Acute Kidney Injury in COVID-19
Caring for Patients Requiring
Alternative Renal Replacement Therapy
in Critical Care Units

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Introduction

A shortage of consumables to provide haemofiltration/haemodiafiltration in Critical Care Units (CCU) during the COVID-19 pandemic has led to alternative renal replacement therapies (RRT) being introduced to manage Acute Kidney Injury (AKI).

Patients with AKI requiring renal replacement therapy can be managed either by intermittent or continuous dialysis therapies, depending on their cardiovascular stability and the intended rate of fluid removal (ultrafiltration). Continuous RRT has become the preferred modality for managing haemodynamically unstable patients with AKI. The different CRRT modalities can use diffusion, convection, or a combination of both for solute clearance. Unlike Intermittent haemodialysis CRRT is performed continuously (24 hours per a day) with a typical blood flow of 100 to 300 mL/min and a dialysate flow of 17 to 40 mL/min. It is performed mostly through veno-venous vascular access. Solute clearance occurs by convection. No dialysate is used. The rate at which ultrafiltration occurs is the major determinant of convective clearance. Intravenous ''replacement fluid'' is provided to replace the excess volume that is being removed and replenish desired solutes. Whilst CVVH is the preferred modality in the critical care setting, to date there is no compelling evidence to suggest that intermittent therapies are inferior in terms of mortality or restoration of residual renal function.

The purpose of this document is to outline the alternative renal replacement therapies and associated nursing care that can be used to treat AKI in CCUs related to COVID-19. These include:

- Intermittent Haemodialysis (IHD)
- Slow/Sustained low efficiency daily dialysis (SLEDD)
- Prolonged Intermittent Renal Replacement Therapy (PIRRT)
- Acute Peritoneal Dialysis

Overview of Alternative Renal Replacement Therapies to treat AKI in CCUs related to COVID-19

Intermittent Haemodialysis

Traditionally, nephrologists manage AKI with IHD, with frequency and duration based on clinical assessment. Blood flow rates tend to be slower e.g. 250 mL/min with a dialysate flow rate of 500 mL/min. In IHD, solute clearance occurs mainly by diffusion, whereas volume is removed by ultrafiltration. Advantages of IHD include rapid solute and volume removal, with rapid correction of electrolyte disturbances, such as hyperkalaemia, and rapid removal of drugs or other substances in fatal intoxications in a matter of hours. IHD also has a decreased need for anticoagulation as compared with other types of RRT because of the faster blood flow rate and shorter duration of therapy. The main disadvantage of IHD is the risk of systemic hypotension caused by rapid electrolyte and fluid removal. Sodium modelling, cooling the dialysate, increasing the dialysate calcium concentration, and intermittent ultrafiltration may be used to improve haemodynamic stability during IHD.

IHD is performed using a haemodialysis machine, with the capability to run at low blood and dialysate flow rates. In addition, a water supply and reverse osmosis unit is required. Lining a priming using standard extracorporeal circuit tubing, appropriate to the machine a dialyser (size & clearance dependent on clinical need) and priming fluid as per usual IHD protocol. A small dialyser is recommended as minimises the risk of disequilibrium syndrome. Vascular access is required which is usually a tunnelled line to be used exclusively for dialysis. Anticoagulation will be dependent on status of the patient, but options are unfractionated heparin or low molecular weight heparin, which can be given in divided doses. Consideration for dosing should be given if 'therapeutic' regular anticoagulation is already being administered.

Slow/Sustained low efficiency daily dialysis (SLEDD)

SLEDD is a hybrid that provides RRT for an extended period of time (ranging from 6 to 18 hours) but is intermittent in frequency (minimum 3 x week typically 5 x week). SLEDD offers advantages for patients requiring frequent interventions or repositioning and for patients where continuous anticoagulation is to be avoided. As an extended duration therapy, SLEDD allows for a significant reduction in ultrafiltration rates when compared to IHD, e.g. <5ml/kg/hr, optimal to allow time for vascular refilling and minimise the risk of haemodynamic instability. The advantages of SLEDD include reduced rate of ultrafiltration facilitates better haemodynamic stability; lower solute removal thereby minimising solute disequilibrium; longer duration enables greater dialysis dose; can be undertaken on current haemodialysis equipment; enables several patients to receive on-going renal replacement therapy using the same machine. SLEDD can be performed on a standard intermittent haemodialysis machine as outlined in IHD. The patient will require vascular access and anticoagulation as per IHD. Due to the length of the treatment consideration needs to be given for Hypokalaemia, Hypophosphatemia and use of unfractionated heparin.

Prolonged Intermittent Renal Replacement Therapy (PIRRT)

PIRRIT is a gentle 6- to 12-hour hybrid RRT which provides intermittent haemodialysis at a slower treatment rate for patients who are haemodynamically unstable. It has been shown to reduce hypotensive episodes during fluid removal due to the longer therapy duration. PIRRT provides adequate volume and solute control with shorter treatments and higher flow rates and can be performed on a standard intermittent haemodialysis machine as outlined in IHD. The patient will require vascular access and anticoagulation as per IHD.

RRT prescription

Frequency and duration of RRT will depend on the selected modality, see table 1 for examples

Table 1 Examples of RRT prescription

	IHD	SLEDD	PIRRIT
Frequency	3-4 x week	4-6 x week	3-5 x week
Duration	2-4 hours	8 hours	3-6hrs
Blood Pump Speed	250-400 mls/min	200-300 mls/min	150-200mls/min
Dialyser	Low Flux	Low Flux	Low Flux
Dialysate Flow rate	500-800 mls/min	300-400 mls/min	300- 400ml/min
Anticoagulation	Usually LMWH	LMWH / UFH	LMWH/UFH

Acute Peritoneal Dialysis

In peritoneal dialysis (PD) the peritoneum is used as a semi-permeable membrane for diffusive removal of solutes. A dialysate solution with a high concentration of glucose is administered into the peritoneal cavity through a catheter where it dwells for a prescribed period, allowing solutes to diffuse from blood in the capillaries into the dialysate. The saturated dialysate is then drained and discarded, and fresh dialysate reintroduced. High concentrations of dextrose are used in the dialysate to create an osmotic gradient for ultrafiltration. Criteria for selection for acute peritoneal dialysis includes: No previous major abdominal surgery, particularly scars around the umbilicus; cardiovascular stability; availability of skilled healthcare professionals to insert PD catheter. Absolute contraindications are: Abdominal obesity; abdominal distension due to constipation; known abdominal aortic aneurysm[2]. Advantages of PD include technical simplicity, haemodynamic stability, and lack of need for anticoagulation or vascular access. However, Acute PD requires the surgical or medical insertion of a PD catheter. The availability of skilled healthcare professionals attached to ICUs to perform this procedure makes its use limited along with concerns that PD may compromise patient respiratory status due to increased abdominal pressure from instilled dialysate, cause hyperglycaemia, and provide insufficient solute clearance in hyper catabolic patients. However, where there is on site expertise and support there has been success with acute PD in managing AKI. The acute PD prescription will be based on clinical assessment of biochemistry and fluid status and reviewed daily

Table 2 Example Acute PD Prescription [2]

	Session 1 (CCPD/IPD)	Session 2	Session 3
Time	12-18hrs	16hrs	12-16hrS
Total Volume	20-30L	20-30L	15-25L
Fill Vol	1.3-1.6L	1.5-2.0L	1.5-2.0L
Last Fill	0ml	0ml	1.0-1.5L
Cycles	9-14	9-20	
Dwell Time	20-40mins	20- 75mins	
Dextrose strength			

*CCPD – continuous cycling PD, IPD Intermittent PD

Although each modality has a role in the management of patients with AKI, choice may be limited based on availability of equipment and support from renal teams. Each form of RRT has its own advantages and disadvantages as summarised in table 3.

Table 3 Advantages and disadvantages of each type of RRT.

Treatment	Advantages	Disadvantages
IHD	Short duration Less anticoagulation Good K+ clearances Rapid volume & solute removal	Requires specialist training Requires water supply/ safe removal of effluent Electrolyte disequilibrium Possible cardiovascular instability Risk of systemic hypotension caused by rapid electrolyte and fluid removal.
SLEDD	Haemodynamic stability Lower solute removal Minimise solute disequilibrium Greater dialysis dose over longer time Minimal anticoagulation	Risk of hypokalaemia Risk of Hypophosphatemia Time/length of treatment
PIRRIT	Haemodynamic stability Minimise solute disequilibrium Minimal anticoagulation	Requires specialist training Requires water supply/ safe removal of effluent Time
Acute PD	Haemodynamic stability Lack of need for anticoagulation Lack of need for vascular access.	Requires specialist HCP to insert PD catheter Requires specialist training Availability of equipment Challenges nursing in prone position May compromise patient respiratory status due to ↑abdominal pressure from instilled dialysate, Possible hyperglycaemia Insufficient solute clearance in hypercatabolic patients

Further information, protocols, national guidance and patient information [4,5,6 ,8]can be found respectively at https://britishrenal.org/dialysis-protocols-for-use-in-icu/ https://renal.org/covid-19/

https://www.kidneycareuk.org/news-and-campaigns/coronavirus-advice/

Models of Care

Depending on the proximity of renal services to Critical Care units' different models of care will be in place to support the delivery of alternative RRT. For areas where renal services are located on the same sites as Critical care units these may include:

- Peripatetic acute dialysis teams
- Renal Nurses providing support to train/supervise CCU nurses in IHD/SLEDD/Acute PD
- Dually trained CCU/Renal nurses
- Nephrology MDT support
- Jointly appointed Intensivist/Nephrologist

The importance of collaborative working has never been more significant than during this pandemic. The combined knowledge and skills of specialist nurses and doctors to ensure patients with AKI have access to the best possible treatment has been demonstrated by the work of the joint Critical Care and Renal Associations/Societies and patient charities[4,5,6,7]

Assessment and Management of patients with COVID-19 requiring RRT

Clinical assessment

Patients should be routinely assessed for baseline observations prior to commencement of any RRT and in line with general principles of patient assessments within critical care.

Broadly RRT will be commenced for the following reasons:

a) Hyperkalaemia unresponsive to medical treatment
b) Fluid overload unresponsive to medical treatment
c) Persistent or worsening metabolic acidosis
d) Uraemia – in a closely monitored critical care patient this will be more likely noted from blood tests not symptoms.
It is important to clearly define the goals for each RRT session, and this will help to define the prescriptions and identify parameters to monitor closely for changes during and after treatments.

Biochemistry
Clearance of smaller molecules is affected by a number of factors within RRT.
These include:

- Selection of dialysate (different concentrations will be available to choose from)
- Size of dialyser
- Treatment choice
- Blood flow rate
- Length of time of treatment
- Dialysate flow rate

Careful consideration needs to be given to patient's pre-treatment bloods to ensure that removal of these electrolytes doesn't happen too quickly. Post treatment there needs to be time to allow for blood results to settle (post dialysis rebound) as electrolytes still move from peripheral compartments to the arterial circulation post treatment. Check bloods at least 1 hour after treatment has finished.

Vascular Access

Management of vascular access should be as per local protocol aiming to reduce risk of sepsis and central venous access failure. If a joint team (renal and ICU nurse are providing care) ensure that there is a standardised protocol that both are familiar with. The dialysis access should be assessed for signs of infection and patency prior to each use, with findings clearly documented.

Flushing and locking of temporary dialysis access should take place after each treatment. A combined anticoagulant and antimicrobial catheter lock solution such as DuraLock-C® or Citra-lock® is recommended.

Competencies for care of dialysis access should be available from the supporting renal unit.

Machine Considerations

Temperature

The temperature on the machine is normally set between 35.5- 36.5°C. It is important to remember that RRT may mask a fever and therefore there should be regular microbiological surveillance while the patient is dialysing. Beware the rebound pyrexia when the patient comes off the treatment. Machine temperature can be reduced to help patients who suffer with hypotension.

Transmembrane pressure (TMP)

Transmembrane pressure (mm Hg) is the hydrostatic pressure gradient which allows for ultrafiltration or convection across the dialyser membrane i.e. pulls water from the blood to the dialysate compartment. This is achieved by applying a negative suction pressure in the dialysate compartment relative to the positive hydrostatic pressure in the blood compartment.
If TMP is increasing it may be indication that blood is becoming thicker, and more difficult to remove fluid from. A drop in TMP could be due to a leak or filter rupture (rare)

Venous pressure alarm

During a haemodialysis treatment, blood flows from the patient's access to the dialyser via the arterial line, passes through a venous drip chamber and back to patient. The pressure needed to infuse blood through the venous line is referred to as the venous pressure. A rise in venous pressure indicates an issue with returning blood, and suggests clotting is occurring somewhere in the extracorporeal circuit.

Arterial pressure alarm

The arterial pressure is a negative or vacuum type pressure that represents the amount of force required to remove blood from the body. High arterial pressures mean that there is a problem with blood flow from the patient's access, or there is a kink in the blood tubing between the patient and the blood pump.

What to do if there is a venous or arterial pressure alarm

- Check lines for kinks
- Consider flushing lines with saline or changing anticoagulation rate.
- Consider stopping treatment and washing back patient's blood
- Consider in extreme situations changing the dialyser during treatment – only by competent experienced renal nurse

Dialysate flow rate

The dialysate flow is the rate in mL/min that the dialysate (dialysis fluid) is moving through the dialyser. The dialysate flow rate can be set anywhere between 300 and 1,000 mL/min.

Ultrafiltration*: *UF goal, UF time, UF rate, and UF removed.

- UF goal is the total amount of fluid in ml to be removed from the patient during the dialysis treatment
- UF time is the amount of time over which the fluid will be removed from the patient.
- UF rate is the rate at which the fluid will be removed from the patient, represented in ml/hr

The UF removed is the amount of fluid in ml that has been removed from the patient

Trouble shooting during dialysis

Hypotension

Hypotension can occur for a number of reasons during RRT

- Excessive or too rapid fluid removal
- Inability to vascularly refill, fluid may be 'in the wrong place' and may need time to equilibrate. Maintenance of blood volume during dialysis session relies on rapid refilling of blood compartments from surrounding tissue spaces. A reduced blood volume results in reduced cardiac filling and reduced cardiac output and therefore hypotension.
- Reflection of underlying illness.
- Myocardial infarction,
- Sepsis
- Cardiac arrhythmias precipitated by electrolyte disturbances (RRT can lead to excessive potassium and magnesium removal).
- Reaction to the dialyser leading to the release of inflammatory mediators (rare)
- Haemodynamically unstable
- Blood flow rate too high (pump speed)

Prevention: Pre dialysis fluid assessment, assess JVP, oedema and chest for fluid. Consider sodium levels/profiling &/or UF profiling. Review antihypertensive medication
Treatment: stop fluid removal, give bolus of normal saline, lay patient flat if not already flat. Re-asses fluid status, adjust RRT prescription.

Blood loss due to clotting during dialysis

Remain vigilant for signs of clotting during RRT. This is more likely when no anticoagulation is used (consider regular saline flushes) and lower blood flow rates, particularly when larger dialysers are used. Always ensure that the vascular access is functioning well before connection. If lines have poor flows on flushing consider whether this needs to be reviewed to minimise risk of blood loss on dialysis due to clotting.

- Observe blood lines for darkening of blood
- Observe machine for changes in pressures and alarms. Always check the line from patient back to machine for kinks and twists initially.

If the signs of clotting are not recognised and acted upon, the patient can lose the entire extracorporeal circuit. Prevention: adequate anticoagulation. Treatment: stop dialysis, disconnect patient. Check Hb & biochemistry, review and recommence RRT if necessary.

Dialysis Disequilibrium Syndrome

Dialysis disequilibrium syndrome (DDS) is the occurrence of neurologic signs and symptoms, attributed to cerebral oedema, during or following shortly after intermittent hemodialysis. DDS occurs due to rapid high solute removal/correction of uraemia. Symptoms include

- Headache
- Nausea/vomiting
- Loss of consciousness
- Confusion

*These are difficult to define in patients who are ventilated

Prevention: use low flux dialyser, slow blood & dialysate flows. Treatment: reduce blood pump speed, stop Ultrafiltration & stop RRT. Seek urgent medical advice, check blood chemistry

Competencies required for RRT

- Knowledge of type of RRT being administered and associated equipment required
- Pre RRT assessment/ documentation
- Understanding of RRT prescription
- Preparation of machine
    - Check clean & disinfect pre dialysis, connect water / drain
    - Lining and priming of dialysis machine
    - Knowledge of dialysis acid concentrates available and their appropriate use
- Ability to programme haemodialysis machine
    - Treatment time
    - Total fluid volume to be removed and profile
    - Isolated / intermittent ultrafiltration
    - Dialysis adequacy (Kt/V)
- Vascular Access assessment
- Anticoagulation
- Demonstrate ability to recognised deteriorating patient and take appropriate actions especially with regard to fluid depletion
- On completion of treatment, perform disconnect procedure
- Post dialysis observations / evaluation /
- Cleaning and sterilisation of machine, disposal of consumables.

Dialysis machine competencies are designed and available through companies with training videos/ materials in addition to training support from the renal team. Maintaining competencies may be a challenge depending on the frequency of the use of these alternative treatments.

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