Home Hemodialysis

41

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Introduction

Although its use has diminished in the United States and currently stands at about 2%, hemodialysis performed in the patient's home has been a safe and effective form of dialysis therapy for over 40 years and was a predominant form of dialysis therapy in the 1960s and 1970s [1]. With the advent of newer technology and the increasing cost structure of center-based hemodialysis therapy, home hemodialysis is likely to become more prevalent. Thus, the physician managing vascular access will need to be cognizant of the specifics of hemodialysis at home. This chapter will focus on the differences between center-based dialysis and home hemodialysis and discuss self-cannulation principles and ergonomics, changes in dialysis frequency and length, and clinical monitoring of the access from a remote location.

History

Hemodialysis has been performed successfully in patients' homes for over 50 years. In fact, prior to the development of large-scale outpatient hemodialysis facilities, home hemodialysis was a major form of delivery of the therapy. When legislation granted coverage for hemodialysis to most citizens regardless of age in the 1970s, there was a rapid expansion of outpatient hemodialysis and a movement away from home hemodialysis [2].

With the introduction of new technology and easier to use dialysis machines, home hemodialysis has increased in popularity slightly over the last decade. The suggestion of improved outcomes with longer dialysis sessions and/or more frequent hemodialysis, which can be practically accomplished at home, has also renewed interest in home hemodialysis (Table 41.1).

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Technical Concerns

Machine

The choice of a machine is important not only for the patient but also for the home dialysis program. Machines will differ in their cost, maintenance, physical footprint, portability within and outside the home, plumbing and electrical requirements, training time, setup and breakdown time, and water and dialysate preparation. While it is feasible and sometimes helpful to use multiple hemodialysis machines within a home program, this will introduce more required training, knowledge, and experience of the entire staff. Almost any dialysis machine can and has been utilized in the patient's home.

Several dialysis machines have been studied for safety and efficacy in the home and approved for home use by the US Food and Drug Administration [3, 4]. The *NxStage System One* utilizes a cartridge-based extracorporeal circuit and dialysate of up to 60 L with lactate as a buffer. Its maximum dialysate flow is 300 ml/min. The *Fresenius 2008 K@home* is based on a traditional hemodialysis machine requiring water treatment similar to traditional hemodialysis and bicarbonate as a buffer. Four other hemodialysis machines designed specifically for home hemodialysis are under development: the *Tablo hemodialysis machine* from Outset Medical with an integrated patient interface and production of dialysate from tap water; the *PAK hemodialysis system* from Fresenius Medical, a sorbent-based hemodialysis system; the *Vivia hemodialysis machine* from Baxter which reuses the dialysis membrane and bloodlines; and the *SC+ hemodialysis machine* from Quanta Fluid Solutions which also uses a cartridge-based setup.

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Table 41.1 Common types of home hemodialysis

Type	Blood flow (ml/min)	Dialysate flow (ml/min)	Ultrafiltration rate (ml/kg/h)	Frequency per week
Staff assisted	350–500	500–800	10–15	3
Traditional	350–500	500–800	10–15	3–4
Short daily	350–500	100–350	5–10	4–6
Nocturnal	200–300	100–300	1–3	3–6

Water

Successful dialysis starts with the production of water free from microbiological and chemical contaminants that can harm the patient [5]. The Centers for Medicare and Medicaid Services (CMS) has applied water quality and testing standards developed by the Association for the Advancement of Medical Instrumentation (AAMI) since 1987. These standards are updated approximately every 5 years [6]. While water production in the outpatient unit is similar in each unit, each patient's home installation will be unique. In the home environment, the water system will be unique in every installation while adhering to the same AAMI standards.

While the cost of providing water and dialysate in the outpatient unit is usually less than 2 % of the overall cost of the treatment, it is a major cost in home hemodialysis and also may entail cost to the patient for additional electricity, water usage, sewer drainage, and plumbing.

Dialysate

Dialysate can be provided in a patient's home in a number of methods: bagged dialysate delivered to the patient's home similar to peritoneal dialysis, dialysate prepared in the patient's home prior to dialysis, or in-line dialysate from an appropriate water source mixed at the machine. Cost, convenience, storage, installation, and maintenance all factor in the type of dialysate to utilize.

Bagged dialysate similar to peritoneal dialysis has the advantage of providing a sterile, ultrapure dialysate to the patient. However, limitations accompany this advantage. Practical considerations of delivery, storage, cost, and logistics generally limit this method to approximately 30 l of dialysate yielding a single-pool urea Kt/V ($spKt/V_{urea}$) of approximately 0.7 in the typical 80 kg adult, whereas most current guidelines for thrice weekly hemodialysis recommend a $spKt/V_{urea}$ of approximately 1.2. Thus, in the absence of significant residual renal function, hemodialysis will need to be performed more than three times per week. Second, lactate is typically the base in bagged dialysate fluid for stability, compatibility with calcium, and microbiological concerns. Lactate showed improvement in tolerability over acetate as a hemodialysis buffer before the widespread introduction of bicarbonate-based buffer [7]. Yet, in hemodialysis with a lactate buffer, serum lactate levels will be increased slightly during the treatment, and patients with significant liver dysfunction, higher volumes of dialysate, and/or poorly controlled diabetes may not tolerate lactate.

Attempting to replicate dialysate production similar to the outpatient unit or the acute care setting in the hospital also has limitations. Typically either a reverse osmosis (RO) machine or a deionized (DI) water system must be installed in the patient's home. A disadvantage of the RO system is another machine to install, maintain, and monitor. The DI system usually requires an outside vendor to change the tanks and regenerate the beads in addition to plumbing installation delivering the water to the machine in the home.

Several systems that produce water and dialysate in novel methods in the home are being developed. These include the use of sorbent, distillation, and miniaturization of the dialysate production.

Management of the Vascular Access

For the home hemodialysis patient, several additional aspects of vascular access management need consideration: patient training, technique, ergonomics, safety, remote management of potential infection, and clinical monitoring of the vascular access outside of the dialysis clinic. All types of vascular access utilized in center-based dialysis have been successfully utilized in patients at home. The type of access should not be a deterrent to a patient dialyzing at home.

Rarely is fear of cannulation an insurmountable obstacle to home hemodialysis training. Currently, approximately half of home hemodialysis patients cannulate themselves and half have caregivers performing cannulation. Since all dialysis patients may be taught self-care in any aspect of their therapy, it is often helpful to begin cannulation training in the outpatient dialysis center before starting home hemodialysis training (unless the patient is new to hemodialysis).

For the patient with the arteriovenous fistula (AVF), either the rotating site ("rope-ladder") or single-site ("buttonhole") method of cannulation can be chosen. Although many practitioners believe the self-cannulator has less discomfort and easier needle insertion, this has not been adequately studied, and the infectious risk appears higher as currently practiced with buttonhole cannulation [8–10].

The sites of cannulation should be chosen with careful collaboration between the training nurse and the patient. The patient should give significant input to the ergonomics of cannulation and decannulation, while the nurse should choose the safest sites. For example, the nonmedical person choosing a site to insert a needle may inappropriately see the top of an aneurysmal dilatation as the easiest site to be successful. Removal of the needle also demands careful attention especially for the self-cannulator. The synchrony of safe needle removal, placement in an appropriate waste container, pressure, and hemostasis is often more technically difficult than needle insertion. Another ergonomic factor for the self-cannulator at home is the insertion and subsequent removal of both arterial and venous needles in a proximal or upward direction in both AVF and AVG.

Similar to peritoneal dialysis, aseptic technique cannot be emphasized, monitored, and retrained enough. Aseptic technique is often a foreign concept to the new home hemodialysis patient.

Unlike peritoneal dialysis, the signs and symptoms of an access infection in a home hemodialysis patient can be subtle. The threshold for a clinical evaluation, potential blood cultures, and possible preemptive antibiotics should be low. How and where to perform these should be determined prior to the end of patient training for each patient so no delay will occur when a potential problem develops. With a documented access infection, the patient's aseptic technique should be reviewed, observed, and adjusted as needed. Similarly, the home hemodialysis program should monitor their rate of bloodstream infections carefully.

Changes in the vascular access should be noted for possible intervention. An unexplained decline in urea kinetics would be one measure. Reports from patients of changes in blood flow, increased venous pressure during dialysis, or a change in bleeding after pulling needles may indicate a problem with the access. One of the advantages of home dialysis is that a full exam of the access can occur monthly by the physician without needles in place and a complete range of motion of the limb. Assessing the appearance, thrill, bruit, augmentation, temperature, and location of the cannulation sites is easy to do in the home patient during a clinic visit by both the nurse and physician.

Safety Considerations

Home hemodialysis as currently practiced has an excellent safety record [11]. In one review of two home hemodialysis programs, only seven serious events were noted over 500 patient-years, and most of those events were operator errors that could be prevented by a combination of technology and education. However, several specific topics merit discussion.

Hypotension

Some have estimated that intradialytic hypotension, defined as the need to stop ultrafiltration and administer saline intravenously, occurs in up to 20 % of conventional hemodialysis treatments. Hypotension in the home environment poses a clear safety risk and must be minimized. The most common cause of intradialytic hypotension in the home environment is incorrect calculation or entry of the ultrafiltration volume. Some of the strategies to reduce hypotension in the outpatient center also are available in the home such as limiting the ultrafiltration rate to ≤ 10 ml/kg/h, decreasing the dialysate temperature, and avoiding antihypertensive medications prior to the dialysis treatment.

Bleeding

Miscannulation of AVF or AVG should be reported promptly to the home dialysis nurse to determine the cause such as incorrect location, angle, depth, or advancement of the needle. Infiltration of blood into a misplaced venous needle can cause significant blood loss and pain and impair the future function of the access. Venous dislodgement of a needle with the arterial needle still in place with the blood pump engaged can lead to life-threatening blood loss quickly, particularly if the patient is performing a nocturnal hemodialysis treatment while sleeping. Fortunately, this is a rare event but moisture detectors placed near the venous needle can help prevent this from occurring.

Outpatient Follow-Up

One of the most surprising aspects of home hemodialysis is the effort the provider must provide after successful training. Most nephrologists perform a face-to-face encounter monthly with their home hemodialysis patients, usually in conjunction with a multidisciplinary team of nurses, social workers, and dieticians.

Since the use of the vascular access occurs outside the purview of the dialysis team, managing the vascular access can be challenging. However, since the patient is not undergoing dialysis at the time of the evaluation, a comprehensive exam of the access can be performed in addition to a monthly review of other parameters of the access which are:

- Cannulation sites
- Change in appearance of access
- Difficulty with cannulation
- Increased time to hemostasis
- Change in the thrill of the access

- Assessment of the venous outflow with elevation of the arm
- Venous pressure in access at initial blood flow
- Venous pressure in access at final blood flow
- Unexplained change in urea kinetics
- Unexplained elevation in plasma potassium

The outpatient clinic visit often works best if a multidisciplinary approach including the dialysis nurse, dialysis social worker, and renal dietician is utilized. Treatment logs for the month are reviewed for problems. Most patients draw their monthly blood work themselves and bring it to the center for analysis. Full medical waste containers can be exchanged for empty containers. While many supplies may be delivered to the patients' homes, it is often more cost-effective to have the patient pick up smaller supplies such as needles, gauze pads, syringes, etc., at this visit.

As with all forms of dialysis, problems will occur that require medical attention. A clear communication strategy should be in place for the patient. Technical problems with the machine should be routed to either the biomedical technician of the dialysis center or the technical support staff of the dialysis machine manufacturer. Medical problems should be routed to the home dialysis nurse or nephrologist on call. Many home dialysis programs will post this contact information physically on the dialysis machine for patient ease.

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