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Home Dialysis in Japan

Contemporary Status.

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Current International Status of Home Hemodialysis

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Abstract
Three times weekly home hemodialysis (HHD) was introduced shortly after the initiation of chronic hemodialysis (HD) treatment in 1960. HHD eliminates the need of transportation to and from the dialysis unit and by allowing patients to set their own dialysis schedule, decreases the burden of treatment on their personal and professional lives. HHD has been found more economical and more highly associated with better patient survival than in-center dialysis. Nevertheless, the global prevalence of HHD decreased between 1980 and 2000 due to the increased availability of dialysis units and continuous ambulatory peritoneal dialysis, advances in cadaveric kidney transplantation, and several other factors. However, the availability of HHD at a frequency of more than 3 times/week, the typical frequency of conventional HD (CHD), in such forms as brief HD sessions of 2–3 h 5–6 days/week and nocturnal HD (NHD) has led to reversals in this trend. Frequent HHD, such as short daily HD (SDHD) and NHD instead of 3 times/week CHD, has been found to significantly improve hypertension, left ventricular mass, renal anemia, quality of life and mortality. On the other hand, NHD has been found to significantly improve hypertension, left ventricular mass, renal anemia, quality of life, malnutrition, mortality and phosphate clearance. Many observational clinical studies and one randomized controlled trial of SDHD and/or NHD have been conducted, and compact and convenient dialysis machines have been developed and used for HHD. The most recent data reported in the national and local registries of selected countries indicate that the prevalence of HHD among all dialysis patients from 2008 to 2010 varied from 0 to 3.3% except in New Zealand and Australia, where it was 16.3 and 9.3%, respectively. As HHD appears to be a more effective and economical dialysis modality than in-center CHD, its prevalence is likely to increase in the future.

Home hemodialysis (HHD) was initially introduced to overcome the difficulty experienced by renal failure patients in transportation to and from dialysis units, which had been thinly distributed among communities during the first stage of chronic hemodialysis (HD) treatment in the 1960s and 1970s. HHD also provides other advantages, including the self-scheduling of treatment, maintenance of privacy, provision of more time with family members, and reduced risk of infection from a dialysis unit. However, it also poses the disadvantages of requiring the services of a helper for self-dialysis, posing the risk of self-cannulation, requiring training in HD procedures, and requiring space to store dialysate, dialyzers, and other dialysis-related equipment and materials in the home. The prevalence of conventional hemodialysis (CHD) in the home has gradually decreased on a global scale with changes in circumstances surrounding HD therapy since 1980.

Nevertheless, the prevalence of HHD is increasing in the USA and several other countries, possibly because forms of HD that require frequent treatment, such as short daily home hemodialysis (SDHD) and nocturnal home hemodialysis (NHD), have been reported to be more effective and less symptomatic than CHD. This article describes the history, present status, advantages and disadvantages, and modalities of HHD currently used throughout the world.

History of Home Hemodialysis

HHD was first conducted by Nosé [1] in the USA in 1961. Scribner [2] trained a physician to look after the first patients to be treated by maintenance HD at home in 1963, 3 years after Quinton and Scribner [3] had developed an external shunt as a means of permanent vascular access, which made repeated HD treatments available for every chronic renal failure patient. HHD programs were subsequently developed by Merrill in Boston, Scribner in Seattle, and Shaldon in London between 1963 and 1964. HHD is currently available in developed countries, and has a high prevalence in Australia, New Zealand, Canada and some European countries. After reaching a high of 40% in the 1970s in the USA [4], the prevalence of HHD fell to 6% in the mid-1980s, and further fell to 0.62% in the 1990s [5]. The increasing age and comorbidity of dialysis patients, and an increase in several factors, including number of dialysis facilities, access to continuous ambulatory peritoneal dialysis, success in cadaveric kidney transplantation, and use of live donor kidney transplantation, have been suggested as the cause of the decline [6]. Above all, governmental cutbacks in funding for dialysis therapy might be the most important reason in encouraging a transition to HHD worldwide, as the number of dialysis patients has been growing worldwide.

In the 1980s, Buoncristiani et al. [7] treated patients with 2-hour sessions of SDHD treatment 6 times/week who failed to respond to CHD treatment. An

NHD program funded by the Ministry of Health of Ontario, Canada, was initiated in the 1990s. The clinical results of the studies reported by Uldall et al. [8] and subsequent studies affected the practices of dialysis physicians. As the clinical effectiveness of SDHD and NHD has become known to dialysis physicians worldwide, the number of SDHD and NHD patients has been gradually increasing. However, the prevalence of HHD in most countries remains very low, currently less than 3.3% of all dialysis patients, except Australia and New Zealand where its prevalence was 9.3 and 16.3%, respectively, in 2010 [9]. HHD has not been selected by many HD patients, nor has it been approved by the governments as a dialysis modality. In the USA, the prevalence of HHD slowly increased from 0.62% in 2005 to 1.0% in 2008. Based on their analysis of a 2010 questionnaire and the USRDS 2010 Report with a 3.1% growth rate, Blagg and Lockridge estimated the current prevalence of HHD in the USA at 1.6% (about 6,800 patients) [C.R. Blagg, pers. commun.]. According to the 2009 ERA-EDTA Registry, the prevalence of HHD in Europe was between 0 and 2.7% of all dialysis patients in 32 countries in 2009 [10].

In Japan, HHD has been used since it was first introduced in 1967 in Nagaya. At the first stage of HHD in Japan, end-stage renal failure patients who wanted to be treated with HD had to buy a batch-type dialysis machine, the Kiil-type dialyzer, and dialysis-related equipment with no financial assistance because the Japanese healthcare system did not cover dialysis treatment at that time. Although reimbursement for HHD by the healthcare system was approved by the Japanese Government in 1998, the prevalence of HHD remains very low at only 0.05% of all dialysis patients in 2007. The two main causes of the low prevalence may be that CHD patients have a good prognosis and high quality of life in Japan, compared to patients in other countries, and that dialysis units are available within 20–30 min at any location anywhere in Japan. HHD has recently gained attention among HD patients after the introduction of more frequent and/or longer HD treatments, as reflected by a slight increase in the prevalence of HHD patients to 0.1% in 2010 [11]. The prevalence of HHD from 2008 to 2010 in selected countries is shown in table 1.

Advantages of Conventional Home Hemodialysis

HHD is conducted as a form of 3 times/week CHD using the standard dialysis machines used in dialysis units. It has been shown that compared to in-center HD, CHD at home is cheaper [12, 13] and is associated with both better patient survival [14–17] and greater patient rehabilitation [16]. However, no randomized control trials (RCTs) comparing in-center and HHD patients have been conducted, and home CHD has been evaluated only in observational cohort studies.

Table 1. Prevalence of HHD among all dialysis patients in selected countries, 2008–2010

Country	HHD, %	Registry	Country	HHD, %	Registry
USA	1.0	USRDS 2010[1]	Italy	2.7	ERA-EDTA 2009
Argentina	0.0	USRDS 2010	Japan	0.1	JSDT Registry 2010[2]
Australia	9.3	ANZDATA 2010[3]	Malaysia	1.0	USRDS 2010
Austria	0	ERA-EDTA 2009[4]	Mexico	0	USRDS 2010
Bangladesh	0.3	USRDS 2010	New Zealand	16.3	ANZDATA 2010
Belgium	0.7	ERA-EDTA 2009	Philippines	0	USRDS 2010
Canada	3.5	CORR 2011[5]	Poland	0	ERA-EDTA 2009
Denmark	2.7	ERA-EDTA 2009	Spain	0.1	ERA-EDTA 2009
Finland	1.6	ERA-EDTA 2009	Serbia	1.3	USRDS 2010
Norway	0.1	ERA-EDTA 2009	Taiwan	0	USRDS 2010
Sweden	1.2	ERA-EDTA 2009	Thailand	0	USRDS 2010
Netherlands	1.0	ERA-EDTA 2009	UK	1.2	ERA-EDTA 2009
Hong Kong	0.41	USRDS 2010	Uruguay	0	USRDS 2010

[1] 2008 data as reported from the United States Renal Data System (USRDS) 2010.
[2] Japanese Society for Dialysis Therapy, present status of chronic dialysis in Japan on December 31, 2010.
[3] Australia and New Zealand Dialysis and Transplant 2010 Registry.
[4] European Renal Association-European Dialysis and Transplantation Association Annual Report 2009 Registry.
[5] Canadian Renal Replacement (CORR) 2011 Registry.

Advantages of More Frequent HHD

Moreover, almost all the clinical trials that described the benefits of SDHD and NHD were observational cohort studies, with few being RCTs or ongoing studies. The advantages reported in these studies are likely clinical advantages. To fill this research gap, RCTs should be conducted to compare SDHD and/or NHD with CHD in order to compare home CHD with in-center CHD. Lockridge [18] conducted the study of an NHD program with the largest number of participants, while Culleton et al. [19] performed the only randomized NHD study to have been reported to date in 2007. In the USA, SDHD and NHD programs with large numbers of participants were established by the Frequent Hemodialysis Network, with government funding in the 2000s.

Solute Clearances
In a randomized home nocturnal trial comparing 6 and 3 times/week CHD, the FNH found substantially greater differences between NHD patients and controls compared to daytime 6 times/week NHD patients and controls

Table 2. Advantages of HHD in comparison with conventional in-center HD

Conventional HHD		Short daily HHD		Nocturnal HHD	
Clinical advantages	ref.	clinical advantages	ref.	clinical advantages	ref.
Survival	13–17	blood pressure control	15, 23	blood pressure control	19, 24, 26
Rehabilitation	16	left ventricular hypertrophy	15, 23	left ventricular hypertrophy	19, 26
Cost-effectiveness	12, 13, 42	renal anemia	28	renal anemia	24, 26, 29
		survival	17, 30, 31, 34	survival	17, 32–34
		quality of life	16, 23	quality of life	19, 26, 30
		malnutrition	31	malnutrition	32
		mineral metabolism	36	mineral metabolism	19, 26, 37
		solute clearances	20, 22	solute clearances	20, 21
		sleep disorder	39	sleep disorder	38

regarding a wide range of parameters, such as ultrafiltration rate, $stdKt/V_{urea}$, generation rate $(Gn)_{urea}$ to time-averaged concentrations $(TACs)_{urea}$, normalized β_2-microblobulin (β_2M) Gn to TACs of β_2M [20]. Raj et al. [21] found that NHD increases β_2M removal as a result of the higher frequency and dialysis duration of HD. Goldfarb-Rumyantzev et al. [22] demonstrated that solute removal, including that of small and middle molecules larger than urea, was greater in SDHD and long-duration dialysis than in CHD.

Impact of Home Hemodialysis Therapies on Comorbid Conditions and Patient Variables

The clinical advantages of SDHD and NHD are summarized below, and clinical advantages of home CHD, SDHD and NHD are listed in table 2.

Blood Pressure

Multiple observational studies and one RCT trial showed improved blood pressure with fewer or no medications with both SDHD and NHD [19, 23, 24, 26]. One cross-sectional study demonstrated that frequent HD, SDHD and NHD are associated with less dialysis-induced myocardial stunning compared to CHD. This lower incidence of stunning may contribute to the improved outcomes associated with frequent HD therapies [25].

Left Ventricular Hypertrophy

One preliminary RCT using cardiac magnetic resonance imaging demonstrated that 6-times/week NHD improved left ventricular mass and reduced the need for blood pressure medication compared to 3 times/week CHD [19]. Several prospective studies that observed patients who had transitioned from CHD to SDHD or NHD using two-dimensional echocardiography found that these patients experienced reductions in left ventricular mass index [23, 26].

Renal Anemia

Several studies observed an increase in hematocrit and decrease in recombinant human erythropoietin (rHuEPO) requirement with an increase in hemoglobin concentration after conversion from CHD to SDHD [27–29]. 63 patients who transitioned to NHD showed increases in hemoglobin concentration and concomitant decreases in rHuEPO requirement compared to 32 self-care CHD control patients [29]. Several other observational studies observed elevated hemoglobin concentration and decreased rHuEPO dose after transition from CHD to NHD. However, one RCT conducted by Culleton et al. [19] did not find a significant difference in hemoglobin level between the control and treatment groups. A greater number of RCTs using a large number of cases should be conducted.

Quality of Life

Several prospective observational studies using a variety of self-assessment questionnaires, such as the 36-Item Short Form Health Survey (SF-36), Sickness Impact Profile, and Beck Depression Inventory, showed improvement of quality of life measures in patients who had converted from CHD to NHD [26, 30]. In their RCT, Culleton et al. [19] observed clinically and statistically significant improvements in selected kidney-specific domains of quality of life in NHD patients ($p = 0.01$ for effects of kidney disease and $p = 0.02$ for burden of kidney disease), but no difference from controls in overall quality of life as assessed using the EuroQol-5D index.

Malnutrition

Many observational studies have reported improvement of parameters of nutritional status, such as increases in serum albumin level after transition from CHD to SDHD or NHD. Several studies have also reported improvement in appetite, and increase in weight gain with NHD or quotidian HD [31]. In a prospective evaluation of nutritional intake of 15 consecutive patients who converted from CHD to NHD, Ipema et al. [32] reported significantly increased protein intake, as measured by both dietary intake journal and normalized protein catabolic rate, and phosphate intake after transition from CHD to NHD, but no increase in serum phosphate levels.

Survival

In an analysis of 247 NHD patients of the CANadian Slow Long nightly ExtEnded dialysis Programs (CAN-SLEEP), Pauly et al. [33] found that NHD is associated with excellent adverse event-free survival. Johanson et al. [34] studied survival and hospitalization among NHD and SDHD patients in comparison to propensity score-matched controls undergoing 3 times/week CHD and found that NHD is associated with significant reductions in risk of mortality and mortality or major morbid event when compared to CHD, as well as a reduced but non-significant risk of death among patients using SDHD compared to controls. However, they did not find a significant difference between NHD and SDHD patients and matched control cohorts regarding all-cause and specific hospitalizations of death. The findings of several other cohort studies supporting significant improvement in survival with frequent/extended HHD were compared to in-center CHD in Australia, New Zealand [17] and England [41].

Kjellstrand et al. [35] studied the influence of t and Kt/V on survival in 262 SDHD patients and found no association between Kt/V and survival, but found that four factors, i.e. age, weekly dialysis hours, HHD, and secondary renal disease, were independently associated with survival. These findings indicate that undergoing more than 15 h of HD per week maximizes survival in SDHD patients.

Other Clinical Complications

Several observational studies reported that phosphate removal was significantly increased in SDHD and NHD compared with CHD, and that patients no longer require phosphate binders and restriction of dietary phosphate on NHD therapies [32, 36, 37]. Conversion from CHD to NHD or SDHD is associated with improvements in sleep disorders, including sleep apnea, restless leg syndrome [38, 39]. Conversion from CHD to NHD is also associated with improvements of psychomotor efficiency and increases in attention and working memory [40].

Economic Assessment of Home Hemodialysis

Numerous studies have reported that home CHD and frequent HHD are less costly than conventional in-center HD [12, 13, 41]. Recently, Komenda et al. [42] attempted to create a standardized model based on systematic review of the available literature from Australia, Canada, and the UK regarding the costs of and common approaches for assessing direct medical and non-medical costs to determine the economic viability of providing HHD. They found that the modeled costs for SDHHD and NHHD were higher than both in-center and home CHD in the UK, while they were lower than in-center HD and higher than home CHD in Australia and Canada. The higher costs of frequent HHD compared to home CHD are due to higher consumable usage with higher dialysis frequency. More research into the long-term economic viability of providing conventional and frequent HHD and conventional in-center HD is required to conduct a more comprehensive comparison.

Home Hemodialysis Equipment and Systems

Medical staff use standard dialysis machines (a dialysate supply system) for performing HHD at dialysis units. Although many researchers have tried to develop compact and convenient dialysis machines for HHD, few machines can be used in the home.

Aksys PHD
Aksys developed the Aksys PHD as a personal HD system that allows dialyzer and tubing reuse by hot water disinfection. Although available on the US market for SDHD of HHD patients from August 2002 to January 2007, the Aksys PHD is no longer commercially available [43].

NxStage System One®
NxStage (Lawrence, Mass., USA) designed the System One® to be an innovative, flexible device that delivers HD, hemofiltration, and/or ultrafiltration therapies to patients with renal failure or fluid overload [44]. Smaller than CHD machines, this system uses 4- to 6-liter preformed bags of ultrapure dialysate. NxStage offers online sale of dialysate when patients require an increase in dialytic clearances. Recently, this system has become widely accepted mainly in the USA as a portable HD machine for the treatment of SDHD patients, with 6,000 patients reported to have used NxStage System One® in November 2011. The unique characteristics of this system include a highly automated system design with a drop-in cartridge to facilitate training and simple operation.

Renal Solutions Allient Hemodialysis System
Allient (Warrendale, Pa., USA) designed the Renal Solution Allient Sorbent Hemodialysis System, a sorbent cartridge-based system, to serve as a dialysis machine for 3- to 8-hour sessions of HHD. In this system, water is mixed with small packets of dry chemicals that convert to dialysate, which is then continuously generated by the sorbent cartridge in the system [45]. The system requires an electrical source and 6 liters of portable water. The number of home users of this system, however, is remarkably lower than that of the NxStage System One®.

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