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ABC of Kidney Disease, 2nd Edition

Dialysis

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Overview

Indications to commence dialysis are:

intractable hyperkalaemia;

acidosis;

uraemic symptoms (nausea, pruritus, malaise);

therapy-resistant fluid overload;

chronic kidney disease (CKD) stage 5.

There is considerable variation of the level of glomerular filtration rate (GFR) individuals may tolerate before becoming markedly uraemic.

‘Crash-landing’ onto dialysis confers a reduction in patient survival that persists for at least the first three years of subsequent therapy.

Early identification and assiduous preparation mentally and physically are needed in the predialysis phase for those likely to need renal replacement therapy (RRT).

Haemodialysis (HD) involves circulating blood through a disposable dialyser. The vascular access of choice is the arteriovenous fistula (AVF). This, however, requires suitable peripheral veins and needs four to eight weeks for the fistula to mature. If there are no suitable veins, a graft can usually be inserted. Acute access with venous catheters has a high complication rate.

Peritoneal dialysis (PD) involves using the peritoneum as the dialysis membrane, with pre-packaged fluid being instilled into the peritoneal space via a Tenckhoff catheter. This is usually only inserted once the decision to start dialysis is made.

HD is usually performed in four-hour sessions, three times a week, in hospital-based dialysis units.

PD typically involves continuous ambulatory peritoneal dialysis (CAPD), which allows continuous dialysis using three to five exchanges of fluid per day via disposable bags.

Automated peritoneal dialysis (APD), whereby larger volumes of fluid are instilled and drained by the use of a small machine by the bedside, is used when either more intense dialysis is needed or when, for social reasons, the night is the preferred time for treatment.

Introduction

Thomas Graham described the founding principles of dialysis over 100 years ago. Even though the first treatments for acute kidney injury (AKI) were performed in the 1920s, chronic dialysis treatment for end stage renal failure (ESRF) did not become a reality until 1960. In the following few years, a series of breakthroughs in both dialysis technology and vascular access enabled chronic renal replacement therapy (RRT) to become established in both the United States and Europe by the mid-1960s. Chronic haemodialysis (HD) became widely available in the United Kingdom in the early 1970s (largely as a home-based therapy), and continuous ambulatory peritoneal dialysis (CAPD) became increasingly popular during the early 1980s. There are now over 2.0 million patients receiving regular dialysis worldwide and around 36,000 in the United Kingdom alone (Box 1 and Figure 1).

Some basic facts about renal replacement therapy in the United Kingdom

- The most common cause of end-stage renal disease is diabetic nephropathy
- Demand for dialysis will continue to increase over the next 10 years by as much as 150% for HD
- The minimum estimated prevalence of RRT in the United Kingdom at the end of 2003 was 632 patients per million population
- Of new patients, 22% starting RRT are >75 years old and 12% of all prevalent patients are >75 years old
- In 2003, 67.5% of RRT patients received HD and 29.2% PD (3.3% had a transplant)
- The average cost of dialysis is £30 000 per patient per year
- The cost of a kidney transplant is £20 000 per patient per transplant with immunosuppression costs of £6500 per patient per year

- Mortality rate in dialysis patients is about 20% annually

- Commonest cause of death is cardiovascular disease, the risk of which is 30 times higher in dialysis patients than age-matched controls

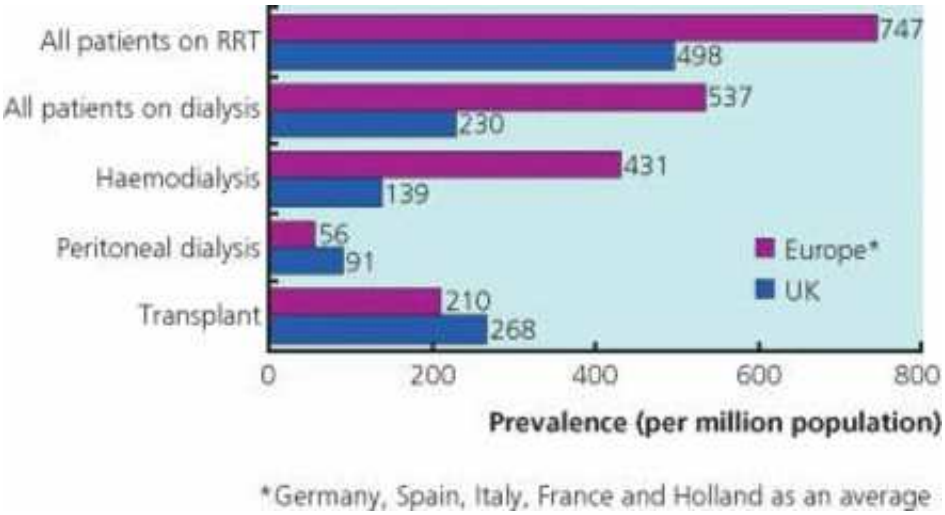

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Figure 1
Patient numbers and modalities of treatment in end stage renal failure.

Indications for Starting Renal Replacement Therapy

There is relatively little difference in opinion about intractable hyperkalaemia, acidosis, uraemic symptoms (nausea, pruritus, malaise) and therapy-resistant fluid overload being firm indications to commence dialysis. There is, however, wider variation in clinical practice as to when to start a relatively asymptomatic patient. A cut-off based on measured or calculated GFR may be applied. In general, this would be set in the CKD stage 5 range (estimated GFR ~10–15 mL/min). The advantages of such a 'well start' are multiple, and allow for maintenance of health prior to the development of significant abnormalities in either overall function or body composition. Furthermore, it allows dialysis provision to be built up slowly to compensate for further reduction of residual renal function (RRF). There is, however, still no robust (randomized controlled) evidence-base for such an approach. It is important to note that there is considerable variation in the level of GFR individuals may tolerate before becoming markedly uraemic. This may necessitate even earlier starts. The potential price for later initiation is that sudden decompensation may occur, requiring emergency treatment and a 'crash-landing'

onto dialysis. This confers a reduction in patient survival that persists for at least the first three years of subsequent therapy.

The general indications for starting dialysis are summarized in Table 1.

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Table 1
Indications for renal replacement therapy

Preparation for Renal Replacement Therapy

Timely and effective preparation for RRT, as well as assiduous management of the complications of CKD, is crucial. Optimal therapy while on dialysis will only partially compensate for previous deficiencies in care, with hypertension, functional/structural cardiovascular disease, malnutrition, parathyroid hyperplasia and renal bone disease already being well established in the predialysis phase. There are a number of key issues, covered below, that require a properly configured multidisciplinary team. They need to be delivered in the most effective and appropriate way regarding an individual's social and ethnic sensibilities.

Choice of Dialysis Modality (see Chapter 1)

Although there may be certain overriding medical or social imperatives, the choice between peritoneal dialysis (PD) and HD (either unit- or home-based) should be free, and not constrained by either clinician's prejudice or resource issues. Sufficient time and information must be provided to allow patients and families to make this choice. Poor or compelled choice will result in a higher chance of treatment failure, and poorer long-term outcomes (therapies are summarized in Table 2).

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Table 2
Relative advantages and disadvantages of haemo- and peritoneal dialysis

Dialysis Access

The vascular access of choice for HD remains the arteriovenous fistula (AVF). This requires the anastomosis of an artery to a suitable segment of vein (usually either at the wrist or in the antecubital fossa). This section of vein receives arterial pressure blood and becomes ‘arterialized’. This results in a structure with a thick wall, readily accessible, and with adequate flow within it to sustain an extracorporeal circuit. If there are no suitable peripheral veins, a piece of synthetic material can be inserted (usually a polytetrafluoroethylene, or PTFE, graft) and this is subsequently needled for access. For the reasons of the time taken for the AVF to mature (4–8 weeks), and an initial failure rate, which may be as high as 30% (especially in older, arteriopathic or diabetic patients), this procedure must be performed in good time (Renal NSF recommends six months in advance of likely need). A Tenckhoff catheter for PD, to allow fluid to be instilled into the peritoneal cavity, can be inserted either at laparotomy, laparoscopically or percutaneously, but usually once the decision to start dialysis has been made (Figure 2).

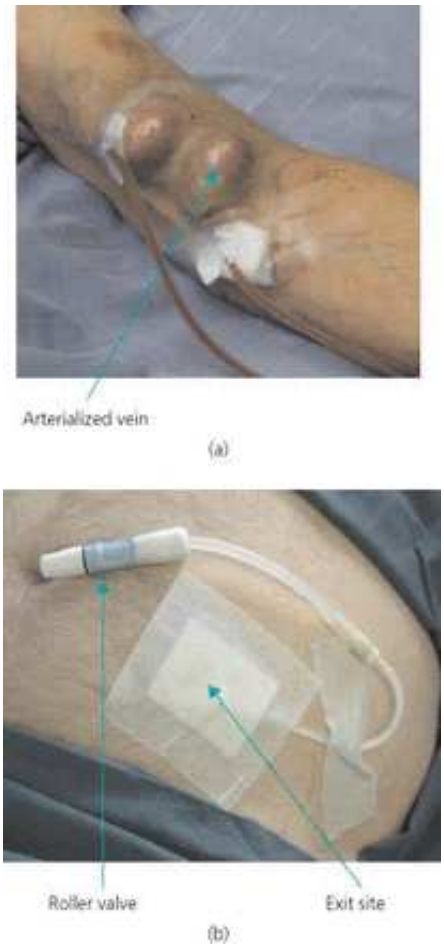

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Figure 2

1. Arteriovenous fistula.

2. Tenckhoff (peritoneal dialysis) catheter.

Dietary Restriction

Specialist dietetic interaction is needed to establish the degree of restriction required in potassium, phosphate, sodium and water intake. The final diet, though, must maintain a reasonable level of protein intake (1 g/kg/day) and avoid malnutrition.

Treatment of Anaemia

This may require correction of absolute and/or functional iron deficiency or other haematinics and starting erythropoietin therapy (see Chapter 2).

Psychosocial Issues (see Chapter 3)

Support for both the patient and their family is required for the psychological impact of RRT, and practical guidance from a specialist social worker into the benefits etc. that are available if work becomes problematic. Sexual function is often affected, with problems with both libido and erectile dysfunction (amenable to the conventional range of interventions). Although fertility in women of child-bearing age is impaired, effective contraception is essential due to the immense problems associated with pregnancy while on dialysis. These risks are largely normalized by successful transplantation.

Renal Replacement Therapy

Haemodialysis

HD involves circulating blood through a disposable dialyser. This contains hollow fibres of a selectively permeable material, giving a large total surface area (1–2 m2). Dialysate is produced by the continuous combination of concentrate with highly treated tap water (microbiologically pure, low endotoxin concentration and depleted in minerals). This flows around the hollow fibres in the opposite direction to blood. It contains a low concentration of factors to be removed and a higher concentration of bicarbonate, allowing diffusion into the blood and correction of acidosis. Removal of accumulated fluid is achieved by applying a pressure gradient across the dialysis membrane, resulting in controlled ultrafiltration (Figure 3).

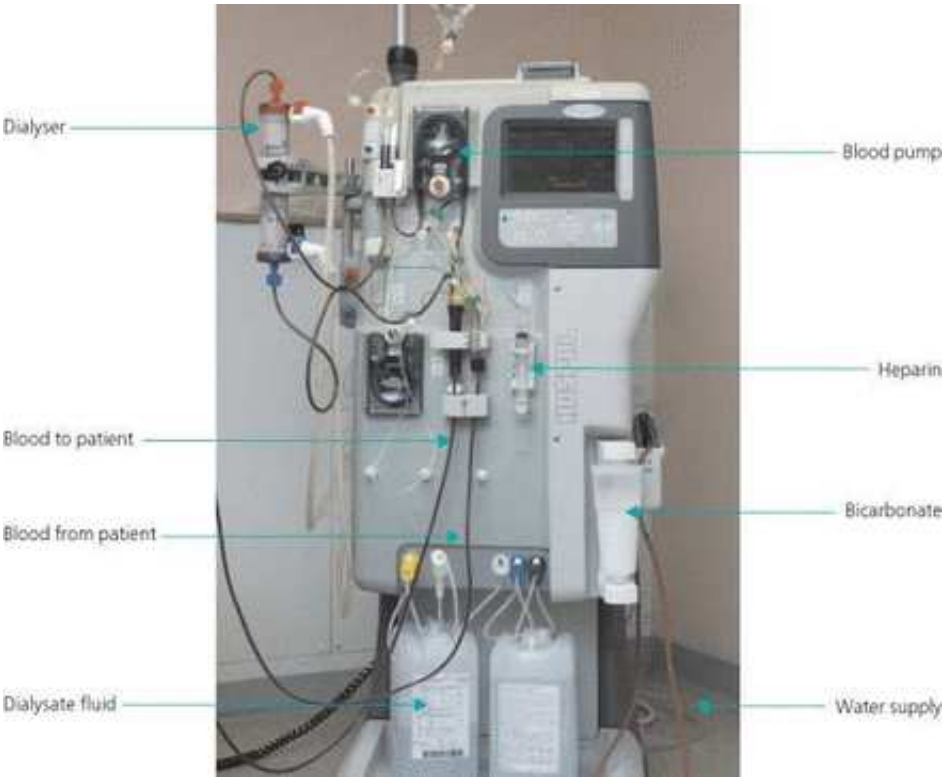

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Figure 3
Haemodialysis machine.

Conventionally, heparin is used to prevent clotting and the treatment is performed three times a week, for 3–5 h per session. This results in adequate control of biochemistry (though not normalized), fluid overload, acidosis and uraemic symptoms in *most* patients.

Peritoneal Dialysis

This technique involves using the peritoneum as the dialysis membrane. Pre-packaged fluid is instilled into the peritoneal space. It is allowed to dwell for a period of time. Waste products to be removed diffuse from the blood into the fluid. Again, the dialysate contains factors that do not need to be removed at similar concentrations to normal plasma (calcium, magnesium, sodium etc.). Acidosis is corrected by the diffusion of buffer from the fluid into the blood, and ultrafiltration occurs down an oncotic gradient. This is produced by the fluid having a higher osmolality than plasma (due to a high concentration of glucose or glucose polymer within the instilled fluid).

Ready drainage relies on good tube placement and function. The most common

cause of failure is constipation with tube displacement, or inspissation of omental fat into the catheter's multiple distal perforations. PD patients characteristically are prescribed aperients to ideally promote two soft bowel motions per day. The main limitations of the technique relate to the development of peritonitis, resulting from either an infected exit site, poor adherence to the technical challenges associated with PD bag changes or bacterial translocation across the bowel wall.

There are a number of refinements of the PD method. CAPD involves 3–5 exchanges of fluid per day, every day (due to the intrinsically lower solute removal efficiency compared with HD). The patient performs these manually, with the bag being disconnected between each exchange.

In some patients, either more intensive dialysis is needed or, for social reasons, the night is the preferred time for the treatment to take place. In this setting, automated peritoneal dialysis (APD) can be used. This allows larger volumes to be instilled and drained by the use of a small machine by the bedside (Figure 4). Assisted APD is a method by which patients can undergo APD at home either while they are waiting to be trained or if they are unable to do the dialysis themselves. It does have cost implications but offers great benefits to patients. A paid carer visits once a day to strip and prepare the APD machine for the next dialysis. The patient or a family member will perform the connection at night and disconnection the next morning. The carer may also perform blood pressure (BP) monitoring and/or exit site dressing.

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Figure 4

1. Peritoneal dialysate fluid.
2. Automated peritoneal dialysis machine.

Up until recently, the composition of all PD fluids was very similar. Glucose was used to produce the oncotic gradient and lactate was used as buffer (absorbed and converted to bicarbonate by the liver). Due to the limitations of using these compounds, and an increasing appreciation of the biological toxicities of glucose degradation products, a number of other fluids have subsequently been developed with a greater degree of biocompatibility (summarized in Table 3).

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Table 3

Types of peritoneal dialysate fluids

Monitoring Adequacy of Renal Replacement Therapy

The aim of chronic dialysis therapy is to replicate as far as possible the normal functions of the failed kidney(s). Patients are monitored, usually monthly, for a wide range of indices relating to solute clearance, mineral metabolism, volume status, nutrition and anaemia (summarized in Table 4).

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Table 4

Treatment aims for dialysis patients

Solute Clearance

This is usually measured as small solute clearance, and the conventional marker is urea. Clearance is measured by blood sampling before and after HD, or with a combination of blood samples and samples of waste fluid in PD. A variety of mathematical treatments are applied to these measurements and the adequacy of clearance calculated. Failure to reach certain thresholds is associated with increasing symptoms, failure to thrive and increased mortality. In HD, dialyser size, blood flow through the dialyser, access quality and treatment time can all be modulated to enhance clearance. In PD the dialysate volumes, number of exchanges, dwell time and use of APD are the main factors that can be altered to vary the efficiency of dialysis. The clearance of other factors can be measured (middle molecules) and these may influence the development of some long-term complications.

Maintenance of Dry/Desired Weight

This refers to the patient's weight best replicating the normal level of hydration (Table 5) and is important in managing hypertension and preventing the development of left ventricular hypertrophy and cardiac failure.

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Table 5
Monitoring fluid balance

Residual Renal Function

Maintenance of RRF reduces mortality and facilitates volume management, while avoiding the draconian fluid restriction required in anephric patients (500–750 mL/day). Nonsteroidal anti-inflammatory drug (NSAID) usage may reduce RRF, and therefore continued caution is required even in patients established on RRT.

Mineral Metabolism and Renal Bone Disease

This requires careful modulation of phosphate binders (type and dose), vitamin D and calcimimetics/parathyroidectomy.

Other Factors

These include assessment of suitability for transplantation and monitoring of complications (Table 6 and Figure 5).

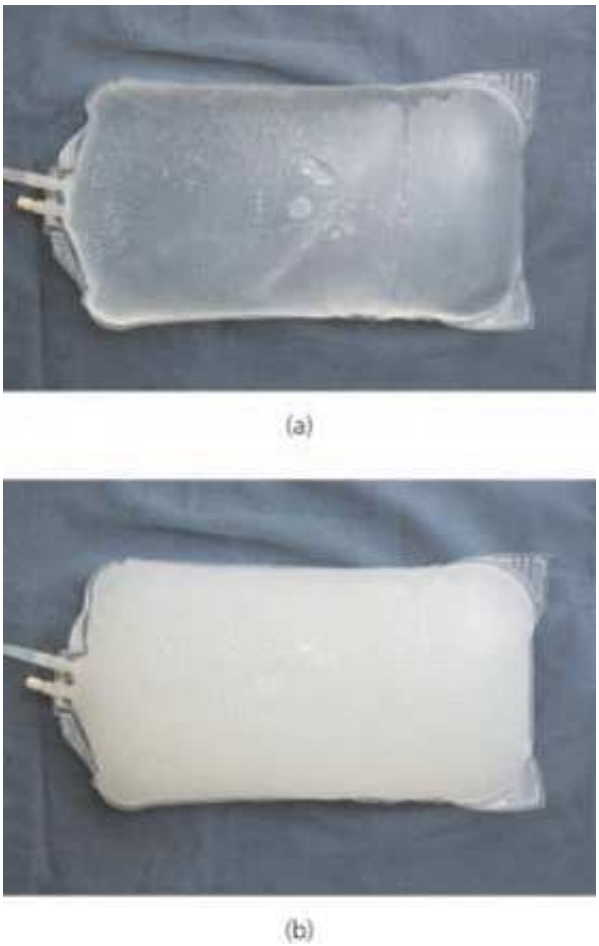

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Figure 5

Drained fluid in peritoneal dialysis peritonitis.

1. Normal peritoneal dialysate drainage.

2. Cloudy dialysate drainage in peritonitis.

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Table 6

Complications of dialysis

Developments in Delivery of Renal Replacement Therapy

PD continues to be an important treatment modality, both in the United Kingdom and Holland—two European countries with socialized healthcare systems and chronic underfunding of HD facilities—and in particular across the developing world. In the United Kingdom, the National Institute for Health and Clinical Excellence (NICE) published clinical guidelines in 2011 on PD particularly recommending it for patients who have RRF, all children under two years of age and adults without significant associated comorbidities. Wholesale adoption of the newer and more expensive PD solutions is currently being handicapped by the lack of appropriate outcome studies, although they do seem to have a wide range of benefits in terms of peritoneal function, systemic biocompatibility and cardiovascular response.

HD technology is also becoming more complex, with the use of biosensors to detect the physiological response to treatment and run biofeedback systems to improve treatment tolerability. Perturbations of dialysate temperature and sodium concentration, as well as adding a degree of convective clearance to dialysis, can ameliorate the common problem of intradialytic hypotension (IDH). These technologies, however, are largely adaptive to compensate for the high ultrafiltration rates and short treatment times driven by current pressures on dialysis resources. Increasing interest is occurring in daily dialysis (short hours during the day, or long, low-efficiency treatment overnight) in either a unit- or home-based environment.

There is a resurgence of interest in home-based HD, with improvements in water preparation and machine portability, and the increasing realization that with long overnight (quotidian) dialysis, or daily short-session dialysis, there can be very significant improvements in anaemia, calcium–phosphate balance, acidosis, nutrition, BP, lipid profiles and left ventricular hypertrophy compared to ‘standard’ thrice-weekly, four-hour sessions.

It is certain that the escalating numbers of patients on treatment and increasing comorbidity load will require continued refinement of RRT, while not replacing the need for early identification and assiduous preparation mentally and physically in the predialysis phase.

Further Reading

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