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The quality of life and cost utility of home nocturnal and conventional in-center hemodialysis

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The quality of life and cost utility of home nocturnal and conventional in-center hemodialysis.

Background. Home nocturnal hemodialysis is an intensive form of hemodialysis, where patients perform their treatments at home for about 7 hours approximately 6 nights a week. Compared with in-center conventional hemodialysis, home nocturnal hemodialysis has been shown to improve physiologic parameters and reduce health care costs; however, the effects on quality of life and cost utility are less clear. We hypothesized that individuals performing home nocturnal hemodialysis would have a higher quality of life and superior cost utility than in-center hemodialysis patients.

Methods. Home nocturnal hemodialysis patients and a demographically similar group of in-center hemodialysis patients from a hospital without a home hemodialysis program underwent computer-assisted interviews to assess their utility score for current health by the standard gamble method.

Results. Nineteen in-center hemodialysis and 24 home nocturnal hemodialysis patients were interviewed. Mean annual costs for home nocturnal hemodialysis were about $10,000 lower for home nocturnal hemodialysis ($55,139 ± $7651 for home nocturnal hemodialysis vs. $66,367 ± $17,502 for in-center hemodialysis, $P = 0.03$). Home nocturnal hemodialysis was associated with a higher utility score than in-center hemodialysis (0.77 ± 0.23 vs. 0.53 ± 0.35, $P = 0.03$). The cost utility for home nocturnal hemodialysis was $71,443/quality-adjusted life-year (QALY), while for in-center hemodialysis it was $125,845/QALY. Home nocturnal hemodialysis was the dominant strategy, with an incremental cost-effectiveness ratio (ICER) of −$45,932. The 95% CI for the ICER, and 2500 bootstrap iterations of the ICER all fell below the cost-effectiveness ceiling of $50,000. The net monetary benefit of home nocturnal hemodialysis ranged from $11,227 to $35,669.

Conclusion. Home nocturnal hemodialysis is associated with a higher quality of life and a superior cost utility when compared to in-center hemodialysis.

Key words: economic analysis, hemodialysis, home, prospective studies, resource allocation.

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End-stage renal disease (ESRD) decreases a person's length and quality of life [1–3]. Indeed, patients requiring dialysis have a quality of life worse than individuals with recurrent breast cancer [4]. Different forms of treatment for ESRD lead to different levels of quality of life; for example, home hemodialysis and kidney transplantation have been associated with a higher quality of life than in-center hemodialysis [3, 5–13].

Daily home nocturnal hemodialysis was developed in Toronto in 1993 [14]. Patients place themselves on dialysis at night, receive treatment while they sleep, and disconnect themselves the following morning. A typical home nocturnal hemodialysis treatment lasts 6 to 8 hours, and is performed 5 to 7 nights a week. Home nocturnal hemodialysis has been associated with improved biochemistry, blood pressure, cardiac function, and sleep patterns [15–22]. Preliminary data suggests higher quality of life for home nocturnal hemodialysis [abstract; Brissenden JE *et al*, *J Am Soc Nephrol* 9:168A, 1999], but no analysis of quality of life and economic utility exists. Additionally, some authorities suggest that improvements in quality of life in intensively dialyzed patients is partly due to improvements in quality of life in all dialysis patients, a claim that makes a reanalysis of conventional hemodialysis patients worthy.

All forms of dialysis are expensive. In-center hemodialysis, the most common dialysis modality in North America, costs between $60,000 CAN and $95,000 CAN annually per patient [23–27]. Hospital-based treatments are generally more expensive than home-based treatments ($88,585 CAN for in-center hemodialysis vs. $26,048 CAN for home conventional hemodialysis) [24]. Moreover, the Toronto experience demonstrates lower costs for home nocturnal hemodialysis than in-center hemodialysis ($56,394 CAN vs. $68,935 CAN) despite the more frequent and intensive treatments [28].

In this study, we hypothesized that patients performing home nocturnal hemodialysis would have a higher quality of life than those performing in-center hemodialysis.

The purpose of this study was to determine whether these quality-of-life results would lead to a superior cost utility for home nocturnal hemodialysis compared to in-center hemodialysis.

METHODS

Patient population

The home nocturnal hemodialysis group was formed from patients at the Humber River Regional Hospital in Toronto. To be eligible for this program, individuals needed to be proficient in English, have the capacity for self-care training, and have a life expectancy of longer than 1 year. Either the patient or someone living in the home needed to have sufficient dexterity, vision, and auditory acuity to perform this type of dialysis. To be eligible for this study, home nocturnal hemodialysis patients had to be performing the modality for at least 3 months prior to enrollment.

St. Michael's Hospital in Toronto, Canada was selected to provide patients for the control group because it has a large in-center hemodialysis program located in the Greater Toronto area, is university affiliated, and had no home hemodialysis program at the time of the study. All in-center hemodialysis patients at St. Michael's Hospital were screened based on the entry criteria for the home nocturnal hemodialysis program at Humber River Regional Hospital. The St. Michael's Hospital hemodialysis medical director (who was not involved with this study) then screened this group to only those judged to be appropriate for home hemodialysis therapy. Individuals selected were eligible to participate if they expressed an interest in home hemodialysis after description of the modality (although they did not need to agree to switch modalities).

A prospective descriptive costing study was performed from January 1, 2000 to March 1, 2001. The full methodology and results of this study are published elsewhere [28]. Local and university ethics review boards approved the protocols and consents.

Assessment of dialysis intensity

There is significant controversy regarding how best to measure dialysis adequacy in intensively dialyzed individuals. As our hypothesis assumes a more intensive delivery of dialysis to the home nocturnal hemodialysis group, we measured weekly mean hours of dialysis, and in the absence of consensus, we measured dialysis intensity by calculating single session and weekly single-pool Kt/V during a representative period of the study [29, 30].

Assessment of quality of life

Individuals were approached in a standardized manner by a single interviewer to assess their quality of life. Interviews were scheduled during a routine appointment at the home dialysis clinic for the home nocturnal hemodialysis group, and at the dialysis unit prior to treatment for the in-center hemodialysis group. Interviews were conducted in well-lit and quiet semiprivate offices or examination areas. A single interviewer conducted all of the interviews. Criteria were set prospectively for delaying an interview; specifically, hospital admission within 1 month, current treatment with antibiotics, initiation or dose titration of a psychotropic drug within 1 month, invasive outpatient procedure within 1 week or significant life event within 2 months (death or sickness of a friend or family member, change in employment status, divorce or separation from significant other, change of address).

We used the standard gamble technique to measure patient's quality of life. To determine utilities by the standard gamble, participants were given a choice of remaining in their current state of health or accepting a hypothetical medical treatment. If successful, this hypothetical treatment would cure the renal disease, resolve all of their medical issues, and return the patient to the best imaginable state of health. If unsuccessful, the hypothetical treatment would lead to immediate death. The initial chance of death with treatment was randomly chosen and the elicitation choices were repeated in an iterative manner, with the chance of death varied by a bisectional approach (in which the utilities presented were the midpoint of the possible lowest and highest values based on the previous responses and the bounds of the utility scale) in order to determine the maximum chance of immediate death that the participant would be willing to accept for the chance of full health [31, 32].

Standard gamble utilities were elicited through a standardized interview, with the instructions for the patient written on a prompt card for the interviewer. A computer-based utility generator provided assistance (*http://individual.utoronto.ca/bayoumi/prospec*). This program visually presented the gamble probabilities in the form of a circle, transected such that the circle consisted of two colored areas, one representing the relative probability of immediate death, the remaining area representing the relative probability of a successful cure. Patients were allowed to choose not to gamble.

Cost utility analysis

Once costs and benefits had been determined for an intervention, attempts were made to determine the value for the money that the new treatment provided. In this study, the mean utility score as determined by the standard gamble method measured the effectiveness of dialysis for each study group. A simple ratio of the mean costs by the mean utility score provided the cost utility for each study group relative to no treatment. A ratio of the difference in mean costs of two therapies by the difference in their mean utility score produced an incremental cost-effectiveness ratio (ICER), which was placed in one of the quadrants of a cost-effectiveness plane (see Fig. 1) [33–35].

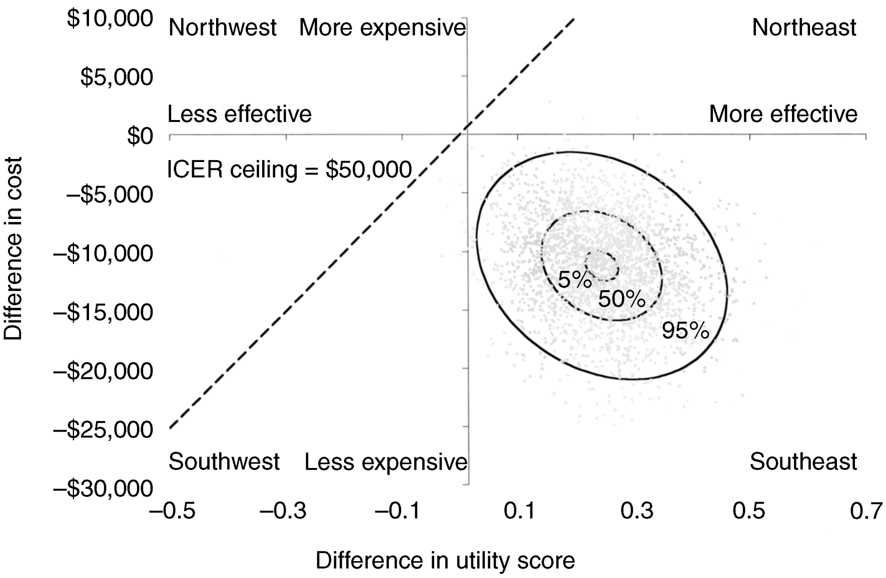

Fig. 1. Confidence interval ellipses (5%, 50%, and 95%) for the incremental cost-effectiveness ratio (ICER) of home nocturnal versus conventional in-center hemodialysis and 2500 bootstrap ICER iterations. Cost-effectiveness ceiling = $50,000.

New therapies in the southeast quadrant are both more effective and less costly than their alternative. They are referred to as dominant strategies and are usually accepted as superior to the alternative. New treatments in the northwest corner are more expensive and less effective than conventional care, and normally rejected. New therapies in the southwest corner (less expensive but less effective) or the northeast corner (more effective but more expensive) must be evaluated in more detail before being accepted or rejected. A maximum cost-effectiveness ceiling can be plotted on the cost-effectiveness plane, representing a hypothetical maximum that society would be willing to pay for an additional benefit (northeast quadrant) or hypothetical minimum cost-savings that society would be willing to accept for a less effective intervention (southwest quadrant). Interventions falling on or to the right of this line are generally considered cost-effective, while those falling to the left are not [36].

To account for uncertainty in the ICER, we calculated its 5%, 50%, and 95% confidence intervals and plotted these on the standard ICER plane, with a maximum cost-effectiveness ceiling of $50,000 [37]. To estimate the distribution of mean costs and effectiveness, we used the bootstrap technique. The bootstrap is a method to estimate statistical precision using resampling (the random selection of data from the original data set) that is particularly useful when a mathematical formula is not readily available. Each data point may be sampled more than once. For each randomly drawn sample ($N = 2500$), we calculated mean and incremental costs and effectiveness scores and incremental cost-effectiveness ratios and used the resulting range of values to calculate the corresponding confidence intervals [38].

Net monetary benefit

While ICERs are popular, they do not perform well under uncertainty as calculation of their confidence intervals is controversial and they are difficult to use in regression analyses [39–44]. A newer measure known as the net monetary benefit (NMB) addresses these concerns [33]. Simplistically, the NMB is calculated by assigning a monetary value to the incremental benefit achieved, and subtracting from this the incremental cost of achieving this benefit [33]. A positive NMB implies that the cost of a new therapy is less than the value of the additional benefit achieved. A negative NMB implies that an intervention should be rejected, as its costs are higher than the value of the benefit achieved. Difficulties arise in how to place a monetary value on a clinical improvement. This valuation is performed by assigning a monetary value (λ) to a unit of effectiveness, and multiplying λ by the net number of units of effectiveness achieved (so that $N\hat{M}B = \lambda \cdot \Delta\overline{E} - \Delta\overline{C}$). Lambda represents the maximum amount that a society would be willing to pay for the incremental improvement in outcome (and therefore its maximum value). As the value of λ for a given clinical improvement is controversial, we tested the full range of λ from 0 to approaching infinity.

For our study population, we constructed a NMB for each patient, and then calculated a regression line for the effect of type of dialysis on NMB. The regression analysis was extended to include modeling of the effects of any covariate with a correlation coefficient P value <0.10. The regression coefficient for a variable is the estimate of its NMB. An acceptability curve (which represents the most accurate estimate that home nocturnal hemodialysis is cost-effective) was generated across the

Table 1. Demographics

	In-center hemodialysis	Home nocturnal hemodialysis	*P* value
Number	19	24	
Gender (*% male*)	68	75	0.63
With diabetes %	11	8	0.81
With coronary artery disease %	11	21	0.35
With peripheral vascular disease %	5	13	0.42
With congestive heart failure %	5	21	0.14
With post secondary education %	69	60	0.71
Married %	54	94	<0.01
Age (*years*)	50.1 ± 9.3[a]	47.2 ± 7.7[a]	0.26
Duration end-stage renal disease *years*	7.1 ± 6.0[a]	9.4 ± 7.1[a]	0.27

[a] Mean ± standard deviation

Table 2. Correlation of baseline variables with utility score

	Correlation with utility score	
	Pearson's *r*	*P* value
Male gender	−0.012	0.94
Age (*per year*)	−0.322	0.04
Duration end-stage renal disease (*per year*)	0.232	0.13
Diabetes	−0.154	0.33
Coronary artery disease	−0.259	0.09
Peripheral vascular disease	−0.250	0.11
Congestive heart failure	−0.168	0.28
Married	−0.104	0.58
College or university education	0.196	0.44
Dialysis modality is home nocturnal hemodialysis	0.397	<0.01

full range of λ [45]. For any value of λ, the probability that home nocturnal hemodialysis is cost effective is equal to $1 - P/2$, where P is the P value for the regression coefficient for the type of dialysis.

Statistics

Means were tested with the Wilcoxon rank-sum test. Categoric variables were tested using the chi-squared test. Pearson's correlation was used for multivariate analyses. Variables found to have a significant correlation with outcome were subsequently modeled in the regression analyses, fitted using the standard least squares approach. A two-tailed significance level of 0.05 was used for all tests. SPSS version 11.0 for Windows and JMP version 5.0 for Macintosh were used for the statistical analyses.

RESULTS

Population

Of the 34 patients participating in the home nocturnal hemodialysis program during the study period, 31 met entry criteria. Of these, two agreed to participate in the longitudinal costing study, but declined to participate in the quality-of-life assessment. In addition, two were unable to schedule an interview during the study period that did not conflict with the prespecified delay criteria, and three were transplanted prior to being interviewed. In total, 24 patients remained for analysis.

A total of 182 in-center hemodialysis patients were screened, with 29 individuals passing both the home nocturnal hemodialysis group entry criteria and the judgment of the program director. Of these, three lacked interest in home dialysis modalities and three declined to participate. Of these 23 individuals, two were transplanted prior to being interviewed, one agreed to participate in the longitudinal costing study but declined a quality-of-life interview, and one was unable to schedule an interview during the study period that did not conflict with the delay criteria. This left 20 patients who were interviewed. One of these patients refused on moral grounds to gamble against death and was excluded from the analysis.

The baseline demographics features of the two groups were similar, with the exception of marital status, where a greater proportion in the home nocturnal hemodialysis were married (see Table 1). Approximately 70% of the in-center hemodialysis group were performing self-care dialysis at the hospital.

Dialysis intensity

The single-session Kt/V for the home nocturnal hemodialysis group was 1.6 ± 0.2, and was 1.4 ± .2 for the in-center hemodialysis group. Weekly Kt/V was 9.0 for the home nocturnal hemodialysis group, and was 4.0 for the in-center hemodialysis group.

Quality of life

Home nocturnal hemodialysis was associated with a higher utility than in-center hemodialysis (0.77 ± 0.23 vs. 0.53 ± 0.35, $P = 0.03$). Other than home nocturnal hemodialysis as the modality of dialysis, the only baseline variables significantly correlated with higher utility scores were lower age and the absence of coronary artery disease (see Table 2). Marital status, which was different between the groups, did not correlate with utility score in either study group or the overall group. A regression model was created testing the predictive effect of dialysis modality, age, and coronary artery disease on the utility score. In this model, higher utility scores continued to be associated with home nocturnal hemodialysis as dialysis modality (estimate 0.25, $P < 0.01$), and absence of coronary artery disease (estimate 0.24, $P = 0.04$), while younger age was no longer significant (estimate 0.007, $P = 0.13$; model adjusted R^2 0.25, $P < 0.01$).

Table 3. Summary of costs[a]

	Mean annual cost				
	Quality of Life study subgroup			Full-study group	
	IHD	HNHD	*P* value[b]	IHD	HNHD
Number	19	24		23	33
Staff	$22,005	$10,938	<0.01	$22,056	$10,932
Direct hemodialysis materials	$ 6,413	$16,669	<0.01	$ 6,575	$16,587
Medications	$11,546	$ 8,150	0.11	$12,029	$ 8,989
Overhead and support	$12,365	$ 4,181	<0.01	$12,393	$ 4,178
Physician fees	$ 6,650	$ 6,650	1.00	$ 6,650	$ 6,650
Admissions and procedures	$ 5,271	$ 818	0.09	$ 6,997	$ 1,173
Depreciation	$ 871	$ 6,139	<0.01	$ 871	$ 6,139
Lab tests and imaging	$ 1,246	$ 1,594	0.04	$ 1,364	$ 1,744
Total	$66,367	$55,139	0.03	$68,935	$56,394

Abbreviations are: IHD, in-center hemodialysis; HNHD, home nocturnal home dialysis.
[a]All costs expressed in year 2000 Canadian dollars
[b]*P* value for comparison of IHD quality of life subgroup to HNHD quality-of-life subgroup

Table 4. Cost utility results

Group Variable	Mean	SD	SE	*P* value
IHD (*N* = 19)				
Cost	$66,367	17,502	4015	
Utility	0.527	0.347	0.08	
	Correlation = −0.229			0.345
HNHD (*N* = 23)				
Cost	$55,139	7,651	1562	
Utility	0.772	0.230	0.047	
	Correlation = −0.163			0.447
Increments				
Cost	−$11,227		4321	0.029
Utility	0.244432		0.093	0.028
Cost utility ratios				
IHD	$125,845			
HNHD	$71,443			
Incremental cost-effectiveness ratio (ICER)	−$45,932			

Abbreviations are: IHD, in-center hemodialysis; HNHD, home nocturnal hemodialysis.

Costing study results

The subjects in this study were a subset of our previous costing study, and the results specific to this group were similar to those results (Table 3). Total health care costs for the home nocturnal hemodialysis group compared to the in-center hemodialysis group were significantly lower ($55,139 ± $7651 vs. $66,367 ± $17,502, $P = 0.03$). Specifically, staffing and overhead were significantly less costly for home nocturnal hemodialysis. In contrast, direct hemodialysis materials, depreciation, laboratory tests, and imaging were all significantly more expensive for home nocturnal hemodialysis.

Cost utility analysis

Coupled with the lower costs for home nocturnal hemodialysis, the cost utility for home nocturnal hemodialysis was $71,443/quality-adjusted life-year (QALY), while for in-center hemodialysis it was $125,845/QALY. Home nocturnal hemodialysis was the dominant strategy, with an ICER of −$45,932 (Table 4). Figure 1 plots this result, along with 5%, 50%, and 95% confidence interval ellipses and with the ICER generated by 2500 bootstrap iterations. From the bootstrap data, the 95% confidence interval of the ICER was −$13,976 to −$142,998.

Net monetary benefit

The NMB of home nocturnal hemodialysis ranged from $11,227 (λ = $0) to $35,669 (λ = $100,000) (Table 5, dispersion of individual patient values, Fig. 2). When a multivariate regression model was used, including age and presence of coronary artery disease as covariates (plus interactions with dialysis modality), the NMB of home nocturnal hemodialysis ranged from $11,258 (λ = $0, $P = 0.010$; adjusted R^2 0.115, $P = 0.05$) to $35,819 (λ = $100,000, $P = 0.001$; adjusted R^2 0.20, $P = 0.001$) (Table 5). As demonstrated by the acceptability curves, this data suggest that the probability that home nocturnal hemodialysis is cost-effective exceeds 99% across all values for λ, even when adjusted for significant covariates (Fig. 3).

Table 5. Net monetary benefit (NMB) estimates as λ[a] increases

	λ = \$0 NMB ± SE (*P* value)	λ = \$50,000 NMB ± SE (*P* value)	λ = \$100,000 NMB ± SE (*P* value)	λ→∞[b] (*P* value)
Calculated NMB ($\widehat{NMB} = \lambda \cdot \Delta\bar{E} - \Delta\bar{C}$)				
HNHD	\$11,227 (<0.01)	\$23,448 (<0.01)	\$35,669 (<0.01)	(0.006)
NMB by regression with covariates (age and presence of CAD)				
Explanatory variable				
HNHD	\$11,258 ± \$4158 (0.01)	\$23,539 ± \$6421 (<0.01)	\$35,819 ± \$10,054 (0.001)	(0.006)
Age (*per year*)	−\$111 ± \$247 (0.66)	−\$504 ± \$382 (0.19)	−\$898 ± \$598 (0.141)	(0.127)
Presence of CAD	−\$3,473 ± \$5553 (0.54)	−\$15,321 ± \$8575 (0.08)	−\$27,170 ± \$13,428 (0.050)	(0.043)
Regression model				
R^2 (adjusted)	0.115	0.288	0.298	0.248
Probability > F	(0.05)	(<0.01)	(<0.01)	(<0.01)

Abbreviations are: HNHD, home nocturnal hemodialysis; CAD, history of coronary artery disease.
[a] λ represents the societal maximum willingness-to-pay for a benefit
[b] As λ approaches ∞, the *P* value for the explanatory variable approaches the *P* value of the standard gamble score

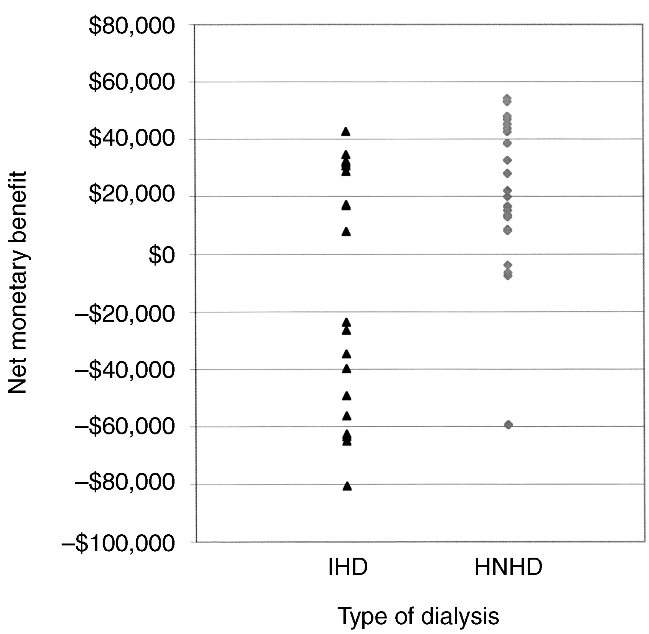

Fig. 2. Net monetary benefit (NMB) individual patient dispersion with λ = \$100,000. Abbreviations are: IHD, in-center hemodialysis; HNHD, home nocturnal hemodialysis.

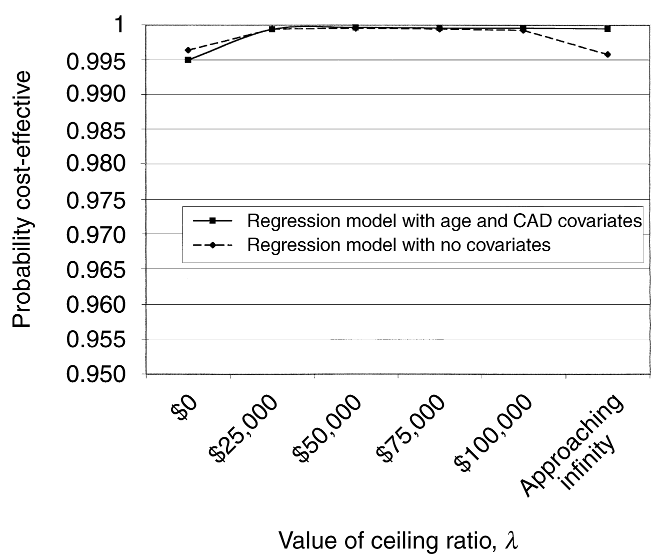

Fig. 3. Acceptability curve for home nocturnal hemodialysis.

DISCUSSION

We assessed whether patients performing home nocturnal hemodialysis have a higher quality of life than similar patients receiving hemodialysis at an in-center unit. These results are the first utility scores from individuals intensively dialyzed by the home nocturnal hemodialysis technique, and support the hypothesis that home nocturnal hemodialysis is associated with a significantly higher quality of life. Indeed, the utility scores seen here for the home nocturnal hemodialysis group are similar to the scores described in those with a successful kidney transplant [10] and agree with anecdotal reports of individuals performing home nocturnal hemodialysis who remove themselves from the transplant waiting list, presumably because they do not anticipate that transplant will further improve their quality of life. On a disturbing note, the conventionally dialyzed individuals had similar utility scores to those seen historically, showing no evidence of improvement in quality of life over time. This is despite the fact that our conventional group was demographically skewed toward individuals expected to have a higher quality of life than many in-center hemodialysis patients (younger age, higher functional status, lower comorbidities).

We attempted to study patients who were as similar as possible. Our in-center hemodialysis group was composed of those who were demographically similar to the home nocturnal hemodialysis group, were interested in and thought to be capable of performing home hemodialysis, but were unable due to the lack of a home program at their hospital. Individuals in the in-center hemodialysis control group were less likely to be married; however, marital status did not correlate with quality of life in this study. Older age and the presence of coronary artery disease were associated with a reduced quality of life in this study. Home nocturnal hemodialysis was strongly associated with a greater NMB, even after adjustment for these factors. However, it is possible that people who choose to do home hemodialysis have immeasurable characteristics that are associated with higher quality of life independent of the form that their home dialysis takes, thus confounding these results.

Although both groups were demographically similar, neither was similar to the "average" hemodialysis patient. In this study, participants in both groups were in general younger, had less diabetes and cardiovascular disease, and had been on dialysis for longer than demographically typical patients from most centers [46]. This may bias the utility scores toward higher values for both groups.

Dialysis patients may have temporary events occur that can cause considerable distress. As our sample size was small, we attempted to perform our interviews on a typical day and delayed interviews in the event of recent experiences that could significantly lower quality of life. This has intentionally biased our utilities toward higher scores than might be seen in a cross-sectional study where interviews were conducted regardless of the patient's current situation. We measured utilities with the standard gamble technique, a commonly used method to measure quality of life in health economics. In contrast to instruments such as the SF-36 that measure health status, the standard gamble and other utility methods reflect an individual's preferences for health states. Because people with similar health status may feel differently about how desirable their health condition is, utility measures tend to have greater variability than psychometric instruments and the correlation between the two techniques has been, at best, modest. Controversy persists regarding the optimal choice of method to measure utility, as all methods are susceptible to biases [47]. Nevertheless, the size and direction of effect in our study are of such magnitude and consistency that it is unlikely that correcting for operative biases would significantly change our results.

As our study examined prevalent patients only, our results do not answer whether home nocturnal hemodialysis will improve quality of life in patients switched from in-center hemodialysis. Future research should prospectively measure quality of life in patients as they move from in-center hemodialysis to home nocturnal hemodialysis.

The home nocturnal hemodialysis program at the Humber River Regional Hospital is the world's first and largest program. Despite this, the sample size is small, and other centers with home nocturnal hemodialysis programs will need to confirm these results to ensure that this is a modality effect and not related to an unmeasured selection bias. Prospective studies of patients before and after changing modalities will also be necessary to support the conclusion that home nocturnal hemodialysis improves quality of life. In addition, the costs that we describe for home nocturnal hemodialysis are from a large and established program. New programs or small programs may not enjoy some of the economies of scale as seen in the Humber River Regional Hospital program.

Previous work by our research group found that heath care costs were lower for patients performing home nocturnal hemodialysis. This study has demonstrated that home nocturnal hemodialysis is the dominant strategy, both lowering costs and improving quality of life. Dialysis programs should consider offering home nocturnal hemodialysis to appropriate patients in hope of seeing better quality of life as well as reduced health care costs.

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