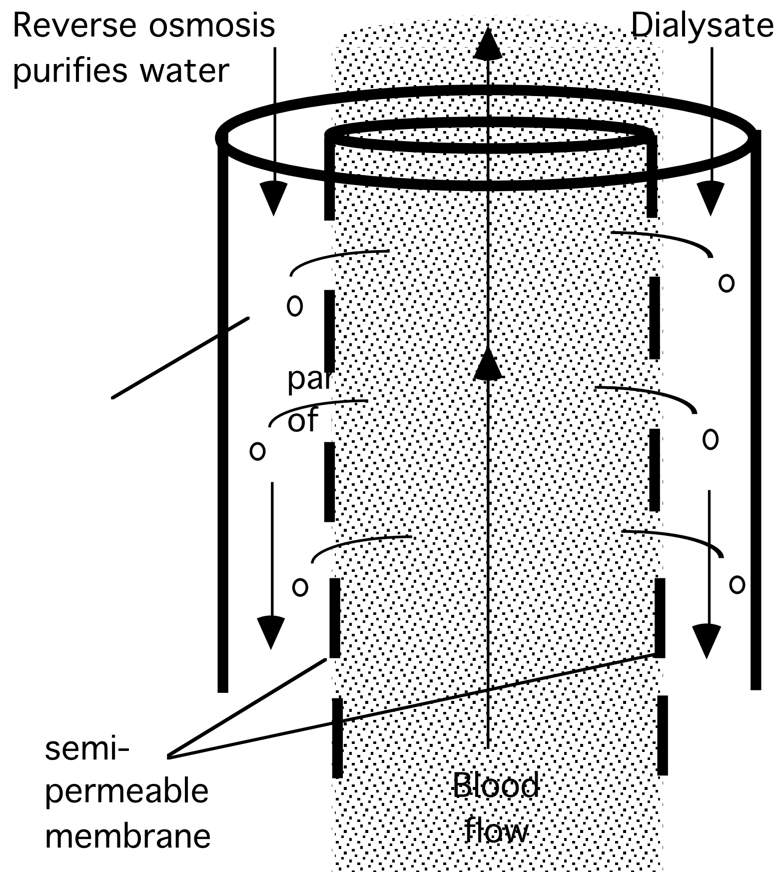

fig 1.

Haemodialytic filtration

The membrane

The **semi permeable membrane** separating the two compartments can be constructed from a synthetic material or it can be made from processed vegetable matter.

If the dialyser membrane is damaged [its **integrity is breached**] allowing blood to escape into the dialysate solution, a **blood leak detector** which monitors the clarity of the **dialysate effluent** alerts the operator because the actual concentration of the blood in the dialysate is often too low to be seen visually though macro leaks are possible..

Conductivity and temperature

The composition and warmth of the dialysate are monitored continuously using a **conductivity meter** and a **temperature probe** to ensure that the dilution of concentrate with water is correct and that the temperature is appropriate and stable. If the composition and warmth of the fluid are not within pre–set physiological limits, the fluid bypasses the dialyser until the limits are met.

Water purity and contamination

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The dialysis membrane is **permeable** to all solute that is less than 2000 daltons in size and, to a lesser degree, to solutes up to 5000 daltons. As a result, electrolytes and metabolic waste products such as **urea** (a nitrogen-based molecule formed from protein metabolism and related to ammonia) and **creatinine** (formed as a result of muscle metabolism) can easily pass through, while larger elements, such as blood cells and proteins are retained.

Solute matter at such small sizes can travel in both directions through the membrane. As a result, fragments of bacteria and trace metal ions such as aluminium can pass from the dialysate into the bloodstream of the client. Purity of water supply therefore becomes a major consideration and the roles of microbiologists, water engineers and biochemists become important in maintaining water pressure, supply and purity. The process responsible for the movement of solute is primarily diffusion [some convective solute transport does occur but its contribution to the replacement of renal function is minimal].

The normalisation of body water during haemodialysis also exploits the semi permeable nature of the dialysis membrane.

A **blood pump** is used to pump blood through the extra tubing used to establish the **extra-corporeal circuit** [extra = outside, corporeal = of the body], through the dialyser, and back to the client [see fig 2].

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fig 2 Extra-corporeal circuit

The client and the machine

Direct access to the client's blood vessels is required and this is achieved through the use of specially constructed **vascular access**. For clients requiring long term care, vascular access is usually established in the form of a **native** or **graft fistula** in the forearm or leg. For clients needing short term care or awaiting the construction of a permanent device, a **catheter** is more commonly used.

Because the internal diameter [**lumen**] of the needle [**cannula**] that is returning the blood to the client is narrower than the tubing in the extra-corporeal circuit, blood is usually returned to the client under pressure. This pressure is **reflected upstream** and into the dialyser where it forces fluid across the dialyser membrane. The pressure is measured at the **venous outlet port** of the dialyser and is similar to the pressure that exists inside the dialyser. It is monitored and recorded as **venous pressure**. Some dialysis machines also record the pressure at the **arterial inlet port** of the dialyser so that an average pressure within the dialyser to be calculated. This not usual.

Two problems can occur during the fluid removal phase:

- If the pressure inside the blood compartment [**venous pressure**] is not great enough to force the required amount of fluid across the membrane, a **negative pressure** has to be generated in the dialysate compartment to assist with fluid removal.

- If excessive pressure exists within the blood compartment, the client will lose too much fluid and in this case a **positive pressure** has to be generated within the dialysate compartment to oppose fluid loss. (Some older machines are not able to create a positive pressure to oppose excessive loss. In this case, the excess must be replaced with either oral or intravenous fluids).

In clinically supervised environments, dialysis nursing staff determine the amount of fluid loss that is required and program the machine accordingly.

The **dialysate pressure**, measured in millimetres of mercury [mmHg], is monitored throughout treatment to ensure that inappropriate pressures are quickly detected.

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Arterial and venous monitoring of blood pressure within the **extracorporeal circuit** is undertaken because:

- if a client's **venous pressure** [discussed above] is high it may represent natural resistance to the return of blood or it may suggest an inappropriately placed needle [**cannula**] which needs repositioning. Low venous pressure usually indicates **clotting** of the blood in the extracorporeal circuit or **kinking** in the blood lines between the pump and the pressure monitor.

- The second pressure monitor on the blood circuit reflects **arterial pressure.** High blood flow rates that are required for satisfactory dialysis usually mean that blood needs to be withdrawn from the client faster than it would normally flow if the needle was not connected to a pump. This creates a **negative arterial pressure** in the tubing between the client and the pump. Arterial pressure reflects the adequacy of blood flow from the client to the pump and, as with venous needles, requires repositioning if it is incorrectly located.
Both these pressures are measured in mmHg.

The presence of a negative pressure in the first part of the blood circuit makes it possible for air to be drawn into the circuit and subsequently pumped into the client. An **air leak detector** monitors the client's blood in the venous portion of the circuit and alerts the operator if such an event occurs.

It is important to note that all haemodialysis machines should incorporate 'fail safe' procedures which isolate the client from the problem should equipment fail. See Australian Standard 3200.1 HE/3/8: Dialysis Equipment.

Disinfection of the exterior of the machine

Because of the extremely high risk of infection to the client if **asepsis** is not a priority for both nursing and technical staff, cleaning procedures must become essential routines. The cleanliness of machines returned from use should be assured by nursing staff [or noted if it has not occurred] and re-established before return for use.

Disinfection of the dialysate and blood paths

During normal use, angles and edges within the fluid paths [blood, dialysate and water circuits] of the dialysis machine tend to catch microscopic fragments of waste metabolite, colloids, metal ions and bacterial fragments. These build up to form a jelly-like bio-film [**bio-burden**] which may become the site for bacterial growth. Increased risks of cross-infection for the client and apparent equipment malfunction [the alarms sound but everything seems to be working] need to be prevented.

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External disinfection, together with disinfection of the dialysate and blood paths should become a routine follow-on for each machine after every treatment.

Routine service

While disinfection should follow every treatment, a schedule of routine checks at regular intervals for all alarm systems and all connections should be part of the maintenance plan for each dialysis machine.

Regular routine water testing should be part of the technical service for fixed location machines - particularly those relying on limited water sources dependent on seasonal rainfall or subject to irrigation overflow.

Activity

Develop a schedule for routine testing and maintenance of a dialysis machine which might be used at a satellite dialysis centre only visited by a technician on a needs basis.
Establish the order of testing, the expected result for each part of the testing, the possible signs of malfunction and the effect that each type of malfunction would have on the well-being of the client - if it was not corrected. Because of the distances [and therefore time and cost] of travelling to a satellite centre on an unscheduled visit, suggest possible ways of checking each apparent malfunction before calling a technician.

Common Problems arising in the Clinical Setting

Difficulties with monitoring equipment appear to cause the most frequent problems for nursing staff and home dialysis clients. Technicians are often called during the problem because the interaction of patient tubing and equipment can be difficult to identify. Large volumes of dialysate being used and the extended time periods involved for the client make rapid response important to reduce expensive waste and disruption to schedules.

Pressure monitoring alarm signals

- Usually caused by faulty or wet isolators.
- Less frequently, kinks in the blood lines or accidental compression of the lines causes alarm.
- Clotting can occur within the dialyser. This is less likely when appropriate anticoagulation forms part of the prescription.

Fluid loss inaccuracies

- Most commonly, the scales used to determine the client's weight are not sufficiently accurate or stable or the client has not weighed him/herself

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properly. It is also possible that a miscalculation has been made. Check the accuracy of the scales by weighing yourself several times to check accuracy and replicability of reading before looking for more complex problems.

- Apparent losses can be generated by kinks or compression in the blood lines.
- If a proper maintenance schedule has been established, a much less likely problem can be created when the pressure monitors are not providing accurate readings. The flow control cells of the pressure monitors can become clogged with a jelly-like biofilm [**bio-burden**] which restricts sensitivity and prevents them from reading accurately. Bioburden must be removed by **bleaching** by the operator.

Blood leaks

Because these are mostly microscopic, they must be checked promptly. Blood leaks create bio-burden on the inside of the blood leak as metabolic waste products are returned from the dialyser. The bioburden may then be returned to the client's blood with other contaminants gaining entry through the same breach in membrane integrity. The risk of cross-infection increases rapidly in this case and pathways should be **bleached** if this happens. [A note should be clearly attached to the machine describing its status if it cannot be bleached immediately.]

Water pressure

Low water pressure usually causes the conductivity and temperature alarms to activate. If both are alarming, check the water pressure first.

Power fluctuation

The conductivity alarm will activate if power supply becomes variable. Check power before conductivity.

Temperature

If water pressure and power supply are within normal limits, room temperature may be too warm so water supply is being over-heated before entry to the machine.

Conductivity

If water pressure and power fluctuation are ruled out, there is a technical problem.

Air leaks

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Are commonly created by a **venturi effect** when blood lines are poorly connected or joints are stressed. Nursing staff will normally clear and check all connections.

Activities

Colloidal contaminants and iron are the most common contaminants in town water supplies. Identify how the reverse osmosis units remove contaminants. Explore ways in which the water supply could be purified before it reaches the machine to reduce the strain on the units and to reduce costs. Discuss the practical limitations of such pre–purifying with water engineers or with the water authorities in your area.

Large volumes of water containing blood and body fluids are created during the dialysis process. Identify the standard precautions which must be established as routine when handling blood and body fluids. Outline the risks to patients, carers and technicians if standard precautions are not used when handling these fluids.

Identify a client with end stage renal disease and, after obtaining their permission, discuss their treatment with them. What factors do they feel were important in deciding the type of treatment they are undertaking? How do they feel their treatment has affected their own lifestyle and that of their family and friendship groups?

As a technician involved with ESRD clients, what support can you provide in helping them to adjust more easily to their condition and the impact of treatment on their lifestyle?

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