Continuous renal replacement therapy

David Connor
Overview

• Classification of AKI
• Indications
• Principles
• Types of CRRT
• Controversies
# RIFLE criteria

<table>
<thead>
<tr>
<th>Stage</th>
<th>GFR Criteria</th>
<th>Urine Output Criteria</th>
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</table>
| **Risk** | Baseline creatinine × 1.5  
 or  
 GFR decreased >25%                                                             | UO < 0.5 mL/kg/h for 6 hours                                 |
| **Injury** | Baseline creatinine × 2  
 or  
 GFR decreased >50%                                                             | UO < 0.5 mL/kg/h for 12 hours                                |
| **Failure** | Baseline creatinine × 3  
 or  
 Baseline creatinine decreased >75%  
 or  
 New creatinine ≥350 μmol/L resulting from an acute rise ≥44 μmol/L | UO < 0.3 mL/kg/h for 24 hours  
 or  
 anuria for 12 hours                                        |
| **Loss** | Complete loss of kidney function >4 weeks                                     |                                                             |
| **ESRF** | Complete loss of kidney function >3 months                                    |                                                             |
Classic indications

• Diuretic resistant pulmonary oedema
• Hyperkalaemia refractory to medical therapy
• Metabolic acidosis refractory to medical therapy
• Uraemic complications (pericarditis, encephalopathy, bleeding)
• Dialysable toxins (for example lithium, toxic alcohols & salicylates)
Filtration

- Solute dissolved in solvent
- A transmembrane pressure gradient carries the solute across a semi-permeable membrane (solvent drag)
- Filtration rate dependent on:
  - Membrane permeability
  - Hydrostatic pressure of the blood, which depends upon blood flow
- Effective at removing fluid & mid-sized molecules

Dialysis

- Solute diffusion occurs from an area of high to an area of low concentration across a semi-permeable membrane
- Gradient maintained by an electrolyte solution running countercurrently to blood flow
- Effective at removing small molecules (urea)
- Ineffective at removing larger molecules
- Solute removal is directly proportional to the dialysate flow rate
Filter membranes

- Synthetic
  - High permeability to water (high-flux)
  - High sieving coefficients for solutes in a wide range of molecular weights
  - Allow transfer of solutes with a mass <20 kDa (urea/creatinine/urate/ammonia/heparin/drugs)
  - Cause less damage to platelets and white cells
  - Suitable for either haemofiltration or haemodiafiltration

- Cellulose-based
  - Low permeability to water (low-flux)
  - Activate inflammatory cascade
  - Suitable for dialysis
Dialysate fluid

• Bicarbonate ions can cause:
  – The dialysate to have a short shelf life due to formation of carbonate which dissociates to carbon dioxide and evaporates from the solution
  – Formation of precipitants if mixed with calcium
• Lactate can be used as an alternative buffer
  – Only suitable if liver can convert lactate to carbon dioxide and water, generating bicarbonate ions via the TCA cycle
  – In liver failure, lactate free bags can be used and bicarbonate infused separately from the circuit
• Acetate can also be used as a buffer
• Standard solutions don’t contain potassium or phosphate so supplementation may be required
Baxter Accusol 35

- Most commonly used UK dialysate fluid
- Bicarbonate contained in separate pouch
- Once mixed, must be used within 24 hours
- Precipitation has been noted in filter lines (MHRA 2008)

<table>
<thead>
<tr>
<th>Ionic composition</th>
<th>Mmol/L</th>
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<tbody>
<tr>
<td>Ca$^{2+}$</td>
<td>1.75</td>
</tr>
<tr>
<td>Mg$^{2+}$</td>
<td>0.5</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>140</td>
</tr>
<tr>
<td>Cl$^-$</td>
<td>109.5</td>
</tr>
<tr>
<td>HCO$_3^-$</td>
<td>35</td>
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</tbody>
</table>
Continuous Veno-Venous Haemofiltration (CVVHF)

- Replacement fluid may be pre or post the filter membrane
- Pre-dilution improves the life of the filter by reducing haematocrit but also decreases its efficiency
Continuous Veno-Venous Haemodialysis (CVVHD)

Roller pump

Dialysate

Roller pump

Filtrate

Roller pump

Blood flow

Dialysate flow

Patient

Diffusion across concentration gradient

Heparin/Prostacyclin

Blood flow 100-200 ml/min

Dialysate flow 1-2 L/h
Continuous Veno-Venous Haemo-Diafiltration (CVVHDF)

- Dialysate
- Roller pump
- Diffusion across concentration gradient
- Replacement fluid
- Roller pump
- Convection across pressure gradient
- Patient
- Roller pump
- Filtrate
- Roller pump
- Heparin/Prostacyclin

Diagram showing the process of diffusion and convection in a CVVHDF system.
Controversies

• Dose
  – Optimal dosing should aim for an effluent flow rate of 20-25ml/kg/hour
  – Based on 2 large multicentre RCTs (ATN & RENAL)
• CRRT versus IHD
  – BEST Kidney observational study showed that the majority of ICUs favour CRRT (80%) with the exceptions of North & South America who prefer IHD
  – Hypotension during IHD leads to increased risk of non-renal recovery
  – Consensus favours CRRT in haemodynamically unstable patients but without formal evidence
• Timing of CRRT
  – BEST Kidney observational study showed the median time to commencement is 5 days
  – Higher RIFLE score at commencement of RRT is associated with increased mortality
  – Late initiation of RRT is associated with increased mortality, longer duration of RRT & longer hospital stay
  – Optimal timing is an unresolved issue requiring further research
• CRRT modality (CVVHF versus CVVHDF)
  – Modalities may be equivocal
  – Unresolved at present
1. Regarding intermittent haemodialysis (IHD):
   • Dialysis occurs via diffusive and convective processes
   • Dialysis is driven by a transmembrane pressure across a haemofilter
   • IHD does not require replacement fluid
   • Hypotension is common
   • IHD is more efficient at removing solute than CRRT
2. Regarding replacement solutions:

- They are added pre-filter
- Bicarbonate is stable in solution
- Bicarbonate-buffered haemofiltration must be used if blood lactate concentrations are initially high
- Patients with blood lactate concentrations persistently >5 mmol litre\(^{-1}\) require bicarbonate-buffered haemofiltration
- Metabolic alkalosis occurs because of over-buffering
MCQ 3

3. Dialysis dysequilibrium syndrome (DDS):
   • Causes symptoms primarily because of cerebral oedema.
   • Is primarily associated with IHD.
   • Presents rapidly during the dialysis cycle.
   • Is more common in patients with epilepsy.
   • Causes symptoms that are self-limiting.
MCQ answers

- FFTTF
- FFFTT
- TTFTT
References

• Gambro, The Prismaflex system brochure