Anaesthetic management of patients requiring vascular access surgery for renal dialysis

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Epidemiology of renal replacement therapy

End-stage renal failure (ESRF) creates a considerable health burden in the UK. Despite the increasing number of kidney transplants and a plateau in the incidence of patients starting renal replacement therapy (RRT), the prevalence of patients undergoing dialysis has been steadily increasing, with over 56,000 individuals registered for RRT in 2013 (Fig. 1). As the population ages and the survival of those on dialysis increases, it is likely that the requirement to provide anaesthesia for renal access will only increase.

Chronic renal disease significantly increases mortality risk, worsening as glomerular filtration rate (GFR) falls. For those aged 35–39 yr who require RRT, the relative risk of death is 16.2 times that of the general population. In addition to the independent risk of death conferred by RRT, many of the commonest causes of ESRF (see Table 1) are serious systemic diseases in their own right, affecting multiple other organ systems.

Decision to offer dialysis

Chronic kidney disease (CKD) describes abnormal kidney function and/or structure, and its classification has evolved, being most recently described by the updated 2015 NICE guidelines on CKD. It had previously been defined as GFR < 60 ml min⁻¹ (1.73 m²)⁻¹ for 3 months or more, or abnormalities of kidney function or structure with implications for health, but the NICE guidance now describes grades of CKD using both GFR and albumin:creatinine ratio (ACR) (Fig. 2).

It is usual for patients with G5 CKD, or less severe but rapidly accelerative disease, to be offered dialysis.

Types of RRT

Peritoneal dialysis

The main advantage of peritoneal dialysis (PD) is that it can be done at home, and it therefore has less impact on daily living. Most patients are on continuous ambulatory PD where they do...
Three dialysate changes during the day and an overnight dwell (when dialysate is left in for some hours). The process requires a level of physical ability and dexterity and is more appropriate for younger and more able patients. Its main complication is the high risk of peritonitis.

Occasionally, it is impossible to site a PD catheter in patients with previous abdominal surgery because of scarring and adhesions.

### Haemodialysis

Haemodialysis requires wide bore vascular access to allow for the large volumes exchanged. If dialysis is urgently required, this can be achieved with a central venous catheter (Vascath) as used in intensive care units for RRT. In less acute situations, such as bridging between peritoneal and haemodialysis, or in the event of graft failure, renal physicians may place tunnelled lines (usually subclavian) on the ward or in an outpatient clinic. Due to the risks of indwelling lines, particularly infection and thrombosis, most patients will progress to some sort of permanent access. This will be either an arteriovenous fistula or a graft. Intensive care-based renal replacement differs from intermittent haemodialysis in being continuous (with the advantage of exerting less rapid fluid and electrolyte shifts) and utilizing haemofiltration (convection across a semipermeable membrane driven by a pressure gradient) in combination with haemodialysis.

### Transplant

Although not the focus of this article, it is worth bearing in mind that many dialysis patients may already be transplant candidates, or will be in the future. It is also not unusual for patients to return to dialysis after transplant failure. There will be some specific features to note in these patients—in particular, the maintenance of immunosuppression.

### Vascular access of RRT

#### Native vein atrial–venous fistula

Created by joining a vein to the adjacent artery, these fistulas are the commonest forms of access for haemodialysis. Compared with grafts, they have much better long-term primary patency rates, reduced rate of thrombosis and infection, and lower incidence of morbidity and mortality. These may be formed by any artery and vein but the most common types are:

- **Radiocephalic**: Often first line. Preserves proximal locations for later use. Lowest flows of all.
- **Brachiocephalic**: More proximal so higher flows achievable. Increased steal effect, which is discussed subsequently.
- **Brachiobasilic transposition**: More difficult to create. Due to relative inaccessibility and therefore reduced frequency of prior access, vein may be better preserved at formation of fistula. Highest risk of steal syndrome. Often used after multiple failed distal fistulas.

A fistula requires maturation time before use (between 1 and 4 months, usually 4–6 weeks) for vessel thickening and enlargement to occur, allowing the repetitive cannulation required for dialysis. The fistula should be within 1 cm of the skin surface to allow easy cannulation and in an accessible anatomical location and relatively straight in shape. They are usually created in the non-dominant arm. Fistulas increase in size over time and may become aneurysmal leading to cosmetic objections by some. These changes lead to an increase in blood flow through the fistula, which, while good for dialysis efficacy, can lead to cardiac failure because of increased venous return to the heart. Steal syndrome is another potential complication.
when diversion of arterial blood through the fistula leads to distal limb arterial insufficiency and ischaemia that may put the limb at risk and require surgical intervention (Figs 3 and 4).

Arterial–venous graft

In cases where it is not possible to approximate artery and vein, or when previous fistulas have exhausted suitable vessels, a prosthetic graft is used to connect the artery and vein and tunneled subcutaneously. Most grafts are synthetic and constructed from polytetrafluoroethylene (PTFE), but biological grafts, such as bovine mesenteric vein, have been used, and bioengineered grafts are in development. Different types and brands offer a variety of characteristics such as variable wall thickness, reinforcement with spiral or ringed PTFE, and the ability to self-seal after puncture using a gelatine sealant as a coating. Grafts have advantages such as ease of cannulation, large surface area, short maturation time (some may be accessed on the day of surgery), but the long-term patency is inferior compared with native vein fistulas and there is a four-fold increase in salvage procedures. They have a six times greater thrombosis rate and 10 times greater infection rate, despite some grafts incorporating antibiotic material (Fig. 5).

The commonest graft configurations are:

- **Forearm loop graft**—anastomosing brachial artery to graft and graft to antecubital fossa vein. The graft is positioned in a looped configuration in the forearm.
- **Brachioaxillary graft**—anastomosing brachial artery to graft and graft to vein in the axilla. The graft is positioned in a straight line in the upper arm.

### GFR and ACR categories and risk of adverse outcomes

<table>
<thead>
<tr>
<th>GFR categories (ml min⁻¹ (1.73 m²)⁻¹), description and range</th>
<th>ACR categories (mg/mmol), description and range</th>
<th>ACR categories (mg/mmol), description and range</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥90 Normal and high</td>
<td>&lt;3 Normal to mildly increased</td>
<td>&gt;30 Severely increased</td>
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<tr>
<td>60–89 Mild reduction related to normal range for a young adult</td>
<td>3–30 Moderately increased</td>
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<tr>
<td>45–59 Mild-moderate reduction</td>
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<tr>
<td>30–44 Moderate–severe reduction</td>
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<tr>
<td>15–29 Severe reduction</td>
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<tr>
<td>&lt;15 Kidney failure</td>
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1 Consider using eGFRcystatinC for people with CKD G3aA1 (see recommendations 1.1.14 and 1.1.15)

Abbreviations: ACR, albumin:creatinine ratio; CKD, chronic kidney disease; GFR, glomerular filtration rate


**Figure 2 Classification of CKD using GFR and ACR categories (NICE).**

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• **Femoro-femoral graft**—anastomosing femoral artery (usually superficial femoral) to graft and graft to femoral vein. The graft may be positioned looped or straight in the thigh.
• Grafts may also be used to bypass stenosed segments of an existing fistula.

**PD catheters**

Often inserted using laparoscopic techniques requiring general anaesthesia. Removal is usually a simple superficial dissection of the line but may be complicated by adhesions or infection and thus has the potential to become a mini-laparotomy.

**Interaction between ESRF and anaesthetic drugs**

Multiple facets of pharmacokinetics are altered in ESRF, not just renal excretion. Depending on the timing of dialysis, patients may be relatively volume overloaded with consequent increase in apparent volume of distribution. Plasma proteins are diluted and less available for drug binding. Some patients will present to theatre straight from dialysis during which time they are likely to be intravascularly volume depleted and may show exaggerated cardiovascular instability and an apparent reduced volume of distribution leading to increased steady-state concentrations of infused drugs. The degree of ionization of drugs will be affected by chronic metabolic acidosis, which, in combination with hypoalbuminaemia and low plasma proteins, increases free drug availability of those drugs that are highly protein bound. As such, the doses of thiopental and benzodiazepines should be reduced by 30–50%. Propofol pharmacokinetics are unaltered in renal failure, but there is some evidence to suggest that patients in established renal failure require higher induction doses to achieve the same levels of hypnosis. This must be balanced against the frequent cardiovascular (CVS) co-morbidities and frailty of patients.

Inhalational agents are ideal for maintenance of general anaesthesia as they are excreted via the lungs.

As most opioids are metabolized in the liver the pharmacokinetics and dynamics of the ingested drug are unaffected by renal disease. However, morphine in particular has active metabolites (morphine-6-glucuronide) that are renally excreted and prone to accumulation and toxic effects; therefore doses should be limited or alternatives found. Oxycodone is widely used in patients with impaired renal function as the prolongation of effect attributable to accumulation in renal failure is much less pronounced. Fentanyl’s fast onset and offset time combined with its lack of active metabolites makes it more suited for postoperative use if required.

Suxamethonium may cause a rise in serum potassium concentration, which should be anticipated with caution in these patients who may already show a relative hyperkalaemia (although they may also have developed some tolerance to hyperkalaemia with chronic renal disease).

Most non-depolarizing muscle relaxants are excreted unchanged by the kidneys. The initial dose wears off by
redistribution but maintenance doses accumulate so doses should be reduced. Atracurium elimination is independent of renal and hepatic function, relying instead on Hofmann degradation, dependent on temperature and pH. Rocuronium relies partially on renal excretion and as such demonstrates prolonged action in renal failure. Both sugammadex and the sugammadex/rocuronium complex are renally excreted. There is evidence of much slower clearance of this complex in renal failure but no evidence of harm or reduced effect. Sugammadex use in patients with creatinine clearance (CrCl) < 30 ml 1 min 1 (including dialysis) is not recommended by the manufacturer, but for those with mild or moderate renal impairment, no dose alterations are suggested.

Local anaesthetics are extremely useful drugs in the context of renal replacement access surgery. In renal failure, metabolic acidosis reduces both duration of action and protein binding. The increased percentage of unbound drug and reduced seizure thresholds in these patients increases potential for toxicity. Maximum doses should be reduced by 25%. Esters are hydrolysed in plasma, while amides undergo hepatic metabolism hence clearance of drug is unaffected by renal failure.

Platelet dysfunction is common in chronic renal failure (CRF), with altered adhesion and aggregation, and is frequently compounded by patients taking antplatelet agents. There is also a theoretical risk of residual heparin effect causing ongoing anticoagulation after dialysis. Performance of neuraxial blockade, and possibly peripheral regional blocks, may therefore be contraindicated, which may in turn present increased risk to a patient consigned to general anaesthesia.

**Perioperative considerations**

Unfortunately, the paucity of kidney transplantation means that RRT can be ongoing for decades and patients have to base their entire lives around it. It is important to recognize how much this may play on the psyche.

Preoperative assessment should focus on the indication for renal access and the complications of underlying disease.

**Preoperative information**

The incidence of ischaemic heart disease is approximately twice that of the general population and represents the commonest cause of mortality in patients on RRT. The prevalence of diabetes mellitus, coupled with the sedentary lifestyle that RRT forces upon many people, means that it is often asymptomatic.

In particular, consider the following:

- hypertension, peripheral vascular disease;
- ischaemic heart disease, congestive cardiac failure;
- diabetes;
- peripheral and autonomic neuropathies;
- immunocompromise because of disease and drugs;
- anaemia; and
- chronic hyperkalaemia, acidosis, and other electrolyte imbalances and fluid shifts around the time of dialysis.

**Investigations**

Electrocardiogram is mandatory in all patients irrespective of age. Dysrhythmias, ischaemia, and electrolyte abnormalities may all be observed. A recent set of bloods including full blood count and electrolytes should always be available. It is important to view the latter in the context of what is normal for the patient, as many will have developed tolerance to chronic electrolyte abnormalities and anaemia. Proximity to dialysis (before or after) may have a profound effect on fluid volume and distribution and electrolytes. It may be useful to know a ‘dry weight’ for the patient to gauge excess fluid volume. It is common to avoid giving i.v. fluids in theatre.\(^{10}\)

**Drugs**

Most patients will have a considerable drugs list, and this must be comprehensively reviewed prior to theatre. Of particular note will be:

- anticoagulants and antiplatelet agents: both in terms of surgery and safety of regional anaesthesia;
- chemotherapeutic agents and disease-modifying anti-rheumatic drugs, e.g. tacrolimus;
- steroids;
- antihypertensives including beta-blockers; and
- hypoglycaemic agents: oral and injectables.

**Anaesthesia**

**Monitoring**

Care must be taken to preserve current fistulas. Blood pressure cuffs must be on the opposite arm or leg. Despite the potential for cardiovascular instability in these patients, arterial cannulation should also be avoided unless absolutely necessary to preserve arteries for future surgery.

**Vascular access**

Avoid accessing fistulas. Source control of bleeding in most fistula sites is easy to do, so wide bore access is not usually necessary. Cannulation attempts should be minimized to preserve vessels for potential future fistula formation and thus the preference for cannulation site is the back of the hand. Use of indwelling dialysis lines by the anaesthetist should be cautioned against, except in an emergency.\(^9\) They commonly contain high-dose heparin, which may be inadvertently injected, and any subsequent line failure or complications may be blamed on improper use.

**Choice of anaesthetic technique**

This will be influenced by the individual anaesthetist, the surgeon and their chosen technique, and the patient’s wishes. Many patients will be undergoing repeat surgery and may have preferences based on personal experience.

**Local anaesthesia**

This is the least physiologically intrusive method but the least well tolerated by patients and some procedures will not be feasible because of location or extent of incisions or depth of surgery.

**General anaesthesia**

There is no single best technique for these patients.

**Points to consider:**

- Cardiovascular co-morbidities and potential for instability.
- Neuropathies and reflux may warrant endotracheal intubation more frequently than in other patient populations.
- Using a combination of general anaesthesia (GA) with regional anaesthesia (RA) is controversial owing to the associated haemodynamic compromise (excessive hypotension
Role of Regional anaesthesia

RA in the form of upper limb nerve blocks is especially useful in fistula formation surgery. It reduces exposure of the patient to the many anaesthetic drugs whose pharmacodynamics and kinetics may be unpredictable and the intrinsic risks of GA. There is evidence that the vasodilatation not only assists the surgeon intra-operatively but also helps graft patency for some hours afterwards. RA causes increased vein diameter and higher vessel flow rates, both of which are predictors for successful fistula formation, and there is evidence to suggest that the use of RA in fistula formation contributes to shorter maturation times, lower failure rates, and higher patency rates. The excellent analgesia reduces the need for medication after operation and can speed discharge.

Potential pitfalls:
- Intercostobrachial nerve (T2) innervates the axilla and upper medial arm. It is not part of the brachial plexus and will need supplementary local anaesthetic in the superficial skin across the axilla to cover surgery for grafts reaching into the medial upper arm.
- Patchy blocks can be topped up by surgeons.
- Often supplemented with i.v. sedation (fentanyl/midazolam/propofol infusion).
- Check coagulation status.

Role of day case surgery

Despite the obvious associated co-morbidity, ESRF is not in itself a contraindication to ambulatory surgery. Especially combined with regional techniques, it is quite possible to discharge patients with new fistulas on the same day.

Timing of surgery

The treatment regime for patients already on RRT must be known. For haemodialysis, this is usually 3 days a week, whereas for PD it is every night. This will affect not only fluid and electrolyte balance but also drugs relying on renal clearance. It is not essential that patients are dialysed on the day of surgery, but there must be a clear plan about when it will happen, especially if they normally dialyse away from the hospital.

Declaration of interest

None declared.

MCQs

The associated MCQs (to support CME/CPD activity) can be accessed at http://www.oxforde-learning.com/journals/ by subscribers to BJA Education.

References