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Home Hemodialysis

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Although it is a markedly nonphysiologic approach to renal replacement therapy, a regimen of thrice-weekly hemodialysis sessions of 3-4 hours delivered in-center has emerged as the standard means of delivering chronic hemodialysis in the United States (US) and throughout the developed world. While this standard approach to hemodialysis (SHD) is life-sustaining for patients with end-stage renal disease (ESRD), the need to travel to a dialysis unit multiple times every week is burdensome, particularly when mobility is limited or travel time is excessive, and it results in a reduced quality of life (QoL).[1] More significantly, survival is poor (annual mortality rate >22%) and hospitalization is common (average 2.03 hospitalizations per year).[2] Finally, the discontinuous nature of SHD is associated with requirements for multiple medications to normalize blood pressure (BP), phosphorous, calcium, hemoglobin, and parathyroid hormone.

Recognition of these problems has motivated interest in more physiologic approaches to the delivery of renal replacement therapy (RRT). Short daily dialysis, extended-duration (6-8–hour treatment), and daily nocturnal hemodialysis (collectively referred to as quotidian dialysis) performed at home rather than at a dialysis unit[1] have emerged as promising solutions to the shortcomings of SHD. Despite the promise of these approaches, however, the percentage of the dialysis population receiving home treatment actually fell from 4.1% of the dialysis population in 1980 to 0.6% (2,105 patients) in 2005.[2] As a result, many nephrologists lack familiarity with nonstandard dialysis. This issue of *Nephrology Rounds* examines the evidence-base to support the use of nonstandard approaches in chronic hemodialysis and reviews pragmatic issues that nephrologists should recognize when considering hemodialysis.

Background

The faults with SHD were recognized soon after it became commonly used as maintenance therapy. The rapid fluid and electrolyte shifts that occur during SHD led Kjellstrand et al[3] to coin the term the "unphysiology of dialysis" in a paper published in 1975. In the late 1970s and early 1980s, initial experiences with extended-duration dialysis and/or daily dialysis delivered as chronic therapies were first described.[4-6] Laurent et al[7] described their initial long-term experience using extended-duration dialysis (approximately 8 hours [hrs] of nocturnal dialysis, 3×/week) in the Tassin region of France in 1983. They subsequently published the 20-year results of this therapy. In the cohort, 98% of patients were normotensive, while 5-year survival was 87%.[8] The striking contrast of these results compared with typical outcomes on SHD led the authors to suggest that extended dialysis delivers a more adequate replacement of renal function than SHD. The results stimulated great interest in quotidian dialysis as an alternative to SHD, but questions remained about whether the results were due to the increased time on dialysis, were primarily attributable to either the high Kt/V ([dialyzer clearance × time]/body volume; mean = 1.67) or to specific characteristics of the relatively homogenous population described in this series.

Survival

The question of whether quotidian dialysis (which is typically delivered at home) results in improved survival compared with SHD remains undecided. To date, large-scale, long-term randomized trials with the statistical power to definitively compare mortality with quotidian dialysis and SHD have not been reported. Nevertheless, a considerable body of nonrandomized evidence has addressed this issue.

Several cases series have now reported on long-term survival (at least 1 year) with quotidian dialysis. In a small study of 26 patients followed for a mean of 33 months, Martins et al[9] demonstrated 100% survival on home hemodialysis. McGregor et al[10] reported on a 30-year experience in a region where extended home hemodialysis (mean of 7 hrs, 3×/week) and continuous ambulatory peritoneal dialysis (CAPD) were the sole available maintenance therapies. Median survival on home hemodialysis was 7.75 years (yrs) compared with only 2.1 yrs in patients

choosing CAPD.[10] Using 1986-1987 US renal data system (USRDS) data, Woods et al[11] found that after adjustment for comorbidity, patients on home hemodialysis had a 42% lower risk of death than in-center hemodialysis patients. Using similar techniques, Blagg et al[12] combined data from 2003-2004 USRDS and their own patients undergoing home short daily dialysis. In this series, survival was 61% better with short daily dialysis compared with SHD.[12] Finally, in a case-control study, Saner et al[13] found that their cohort of Swiss home hemodialysis patients had a 5-year survival of 93% compared with only 64% in individuals matched for age, sex, and cause of ESRD and dialyzed in-center.

A number of additional studies[14-20] have demonstrated equally impressive survival rates on home dialysis. Although these data are retrospective in nature and of limited quality, the weight of available evidence uniformly supports the theory that survival with quotidian therapy is superior to survival typically observed with SHD.

The reason for increased survival is uncertain. The negative findings in the Hemodialysis (HEMO) trial[21] demonstrated that increasing urea clearance above a Kt/V of 1.3 does not improve survival on SHD. Therefore, it is unlikely that the high survival rates seen with quotidian therapies are attributable solely to an increased amount of urea removal. Further studies, preferably randomized trials, will be needed to definitively rule out the possibility that preferential selection of healthier patients for home-based therapies explains the improved survival observed with the use of quotidian therapies.

Hypertension

While questions remain about the effects on mortality, it is clear that increasing the frequency or session length of chronic hemodialysis produces marked improvements in the control of hypertension.[22-24] As noted in the original report by Charra, 98% of the patients with 3×/week nocturnal dialysis (approximately 8 hrs/treatment) were normotensive without the need for any antihypertensive medication.[8]

More recently, a randomized study of 52 patients, demonstrated an 11 mm Hg drop in systolic BP with 5-6 nights/week of home hemodialysis (6 hrs/session) compared with conventional in-center hemodialysis. Sixteen of 26 patients in the home-dialysis group were able to discontinue antihypertensive therapy compared with only 3 out of 26 patients in the conventional-therapy group.[25] Similar improvements in the control of hypertension were observed in patients converted from SHD to short daily dialysis.[26] The explanation for the marked improvement in BP control with quotidian therapy is unclear. Decreased extracellular fluid volume, increased clearance of circulating pressors, or decreased sympathetic activity as a result of reductions in intra- and interdialytic fluid shifts have all been suggested as potential explanations.[22,27,28] The relative contribution of each of these mechanisms may differ in extended-duration and short daily hemodialysis.[22,23,27,29]

Anemia

In contrast to their dramatic effect on BP, neither short daily nor extended-duration dialysis seems to have a consistent impact on anemia or the requirement for erythropoietin.[24] Although several studies have suggested that erythropoietin responsiveness increases with daily dialysis and extended-duration dialysis,[8,30-33] other studies have not confirmed these findings.[34,35] In the only randomized study reported to date, the change in the darbepoetin-hematocrit ratio and the change in hemoglobin concentration, 6 months after the start of therapy, were nearly identical on nocturnal (5-6 sessions/week) hemodialysis and SHD.

Bone metabolism

Nocturnal hemodialysis has a major impact on phosphorous balance.[36,37] In a randomized comparison of nocturnal hemodialysis and SHD, 73% of patients on nocturnal therapy were able to discontinue phosphate binders compared with 12% of patients on conventional therapy.[25] In some patients, phosphorous removal may be increased to such an extent that oral phosphorous supplements or the addition of phosphorous to the dialysate is required in order to maintain phosphorous levels within the normal range.[38,39]

In contrast, improvements in phosphorous control are less consistently observed with short daily therapy. While some studies reported enhanced control,[40] other studies did not identify any significant changes in serum phosphorous or in the requirement for oral phosphate binders with short daily therapy.[24,37] In fact, an increase in the requirement for phosphate binders may be observed when patients are transitioned to short daily dialysis from SHD.[41]

Although these results suggest that SHD does a better job of removing phosphorous than short daily therapy, careful studies have demonstrated much higher phosphorous clearance with short daily therapy than with SHD.[40] The absence of an obvious effect on serum phosphorous levels with short daily dialysis is most likely attributable to an increased phosphorous intake in patients on short-daily therapy compared with patients on SHD. This explanation is consistent with observations that nutritional parameters such as lean body mass, serum albumin, and protein intake improve with both forms of quotidian dialysis.[24,26,40-44] Thus, while nocturnal hemodialysis offers a clearly superior control of serum phosphorous, it is apparent that with both forms of quotidian dialysis nutritional status improves and there is no significant compromise in the control of serum phosphorous.

Although some studies suggest modest improvements in parathyroid hormone levels with quotidian dialysis,[23,25,36,45] other studies do not demonstrate any significant effect on parathyroid hormone.[35,40,46] Further studies are needed to clarify the role of quotidian dialysis in the control of bone metabolism.

Access

Quotidian dialysis requires more frequent access to the bloodstream than SHD, and patients must learn to access their own catheters, grafts, and fistulas in order to self-dialyze. Although venous access remains an important issue with home and quotidian therapies, as it is with SHD, the rate of access complications does not appear to differ markedly between quotidian dialysis and SHD. In the randomized trial by Culleton et al,[25] rates of vascular access complications over 6 months were not significantly different in patients on nocturnal dialysis and SHD. Similarly, a systematic review by Suri et al[24] demonstrated equivalent rates of access dysfunction, permanent access failure, and permanent fistula failure in patients on short daily dialysis compared with patients on SHD. However, there was a trend towards

Table 1: Comparison of standard hemodialysis, short daily dialysis, and nocturnal dialysis

Characteristic	Standard	Short Daily	Nocturnal
Patient control	–	+++	+++
Quality of life	–	+++	+++
Control of hypertension	–	+++	+++
Control of hyperphosphatemia	–	+/–	+++
Control of parathyroid hormone	–	+/–	+/–
Improvement in malnutrition	–	++	++
Access survival	+	+/–	+/–
Patient survival	–	? ++	? ++

Legend: – Poor; +/– Minimal; + Good; ++ Moderate; +++ Excellent; ? Uncertain

increased rates of treatable fistula complications in those studies reporting fistula-specific rates of these events.

Other studies not included in Suri et al's meta-analysis have suggested that arterial-access outcomes in patients on quotidian therapies are equal to or better than outcomes on SHD. A study of 301 patients from a single center, who were dialyzed at home over a 20-year period, reported a 5-year fistula survival of 66%.[47] A similar study of 23 patients, cannulating native fistulas for short daily dialysis, demonstrated 84% access survival at 3 years.[9] These rates compare favorably with fistula-survival rates reported in the USRDS for unselected patients on SHD.[2]

Although catheter use is discouraged in patients on home therapy, catheters appear to function adequately with quotidian therapy. In the London Hemodialysis study,[48] the incidence of catheter bacteremia decreased following the switch from SHD to quotidian therapy. Similarly a recent study by Perl et al[49] demonstrated a decreased incidence of catheter malfunction and increased catheter survival with nocturnal dialysis compared with SHD. Thus, while larger studies to refine the understanding of access function are indicated, fears that dialysis access would prove to be the "Achilles heel" of quotidian dialysis are not borne out by available data.

Quality of life

The ability to dialyze according to an individualized and flexible schedule, the elimination of travel time to and from the dialysis unit, and the favorable effects of quotidian therapies on arterial pressures, nutritional parameters, and serum phosphorous might reasonably be expected to produce profound improvements in QoL for patients transferring to home hemodialysis. However, quotidian therapies require patients to spend a great deal of time on dialysis or preparing for it. Home therapy is effort-intensive, it requires patients to integrate dialysis therapy into their home lives and demands that patients assume direct responsibility for their own care. For some patients these factors are significant burdens that can counteract the aforementioned benefits, thereby yielding a neutral (or even negative) effect on QoL. Therefore, it is worth reviewing the data on QoL in home-dialysis patients.

Not surprisingly, many studies suggest marked improvements in health-related QoL and uremic symptoms, but not all aspects of QoL are improved equally.[1,26,32,35,42-44,50,51] For example, in a small study of 13 patients, Kooistra et al[35] found significant improvements in measures of physical functioning, fatigue, and uremic symptoms. While there were small changes in other aspects of QoL, such as mental health and perception of physical health, improvements in these areas did not achieve statistical significance.[35] Conversely, Heidenheim[52] found that overall QoL improved with quotidian therapy, but that physical function improved only marginally. Furthermore mental health aspects of QoL deteriorated in a small minority.

The possibility that these reports overestimate the potential for improvement in QoL should be acknowledged. All of the aforementioned studies assigned patients to home therapy on the basis of personal preference rather than random allocation. In these reports, the selection of patients with a strong preference for home therapy may have significantly colored evaluations of relative QoL on SHD and quotidian therapy. Consequently, it is reassuring that a randomized study found significant improvements in kidney disease-related QoL for nocturnal dialysis compared with SHD. Change in overall QoL was smaller, but all comparisons favored nocturnal dialysis and some measures of overall QoL were significantly improved in nocturnal patients compared with SHD patients.[25] Thus, available data are certainly consistent with the idea that QoL is markedly improved by quotidian dialysis compared with SHD.

Costs

While per-treatment costs related to nursing and ancillary staff are reduced with home dialysis, costs for dialyzers, dialysate, disposables, and waste removal are increased when dialysis occurs >3 times/week. Home dialysis also requires a considerable investment in training programs and it precludes distributing the costs of the dialysis equipment across several patients, as is typically done in a dialysis unit. Despite these concerns, most studies suggest that self-care quotidian dialysis is a cost-effective therapy compared with SHD.

A study of 2 programs from the same renal service in Australia found that actual expenditures were 10.75% lower for their home nocturnal patients dialyzed 6 nights/week than for their SHD patients.[53] The potential costs savings to the healthcare system from reduced hospitalization rates were not included in this analysis. Similarly, a Canadian study comparing a home nocturnal program with SHD found that annual costs for home nocturnal hemodialysis were $55,139 vs. $66,367 for in-center hemodialysis.[54] Finally, the London Hemodialysis study[55] found that annual costs (in Canadian dollars) for short daily dialysis were $67,300 vs $74,400 for nocturnal dialysis and $72,700 for SHD. The major cost-savings were derived from reduced costs for consults, hospitalization days, emergency room visits, medications, and laboratory tests. Despite the slightly increased costs with nocturnal dialysis, the cost per quality adjusted life-year was significantly lower with both nocturnal and short-daily therapy compared with SHD.

Whether these economic benefits can be translated to the provision of dialysis in the US remains uncertain. Nevertheless, since available data strongly suggest that home-based dialysis is a cost-effective treatment with the potential to reduce the overall costs of care for chronic dialysis treatment, it would be unreasonable to withhold home therapy on the basis of either cost or cost-effectiveness considerations.

Figure 1: NxStage System One™

Photo used with permission.

Pragmatics

The specifics of setting up a home program are beyond the scope of this paper but have been recently reviewed.[56] Briefly, physicians setting up a home program should be prepared to devote considerable effort to obtaining appropriate space, understanding local regulations, and ensuring adequate nursing, nutritional, and social work support for the patients starting home dialysis.

Currently, several different machines are approved for the delivery of home hemodialysis. These include the NxStage System One™, Fresenius 2008K, and the B. Braun Dialog® Plus. The Fresenius and Braun systems are large, nonportable, and require modification of home electrical and plumbing systems to work in the home. In contrast, the NxStage device (Figure 1) was designed specifically for home use; it is easily portable, has a simple user interface, and does not require modification of home electrical or plumbing systems. As a result, the System One is currently the dominant machine on the home market with more than 1,600 patients using this machine as of June 2007.[57]

Patient selection

Lack of awareness about the option for self-care dialysis (home hemodialysis or peritoneal dialysis) is the most important reason for patients using in-center rather than self-care dialysis, and the ignorance on the part of both nephrologists and patients about this option is a major factor in the low frequency (<1%) of home dialysis in the US.[58] Incorporating information on home hemodialysis into predialysis education is a simple intervention that may result in as many as 16% of patients choosing home hemodialysis.[59] Thus, it is incumbent upon nephrologists interested in quotidian dialysis to not only make this modality accessible to their patients, but to present it to their patients as a viable alternative to SHD and peritoneal dialysis.

Which patients should be presented with the option of home hemodialysis? Most programs require that a partner be available to participate in the training. In some cases, the partner may actually perform the dialysis, whereas, in other cases, the partner may simply be available for emergencies. The need for a partner has not been prospectively validated and outside of the US even nocturnal dialysis has been performed successfully without partners.[39] Nevertheless, at present, patients without a suitable partner are typically not considered suitable candidates for home hemodialysis in the US.

In addition to a partner requirement, a suitable home environment is necessary for successful therapy. Minimal requirements include a stable living situation, with an area of the home that has access to electricity and water, and can be dedicated to the performance of dialysis. Room for storage of waste and ancillary supplies is also a prerequisite.

Although the ideal patient is young and has minimal comorbidity, a high burden of coincident disease is not a contraindication, particularly when a reliable partner is available. In fact, such patients may actually do much better with home hemodialysis than continued SHD.[26]

A history of compliance with therapy and reliability is desirable. However, the reasons for noncompliance should be carefully evaluated before refusing a patient. Noncompliance due to substance abuse or psychiatric illness should be distinguished from dietary noncompliance or noncompliance that is a reaction to the loss of control that is inherent with SHD. While the former may result in poor outcomes on home therapy, the latter sources of noncompliance may improve when patients begin quotidian dialysis and regain control of their lives and schedules.

Access

As discussed above, access survival does not appear to be significantly different with home dialysis and SHD. When fistulas are used, the buttonhole technique should be considered. In this technique, the same area of the fistula is repeatedly cannulated until a "buttonhole" forms. After this buttonhole is formed, blunt needles to reduce the pain, as well as the likelihood of infiltration, can be used for cannulation.[39,56]

Prescription

Because hypertension and hyperphosphatemia may improve markedly after switching to quotidian dialysis, these parameters should be monitored very closely in the initial weeks on home therapy. In fact, it is prudent to reduce the dose of antihypertensive medications and oral phosphate binders prior to commencing quotidian

Table 2: Single pool Kt/V equivalents of weekly Kt/V of 2.0[59]		
Treatments per week	**2 hours/ treatment**	**8 hours/ treatment**
4	0.87	0.68
5	0.64	0.51
6	0.51	0.40
7	0.42	0.34

therapy in anticipation of a decreased need for these medications.

Recent updates to the Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines recommend that the minimum dose for short daily and nocturnal dialysis should deliver an equivalent weekly Kt/V of 2.0.[60] On a short daily schedule of 6 treatments/week (2 hrs/treatment), this target is equivalent to a single pool Kt/V per treatment of 0.51. With 6 nocturnal treatments (8 hrs), the delivered Kt/V should be at least 0.40 (Table 2). However, almost all data on urea kinetics were derived from SHD or peritoneal dialysis. Currently, data on the relationship of Kt/V to outcomes with quotidian therapies are nonexistent, and it is uncertain whether Kt/V is the most appropriate measure of dialysis adequacy in this setting.[61] For this reason, some authors suggest that until such data become available, the best guide to dose may be the patient's sense of well-being.[56]

Because frequent dialysis is more efficient than SHD, it is typically easy to achieve these minimum targets on both short daily and nocturnal hemodialysis. However, achieving these targets on short daily therapy may occasionally be more difficult with the NxStage System One than with traditional dialysis machines. The System One is designed to fully saturate the dialysate and it uses a dialysate flow rate of 100-200 mL/min rather than the 800 mL/min typical of standard machines. This technology allows for completion of a typical 2-hr treatment using only 18-24 L of dialysate, which is important for the economic viability of dialysis with this system. However, in patients with very large muscle mass or access recirculation, achieving the recommended clearance occasionally requires increasing the volume of fluid or the dialysis time to impractical levels.

Issues with adequacy are unusual with nocturnal hemodialysis. In all machines, blood flow is typically decreased to 200-300 mL/min. Dialysate flow is started at 200-300 mL/min with standard machines or 18-24 L of total dialysate (38-50 mL/min) with the System One.[25,39] Dialysate potassium is frequently set at 2.0 mEq/L and calcium at 1.25 mmol/L. In some cases, it may actually be necessary to supplement the dialysate with phosphorous in order to maintain serum phosphorous within normal levels. Although it is not FDA approved for this purpose, phosphorous supplementation has typically been accomplished by adding approximately 30 mL of sodium phosphates oral solution to 4.2 L of liquid concentrate. The dialysis prescription should be individualized based on initial responses to these starting parameters.

Monitoring

In initial studies of nocturnal dialysis, patients were monitored remotely and alerted by dialysis alarms if they did not respond appropriately in a timely fashion. With increasing experience, the frequency of remote alarms declined to about 1 in 10 treatments.[39] As a result, most authorities no longer consider remote monitoring a necessity for nocturnal dialysis programs, although the regulations may differ from state to state.

The primary argument for monitoring is that an access disconnect could lead to a massive hemorrhage in an unmonitored sleeping patient. However, it is unlikely that remote monitoring could detect this event and send aid to a distant patient with enough time to successfully intervene prior to exsanguination. Furthermore, an arterial disconnect introduces air into the system and leads to machine stoppage, thereby preventing excessive hemorrhage. Conversely, a venous disconnect does not result in any alarms and, therefore, is undetected by remote monitoring. Instead, the use of tape, elastic sleeves, Velcro® bands, or similar devices to secure needles, connections, and blood tubing are recommended to minimize the chance of a disconnection. Some centers also provide enuresis pads that are placed under the access. These pads provide an audible alarm to alert a patient if excessive moisture is detected.[25,39]

Conclusions

Standard in-center dialysis provides life-saving therapy for hundreds of thousands of patients per year. However, it has significant limitations in terms of mortality, QoL, costs, and control of metabolic and hemodynamic derangements. Although long-term, randomized outcome studies remain unavailable, home dialysis in the form of short daily dialysis or nocturnal dialysis appears to be a promising alternative to SHD that addresses many of the shortcomings. Many patients, even those with significant comorbidities, are suitable candidates and, with appropriate education, more patients can be expected to choose home hemodialysis. Machinery and prescriptions for home dialysis differ in important ways from SHD; however, these distinctions can be easily learned and should not be a barrier for nephrologists interested in offering this therapy to their patients.

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Upcoming Scientific Meetings

2-6 April 2008
The National Kidney Foundation
Spring Clinical Meetings
Dallas, Texas
Contact: Tel. 212-889-2210
Email: clinicalmeetings@kidney.org
Website: www.kidney.org

14-17 May 2008
The American Society of Hypertension (ASH)
22nd Annual Scientific Meeting and Exposition
New Orleans Marriott
New Orleans, Louisiana
Contact: Tel. 212-696-9099
Website: www.ash-us.org

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