RENAL REPLACEMENT THERAPY FOR ACUTE RENAL FAILURE IN CHILDREN: EUROPEAN GUIDELINES

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ABSTRACT

Acute renal failure (ARF) is uncommon in childhood and there is little consensus on the appropriate treatment modality when renal replacement therapy is required. Members of the European Pediatric Peritoneal Dialysis Working Group have produced the following guidelines in collaboration with nursing staff. Good practice requires early discussion of patients with ARF with pediatric nephrology staff and transfer for investigation and management in those with rapidly deteriorating renal function. Patients with ARF as part of multi-organ failure will be cared for in pediatric intensive care units where there should be access to pediatric nephrology support and advice. The choice of dialysis therapy will therefore depend upon the clinical circumstances, location of the patient and expertise available. Peritoneal dialysis has generally been the preferred therapy for isolated failure of the kidney and is universally available. Intermittent hemodialysis is frequently used in renal units where nursing expertise is available and hemofiltration is increasingly employed in the intensive care situation. Practical guidelines for and the complications of each therapy are discussed.

Key Words: acute renal failure; peritoneal dialysis; hemofiltration; hemodialysis; children; guidelines

INTRODUCTION

Acute renal failure (ARF) is uncommon in childhood but its incidence may be increasing and modalities of treatment changing with an increasing number of children being treated in the intensive care unit (ICU) with multiorgan failure. Traditionally children with ARF with renal involvement were only treated with peritoneal dialysis but extracorporeal techniques are being increasingly used in ICUs.

Members of the European Pediatric Dialysis Working Group reviewed all modalities of renal replacement therapy for acute renal failure in children and developed the following guidelines in collaboration with nursing staff during 3 meetings and extensive e-mail discussion. There are no randomised trials of renal replacement treatment in children with ARF. The guidelines are based upon published reports and consensus opinion to emphasise good practice.

1.1 Acute renal failure (ARF) is recognised when renal excretory function declines rapidly. Rising values of plasma urea and creatinine are usually accompanied with oliguria (< 1ml/kg/hr) but occasionally patients may be polyuric. The cause of ARF may be pre-renal, intrinsic or post renal (obstructive) problems and differ between neonates and older children.[1-3]

1.2 The incidence of ARF in children is hard to define as often renal insufficiency in the newborn and on intensive care units is conservatively managed by ICU staff. Outside the neonatal period ARF is an uncommon condition accounting for 8 referrals per million population per year to one regional paediatric nephrology unit in the UK.[4]

1.3 ARF may occur as isolated failure of the kidneys alone with other organ systems functioning normally or in association with multiple organ failure. The mortality of the latter group is considerably higher especially with the growth in pediatric

intensive care. For example, the mortality in neonates and infants is 51% after cardiac surgery for congenital heart defects[4] but is only 3-6% for children with intrinsic renal disease such as hemolytic uremic syndrome (HUS) in developed countries.[5,6]

1.4 The case mix in different units treating ARF and hence mortality and morbidity rates will therefore vary according to local clinical activity and resources.[7,8] Many pediatric renal units will be close to pediatric intensive care units (PICUs) in hospitals which may offer cardiac surgery, liver transplantation, specialist treatment for metabolic disorders, oncology patients etc[6]. Other renal units may be in hospitals that do not have a PICU on site and conversely there may be hospitals offering pediatric intensive care with no specialist pediatric nephrology service.

Recommendations

- All children with ARF require discussion with a pediatric nephrologist. Early transfer for investigation and management is essential in those with rapidly deteriorating renal function or in those with hemodynamic or biochemical disturbances (good practice).[9]
- All children with ARF As part of multi-organ failure require transfer to a designated regional pediatric intensive care unit where there should be access to pediatric nephrology advice and support. (good practice)

Rationale

1.5 Since there are few comprehensive regional pediatric nephrology centres the distances that families may have to travel can be considerable. Children with acute renal impairment may be managed in local hospitals but it is essential that early referral is made, especially if children have evidence of rapidly deteriorating renal function and require an urgent histological diagnosis to determine if immunosuppressive therapy or other treatment is required. Indications for referral include:

- oligoanuria, especially if associated with fluid overload, hypertension, hyperkalemia, hyponatremia, acidosis or the need for blood transfusion. Dialysis is often accompanied by early nutritional support and pediatric nephrology units should be equipped to provide the necessary medical and nursing expertise, combined with dietetic and psychosocial support. The latter support is also important if the child is managed conservatively.
- neonates and premature infants with ARF require transfer to a tertiary neonatal unit with pediatric nephrology team expertise
- Patients with ARF and multi-organ failure require prompt transfer to a designated regional pediatric intensive care unit

1.6 The choice of dialysis therapy for ARF depends upon the clinical circumstances, patient location and expertise available. Peritoneal dialysis (PD) has generally been considered the preferred therapy if there is isolated failure of the kidneys such as HUS. It is regarded as a simpler technique which is universally available. However, hemofiltration (HF) and hemodiafiltration (HDF) are increasing in popularity in PICUs where the facilities to perform hemodialysis (HD) may not be available. HD may be the preferred mode of treatment in more stable patients with adequate vascular access treated on renal units where specialist nurses are available.

Although extracorporeal techniques such as continuous veno-venous hemofiltration (CVVH) or continuous veno-venous hemodiafiltration (CVVHDF) are used quite frequently in adult ICUs there is still limited expertise in many PICUs. Such techniques are very technology dependent and more costly than PD.[10] They are also dependent upon the availability of appropriate nursing expertise.[11] Such expertise can be developed and maintained in units remote from the pediatric nephrology centre by an outreach service using a renal critical care nurse educator.[12]

Recommendation

There is no evidence for the optimum level of renal function for starting renal replacement therapy nor for the optimum dialysis modality. Advantages and disadvantages are listed in Table 1. Consideration should be given to establishing national and international databases to collect this data along with patient outcomes.[6,13]

Table 1: Advantages and disadvantages of various modalities of renal replacement therapy for acute renal failure.

Type	Complexity	Use in Hypotension	Efficiency	Volume Control	Anti-coagulation
Peritoneal Dialysis	Low	Yes	Moderate	Moderate	No
Intermittent Hemodialysis	Moderate	No	High	Moderate	Yes
CVVH	Moderate	Yes	Moderate	Good	Yes
CVVHDF	High	Yes	High	Good	Yes

CHOICE OF THERAPY

Acute PD

2.1 The main advantage of PD is that it is continuous therapy which requires neither anticoagulation nor vascular access and the technique can be used in hemodynamically unstable patients.[14] Acute PD can be performed in units with no HD expertise and is effective in children of all ages, including neonates.[15-18] PD has been used in treating acute pancreatitis, tumor lysis syndrome, intoxications, metabolic diseases and other pathological conditions in children.[19-22] The choice of PD as therapy has always to be individualised, balancing advantages against disadvantages.

2.2 *Limitations in the Use of PD*

Inborn areas of metabolism in the newborn period lead to acute accumulation of neurotoxic metabolites which can be better removed using techniques such as CVVHD.[23,24] The latter technique requires good vascular access which can still be a major problem in small children[25]. Newborns with respiratory diseases, even if on ventilatory treatment, can be treated with PD provided that the fill and exchange volumes are adapted to the clinical situation. However caution is necessary in neonates with necrotizing enterocolitis and older children with suspected bowel perforation.[26]

Preparation for PD

2.3 Dialysis is only possible if the access provides free flow in and out of the abdomen. The choice is between catheters inserted at the bedside under sedation or the placement of a chronic PD catheter by a pediatric surgeon in the operating theatre, or exceptionally at the bedside in ICU.

2.4 The rigid Trocath catheter with a stylet has largely disappeared and surgically placed Tenckhoff catheters are reported to have fewer complications.[27-29] However, the availability of small catheters for percutaneous placement using a Seldinger technique are invaluable in providing acute PD rapidly, especially in the neonatal PICU situation.[13,30]

2.5 Blockage by the omentum is always a risk with PD catheters. If the catheter is to be placed surgically then consideration should be given to partial omentectomy.[31]

2.6 In patients who are having a PD catheter inserted under general anaesthetic the single injection of a cephalosporin antibiotic 20mg/kg should be given as a single IV dose up to one hour prior to implantation of the catheter.[32] Any accidental contamination episodes subsequently should result in the use of prophylactic antibiotics, eg Cefuroxime 125mg/l in the dialysate for 48 hours.

2.7 For catheters that are inserted percutaneously prophylactic antibiotics, eg, Cefuroxime 125mg/l should be added to the dialysis fluid unless the patient is on systemic treatment.

2.8 Heparin, 500 units/l should be prescribed to prevent catheter blockage with fibrin. This is generally maintained for the first 48 hours and longer if the PD fluid remains slightly bloodstained.[33,34]

PD Prescription

2.9 This needs to be individualised for patient size and condition. Automated PD machines are the preferred method for delivering the individualised dialysis prescription and accurately measuring ultrafiltration.[30] Such machines are now available that can deliver dialysis volumes accurately down to 60ml with 10 ml increments. Although such machines now have improved accuracy of UF measurements the dead space of the tubing can reduce dialysis efficiency. A manual PD set can be used using burettes that can accurately measure inflow and outflow with the PD fluid warmed appropriately.[35] With manual sets attempts should be made to maintain a closed drainage system which can help reduce the frequency of peritoneal contamination.[36] Such manual PD sets are commercially available for neonatal patients.

Choice of Dialysis Solution

2.10 The choice of dialysis solution will depend upon the weight, blood pressure and hydration status of the child, bearing in mind the need to create nutritional space as part of the management strategy.[37]

2.11 The general principle is to commence with the lowest concentration of glucose solution possible (1.36%) with stepwise increments. Care is needed if 3.86% glucose solution is required as

a) rapid ultrafiltration can occur, especially in infants

b) hyperglycemia may develop (especially in septic and multi-organ failure patients) leading to hyperosmolarity and loss of effective ultrafiltration

2.12 Icodextrine solutions need a longer dwell time to obtain significant ultrafiltration and so are rarely indicated in acute renal failure.

2.13 Lactate-containing dialysis solutions are likely to be replaced by bicarbonate solutions, which are being evaluated in chronic PD. The routine use of bicarbonate solutions should be considered in neonates or in patients with reduced lactate metabolism or with lactic acidosis.[38,39]

2.14 *Practical points*

- Connect patient and start APD or manual cycles immediately after catheter implantation.
- Heparin 500units/l should be added to dialysis fluid to prevent fibrin deposition and to improve peritoneal solute permeability,[33,34] but it can be absorbed and care is needed in patients with coagulation disorders.
- Use 10-20ml/kg dialysis fill volumes (300-600 ml/m^2) initially depending on the body size and cycle in and out until the dialysate becomes clear.
- Use a PD program with 1-hour dwells during the first 24 hours. Shorter cycles can be considered initially if hyperkalemia needs urgent treatment.
- Adjust the program with increasing dwell times and cycle fill volume (if no leakage problems) until desired fill volume (800-1200ml/m^2) is achieved with adequate UF and biochemical control.[40]
- High intraperitoneal pressure (IPP) can be a problem in the first 2-3 days after surgical catheter insertion. The measurement of IPP may limit the risk of leakage when the fill volumes are being increased and allow optimised pain management but is not yet in routine use.[41]
- Inflow/outflow pain on PD usually diminishes with time. Tidal dialysis is an alternative[42] and bicarbonate dialysis should be considered.[43]

- The amount of ultrafiltration that is prescribed will partly depend upon the volume of oral, nasogastric or total parenteral nutrition that is required combined with fluid for drugs. Ultrafiltration may not be enough without the use of 2.27% or 3.86% glucose solutions.
- The clinical biochemical and nutritional status of the patient should be assessed regularly in conjunction with an experienced renal dietitian.[44] Optimal nutrition is necessary to avoid a catabolic state and associated production of BUN and uremic products.

Rationale

Patients with ARF need constant assessment while on PD and adequacy should be judged in terms of clinical status, ultrafiltration achieved and biochemical parameters, particularly urea, creatinine and bicarbonate levels.[40] Although a link between the dialysis dose and the outcome of adult patients in ARF has been established[45] there are no guidelines as to what constitutes adequate PD in a child with ARF. The aim is to deliver maximum clearance to compensate for the catabolic stress.

2.16 *Complications of Acute PD*

- Leakages can be a difficult problem and are mostly due to a leakage around the catheter. The incidence can be reduced by proper surgical technique when using a Tenkhoff catheter[46] or resuturing around a percutaneous catheter. Fibrin glue injected into the catheter tunnel is a technique under evaluation.[47]
- Poor drainage due to mechanical blockage or catheter migration is all too common. Flushing the catheter and preventing fibrin accumulation by increasing the heparin dosage and/or urokinase is suggested initially.[48] A plain abdominal x-ray is rarely justified as repeated poor drainage will require catheter relocation. If available, a laparoscopic technique may be used to correct poor drainage or replace the malfunctioning catheter.[49]

- Hernias can be a problem in neonates and infants, particularly males. They do not usually require interruption of PD and can be repaired electively by laparoscopic or direct measures when the child's clinical condition has improved or stabilised.
- Peritonitis remains a constant threat, especially if there has been a lot of manipulation of the catheter. The standard features of cloudy PD fluid require urgent attention.[50]

3 CONTINUOUS EXTRACORPOREAL TECHNIQUES

Continuous arteriovenous hemofiltration (CAVH) has largely been replaced by pumped continuous venovenous hemofiltration (CVVH) and continuous venovenous hemodiafiltration (CVVHDF) particularly in intensive care units.[51] Such continuous renal replacement therapies (CRRT) have expanded the possible role of blood purification in the management of critically ill patients. However, there is a lack of randomised trials in patients with sepsis and a recent analysis failed to show a benefit for hemofiltration.[52] Studies in adult ITU patients have shown a lower mortality in patients treated with CRRT compared to IHD but a recent meta-analysis on studies before 1996 concluded that the evidence was insufficient to draw strong conclusions regarding the mode of renal replacement therapy for acute renal failure in the critically ill[53]. A recent randomised trial in adult ICU patients showed a significant survival advantage when the intensity of ultrafiltration was increased.[54]

3.1 *Practical Guidelines for Prescription*

- Since the concentration of solutes in the filtrate is the same as in the plasma, biochemistry is controlled by removing large volumes of filtrate and replacing it with electrolyte containing fluid (HF replacement fluid). As most solutes are distributed within the extracellular and intracellular fluid compartments (total body water), the exchange volume of filtration necessary to control biochemistry relates to total body water. Clinical experience has shown that

a turnover of approximately 50% of body weight in 24 hours is usually adequate for CVVH.

- The extracorporeal circuit requires good central venous access, usually via a dual lumen catheter, to allow the high blood flows necessary to prevent clotting in the hemofilter. Suggested catheter sizes in French gauge (FG) are:

Patient Size (kg)	Vascular Access
2.5-10	6.5FG dual lumen (10cm)
10-20	8FG dual lumen (15cm)
> 20	10.8FG or larger dual lumen (20cm)

  For neonates a 5FG dual lumen catheter may be adequate and access can be obtained via the umbilical vein.[55] A single lumen catheter using "single needle" for CVVHD in very low birth weight infants has also been described[56] but this method may be compromised by high recirculation rates with most available systems. However, the smaller the access the greater the problems.[57] It is possible to consider placing two small sized single lumen catheters in different central veins.

- A low blood flow rate, high hematocrit and high plasma protein concentration will limit the rate at which filtration can occur and solutes (particularly of higher molecular weight) are removed. For a given blood flow rate pre-dilution results in higher clearance of solutes than does post-dilution,[58] but at the expense of greater use of replacement fluid (approximately 20-50% more). Pre-dilution has the potential for extending filter life.
- As with hemodialysis, the blood volume in the extracorporeal circuit should be less then 10% of the patient's circulatory volume. Blood flows of 6-9ml/kg/min or 8% of circulating blood volume prevents excessive haemoconcentration in the filter. Automated machines with appropriate accuracy for children are recommended for delivering the CRRT prescription safely[59] and have replaced pump-assisted hemofiltration using volumetric pumps.[60]

- To achieve a 50% exchange of total body water in 24 hours an appropriate filter should be selected with a surface area no more than the surface area of the patient. Suggested maximum filtration rates are:

Patient Size (kg)	Max Filtration Rate (ml/hr)
< 8.5	250
8.5-20	500
>20	2000

- Under post-dilution conditions, the filtration rate should never exceed one-third of the blood flow.
- A number of filter materials are now available. Synthetic membranes have replaced cellulose acetate as they are more biocompatible causing less complement reaction and anticoagulation needs. The synthetic polysuphone membranes are also thought to aid convective clearance of solutes through solute drag.[61]
- A variety of replacement fluids are available such as lactate, bicarbonate and buffer-free solutions. Bicarbonate or buffer-free solutions should be used in young infants and those intolerant of lactate. If a commercially available bicarbonate solution is freely available then this would be the solution of choice. Careful monitoring of electrolytes, glucose and phosphate is essential as the constituents vary between the solutions.

3.2 *Anticoagulation*

- The goals of anticoagulation are to prevent clotting of the circuit and maintain adequate clearances with minimal risk to the patient.
- Heparin is the standard anticoagulant in Europe but the choice of dosage will depend upon the patient's coagulation status, adequacy of blood flow and blood viscosity. In most patients heparin should be administered as an initial bolus (maximum 50units/kg) at the time of connection to the extracorporeal circuit followed by a continuous infusion of 0-30units/kg/hr. The activated

clotting time (ACT) or whole blood activated partial thromboplastin time (aPPT) are usually used to monitor treatment. The optimal ACT aimed for during hemofiltration is 120-180 seconds. The aPPT should be between 1.2-1.5 times the respective baseline value. Some patients can be treated without heparin in the circuit.[6]

- In those patients who are severely thrombocytopenic or where there is suspected heparin-induced thrombocytopenia, alternative treatment with prostaglandin infusions or recombinant hirudin,[62] a direct thrombin inhibitor, can be considered.[63]
- Regional anticoagulation with citrate has been favoured by some centres.[64,65] Sodium citrates chelates ionised calcium necessary for the coagulation cascade and systemic anticoagulation is avoided by infusing calcium through a separate central line. The disadvantages include the possibility of various acid base and electrolyte disturbances including hypernatremia, hypocalcemia and metabolic alkalosis.

3.3 *Adjustment of the Prescription*

- Any formula for the prescription of HF is at best an approximation or starting point as the needs will be determined by many unmeasured variables such as the rate of solute production, nutritional intake and the actual volumes of the extracellular fluid and intracellular fluid compartments.
- Fluid removal – if only fluid removal is required then relatively low rates of filtration are needed, often referred to as slow continuous ultrafiltration (SCUF). There will be negligible solute removal under these circumstances
- Correction of "uremia" and electrolyte disturbance – this requires the turnover of large volumes per kg of fluid typically of the order of 50% of body weight per day for post-dilution and 75% for pre-dilution (approximately 20-30ml/kg/hr)
- In catabolic patients, the clearances achieved with standard CVVH may not be sufficient. Solute removal may be increased by attempting "high volume exchange" but this may be limited by the practical problems of pediatric

patients with limitations of vascular access and haemoconcentration in the filter. In these cases, small solute clearances can be maximised by establishing diffusive mass transport via a dialysis circuit. This can be performed with CVVHDF or without an additional major ultrafiltration component (CVVHD). The latter technique requires an additional pump to achieve separate control of the dialysate in- and outflow and of the replacement fluid flow. CVVH substitution fluid bags can be used as dialysis fluid. Dialysis fluid flow should be 2-3 times the blood flow if maximal efficacy is desired. This setting requires frequent manual bag exchanges and continuous supervision of the system. For practical purposes, the hemodialysis component can be added for several hours per day to a CVVH regimen.

- CVVHD has recently been recommended as the method of choice for the treatment of inborn errors of metabolism since it supplies maximal clearance of ammonium and other neurotoxic metabolites. When CVVHD is unavailable large volume turnover of body water with CVVH will provide the next best therapy. Rates of up to 100ml/kg/hr have been reported.[66] If possible, blood pump speed also needs to be increased.
- When high turnover and blood flow rates are in use patients should be carefully monitored for hypothermia, hypokalaemia and circulatory failure. Hypothermia may need to be treated with an external warming blanket and hypokalaemia will require replacement. Blood flow should not be increased if the patient develops cardiovascular instability.

3.4 *CVVH and Extracorporeal Membrane Oxygenation (ECMO)*

- In the authors experience the best results are achieved when pre-diluted fully automated CVVH is used, attached to the venous (outflow from patient) side of the ECMO circuit. This appears to reduce problems of shunting blood around the oxygenator and overcomes the problems of the increased haematocrit that may be associated with ECMO. It also reduces the complications of excessive fluid and solute clearances with a free flow when

systemic hemofilters are used in line with the ECMO circuit. When using CVVH in the suggested configuration the 'pigtails' provide access with very little resistance, causing the arterial and venous pressure alarms to activate and shut down the circuit. Therefore, 3-way taps are used to create more resistance to flow into and out of the CVVH circuit. When treating neonatal patients the ECMO circuit increases the extracorporeal blood volume very significantly. Therefore, the blood pump speed should be calculated taking into account the patient's blood volume and the priming volume of the ECMO circuit.

3.5 *Complications of Continuous Extracorporeal Techniques*[67]

- *Hypotension*. Hemofiltration is most commonly used in sick septic children, many of whom will be on pressor therapy. Indeed, the need for pressor agents gives a poorer prognosis.[6] Care should have been taken to minimise the amount of blood in the extracorporeal circuit and blood priming of the hemofiltration circuit may be necessary at the outset. Fluid removal is obviously adjusted according to the patient's clinical state during the treatment.
- *Clotting of the filter and lines*. One of the commonest complications and again is related to the patient's changing clinical status and problems with anticoagulation. This complication occurred in 24% of 89 patients treated with CVVH in a 2 year local audit (B Harvey, unpublished observations).
- Other potential complications of bleeding, anticoagulation toxicity and infections appear to be minimal. Air embolism is a rare but preventable complication of extracorporeal circuits and is greatly reduced with the proper use of automated machinery.

4. INTERMITTENT HEMODIALYSIS[68]

4.1 *Advantages*

The main advantage of hemodialysis (HD) is the relatively rapid removal of uraemic toxins and ultrafiltration of fluid. This makes the technique well-suited for acute situations.

4.2 *Limitations*

HD is not a continuous therapy and it requires good vascular access as with hemofiltration. A purified water supply is also required as well as anticoagulation which should always be minimised. The technique might not be applicable for hemodynamically unstable patients. Often the major limiting factor is the availability of expert nursing staff[69] especially in the ICU situation.[70]

4.3 *Practical Guidelines for Prescription*

- HD is only possible with good vascular access provided either by double-lumen HD catheter or a single lumen catheter of sufficient diameter to achieve flows for single needle dialysis. Catheter lengths vary from 5cm for neonates to 20cm for large adolescents.
- Bloodline choice depends on the priming (extracorporeal) volume, which traditionally has not exceeded 10% of the blood volume (approximately 80ml/kg).
- Dialyser choice depends on the priming volume and maximum flow rate with a surface area that should not exceed the child's surface area and with a urea clearance between 3-5ml/kg/min. There is no evidence for dialyser choice in pediatric practice but meta analysis in adult patients with acute renal failure suggested synthetic membranes appeared to confer a significant survival advantage over cellulose-based membranes but with no similar benefit for recovery of renal function.[71]
- Bloodline priming is usually done with isotonic saline. Small babies, anemic patients and those in an unstable cardiocirculatory condition, require priming with albumin or blood.

- *HD catheter care*. After the session the catheter should be flushed with isotonic saline and filled with undiluted heparin (1000IU/ml) with volumes according to manufacturer's recommendations (usually marked on the catheter itself).

4.4 *HD Prescription*

- The first session should not exceed 2-3 hours but the standard time is usually 4 hours. Longer sessions are advisable to avoid too rapid UF and disequilibrium syndrome.
- All children should be dialysed using volume controlled machines and with bicarbonate dialysate.
- Blood pump rate is usually 6-8ml/kg/min but depends upon the catheter and patient size.[69]
- Ultrafiltration target should not exceed 0.2ml/kg/min for acute patients who should be carefully monitored for hypovolemia and hypotension.
- Sodium profiling is rarely used in pediatric HD practice.
- Anticoagulation is usually with heparin (50-100IU/kg per session including initial bolus). See 3.2 for alternatives.
- Reinfusion is usually done with isotonic saline.

4.5 *Complications Occurring During Acute HD*

- *Hypotension*: switch off the UF and infuse isotonic saline into the venous line until the blood pressure normalises; additional 20% albumin 5ml/kg might be helpful.
- *Hypertension* is treated according to standard hypertension protocols available elsewhere.[72]
- *Disequilibrium syndrome* is now a rare event with adequate control of ultrafiltration and stepwise reduction of uremic toxins.
- *Hypoglycemia*: should not occur with the use of glucose-containing dialysis fluid

- *Anemia*: transfusions are avoided unless patient symptomatic. Erythropoietin may be given intravenously at end of dialysis (50-200iu/kg) to maintain hemoglobin levels.

4.6 *Medications*

- The clearance of drugs on hemodialysis or during CRRT needs to be considered. Reference should be made to standard texts.[73,74]

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