Daily home haemodialysis: issues and implications

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Introduction

When considering survival in chronic dialysis, one is struck by the fact that the probability of 10-year patient survival is 75% in home haemodialysis while with centre haemodialysis and peritoneal dialysis, survivals are 44 and 21% respectively [1]. It is puzzling that in spite of the excellent results delivered by home haemodialysis, the number of US patients on this therapy dropped from 5085 to 2086 between 1980 and 1995 (Health Care Financing Administration, 1996). This decline occurred during the same period that the dialysis population in the USA underwent a threefold increase and home peritoneal dialysis grew in popularity. Many factors were responsible for the decrease in home haemodialysis users. Home haemodialysis is a complex procedure requiring complicated equipment that is not user friendly. Blood access is usually obtained through a fistula or graft puncture (which requires a helper). A training period of at least 6 weeks is necessary in order to learn the technique. There is a potentially lethal risk of air embolism associated with the procedure, making the process stressful for the patient and helper. The overall dialysis procedure is more time consuming simply because a significant percentage of total time is spent in setting up, priming, tearing down, and cleaning the artificial kidney. The effective treatment time makes up only a small portion of the total time spent on dialysis-related tasks.

Is there a way out?

The obvious solutions are easier-to-operate equipment and overall shorter dialysis sessions. One of the major advantages of shorter dialysis sessions is that they allow users to forego the prevailing proportioning system. With shorter dialysis sessions, there is no significant bacterial growth when the dialysis solution is premixed in a tank from water and dry chemicals and used as a single pass, batch-dialysate, positive-pressure system. Also, calcium and magnesium do not precipitate with bicarbonate in the diluted, slightly acidified solution used in short haemodialysis sessions.

What about the frequency of dialysis?

It has never been proven that thrice-weekly dialysis is an optimal or even adequate schedule for haemodialysis patients. In comparison to the normal kidneys, thrice-weekly haemodialysis produces massive fluid shifts and metabolic alterations over a limited time span. In fact the fluctuations induced in the body milieu are so rapid, and therefore so unphysiological, that the phenomena were aptly termed ‘the unphysiology of dialysis’ in a paper published by Kjellstrand et al. in 1975 [2]. A number of authors in the early 1970s reported excellent results with more frequent dialysis [3–6]. For example, Twardowski reported that an increase in dialysis frequency of one treatment per week produced an average increase in haematocrit of 4 percentage points and an average increase in serum albumin concentration of 0.45 g/dl. More recently, excellent results with more frequent dialysis were reported by Snyder et al. [7] and Manohar et al. [8]. It was therefore quite natural to envision that ‘daily short-lasting dialysis, will be, in the near future, the basic form of treatment of uremia’ [6]. Extensive evaluations of daily dialysis reported by Buoncristiani et al. [9] and Hombrouckx et al. [10] show an excellent intradialytic tolerance with a dramatically decreased incidence of symptoms of dialysis, including hypotension, cramps, headaches, and asthenia. Blood pressure normalized in all patients, haematocrit increased, and nerve-conduction velocity slowly improved.

Is there a theoretical basis for this overall improvement?

In 1988, a theoretical analysis of the concept of the unphysiology of infrequent haemodialysis was proposed by Lopot and Valek [11]. The authors compared the overall quality of dialysis by measuring time-averaged concentration (TAC) and time-averaged deviation (TAD) of blood urea. TAC is calculated as...
the area under the curve divided by the total time of investigational interval, whereas TAD is calculated by measuring the area of deviations from the TAC and dividing it by the total time of observation. TAC is an inadequate measure of dialysis adequacy. If one considers a very long dialysis (once weekly) and several short dialyses, the TACs may be identical in both, but in the former, the peak values may be lethally high and hence the patient may die well before the next dialysis. In this situation the TAD will be extremely high. Whereas decrease of dialysis time or dialysis clearance increases TAC without influencing TAD, increased frequency of dialysis without any change in time of dialysis or dialysis clearance decreases not only TAD but TAC as well. For the same total weekly cleared volume (TWCW), i.e., total weekly urea clearance, TAD falls dramatically with increasing frequency of dialysis and TAC falls as well. With high efficiency daily haemodialysis, TAD and TAC are close to those of healthy kidneys, where the urea TAD is less than 1 mmol/L and TAC is less than 4 mmol/L. The relatively high US morbidity and mortality of dialysis patients demands an increase of 'K' as well as 't' to increase total weekly dialysis dose. There is however one important caveat to this. Increasing dialysis dose by increasing 'K' has limitations. Increasing 'K' becomes a progressively weaker tool to increase dialysis dose owing to the self-limiting nature of the dialysis process itself. As the dose of dialysis (Kt/V) is increased by increasing 'K', the efficiency of dialysis decreases due to dilution of the pool of dialysable toxins in body fluids by the returning dialysed blood [12].

As far as manipulating 't' is concerned, there are two sides to the coin. What has been said above in relation to 'K' applies to 't' as well. However, is it scientific and logical to confine the definition of adequate dialysis to small molecular clearance only? What about the factors which independently correlate with cardiovascular morbidity and mortality affecting patient survival on HD? The long slow haemodialysis (3 × 8 h) practiced in Tassin by Charra’s group has adequately shown the beneficial effects of adequate blood pressure control on survival [13]. When considering measures to increase dialysis efficiency by shortening dialysis time, the above argument relating to these ‘other’ measures of dialysis adequacy must be borne in mind.

The only other variable then which can help improve the dialysis efficiency is the frequency of dialysis. As the dialysis frequency increases the Kt/V per treatment decreases, and this improves the dialysis efficiency. As a result, the required weekly Kt/V to maintain the same time-averaged BUN decreases. Daily high-efficiency short dialysis may thus achieve a reasonable balance between the various parameters discussed above.

**What then are the impediments to the concept of home haemodialysis?**

The two main reasons why it has been difficult to implement shorter and more frequent dialysis are time for the patient and money for the provider. With more frequent dialysis, more time is spent on machine setup, tear down, and cleaning. In the absence of reuse of supplies, the cost of dialysis goes up considerably. If the cost of dialyser and blood lines is $60 per dialysis, with thrice-weekly dialysis, the annual cost of these supplies will be $9360 and with daily dialysis this will be $21,900. By reusing dialysers and blood lines, the cost of daily haemodialysis could be reduced to a reasonable level.

Therefore, three components seem necessary to build a system which, besides reducing time for the patient, could cut costs for the provider: (1) the device should have a built-in water-treatment system (automatically cleaned and disinfected daily); (2) the device should have a simple small, positive-pressure, single-pass, batch dialysate system; (3) the device should have a reusable extracorporeal circuit, automatically cleaned and disinfected daily.

In the early 1990s such a machine incorporating all of the above features was designed and patented [14]. It has a built-in water treatment system, a batch system instead of a proportioning system (simplifying machine design and reducing cost), uses positive pressure ultrafiltration (eliminating the need for a deaeration pump), is modelled to reuse dialysate and extracorporeal blood circuit (reducing cost and saving time), and programmed for automated priming, cleaning, and sterilizing of the relevant compartments for dialysis. All these features and ultrashort dialysis should reduce or eliminate a partner’s involvement in the dialysis. In the 2nd International Symposium on Daily Home Hemodialysis, Kenley [15] presented a machine designed specifically for daily home haemodialysis and based on the same principle as Twardowski’s machine [14]. Ahmad [16] also presented his ‘one-button machine’ for daily haemodialysis which, however, incorporates a proportioning system for the dialysate arm.

With more frequent dialysis, concerns regarding blood access are natural. However, contrary to popular notion, more frequently used fistulae do not have higher complication rates or lower survivals, particularly if constant site needle insertion method is used for fistula puncture. De Blasi et al. [17] have reported a 2-year native AV fistula survival of 100% with repeated punctures. Moreover with the coming of age of soft, cuffed, intravenous catheters as a long-term access for haemodialysis, the 1-year survival is now being reported to be as high as 59–94%, values similar to those achieved with arteriovenous grafts [18–21].

With daily haemodialysis, depending upon patient size and dialysis efficiency, the duration of a single dialysis session may be reduced to 60–120 min. If one uses a F 80 dialyser, using blood and dialysate flows of 400 ml/min, an effective whole body clearance (K) of approximately 238 ml/min. will be obtained (Twardowski, unpublished observations). If daily dialysis time is 2 h (120 min), a weekly clearance (Kt) of 200 L (0.238 l/min × 120 min. × 7 days) would result; thus assuming total body water of 40 litres in an
What kinds of patients might benefit most from daily home haemodialysis?

With the combination of higher efficiency (achievable Kt/V of > 6.0 per week, TAC < 5 mmol/l, and TAD < 2 mmol/l) and simplified machinery, a substantial percentage (20% or more) of dialysis patients might opt for home haemodialysis in the future. Furthermore, this modality will be chosen by both new patients and many of those already on haemodialysis. Peritoneal dialysis patients not achieving adequate dialysis for whatever reasons and those who have lost residual renal function also may opt for home haemodialysis. In addition, some centre haemodialysis patients may select self-therapy, either at a self/minimal-care facility or at home.

In summary, daily home haemodialysis now has the potential to offer simplified, shorter and more efficient dialysis and arguably can provide optimal, not merely adequate, dialysis to a potentially significant segment of the end-stage renal disease population.

References

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