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Comparison of health-related outcome measures: Time-tradeoff measures vs. Healthy years equivalents

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Time-tradeoff measures and healthy years equivalents were assessed and compared through an empirical study based on Multi-attribute utility theory. The study included 33 student subjects as a pilot study, and 54 end-stage renal disease patients in Wisconsin. The two outcome measures were compared with the survival duration of 1, 5, and 10 years. The results of the study show that the time-tradeoff method and the two-stage method did not lead to the same numerical quantities, although they aim to measure the same quantities (equivalent numbers of healthy years) theoretically. The healthy years equivalents involved more inconsistencies, and were less reliable than the time-tradeoff measures. Overestimation of the healthy years equivalents was observed. This seemed to be caused by the complex procedure of the two-stage method as well as by the preferences assessment biases. Based on the study experiences, the time-tradeoff measure would be recommended for problems involving generic medical applications and health policies.

1. Introduction

The choice of an appropriate outcome measure is central to the usefulness of variety of clinical decision analyses (Plante et al., 1986). Several utility-based outcome measures and assessment techniques have been proposed in health care among which the performance of the healthy years equivalents (HYEs) and the time-tradeoff measures (TTOs) has long been a subject of heated discussion in the literature (Mehrez & Gafni 1989; 1991; 1993, Johannesson *et al.* 1993; 1994; Buckingham, 1993; Culyer & Wagstaff, 1993; Gafni *et al.*, 1993; Wakker, 1995).

The time-tradeoff technique was developed by Torrance *et al.* (1972) specifically for use in health care. This technique has been used in practice as an "empirical substitute to the standard gamble technique". The time-tradeoff technique is based on a paired comparison in which an individual is asked to choose between two health profiles. One health profile, (Q, T), involves living T years in a health state Q, and the other involves a shorter but healthy life. The length of remaining life of the shorter healthy life is varied until the individual is indifferent between the two health profiles. When an indifferences point is found, we have: (Q, T)~(Q*, TTO), where Q* denotes and excellent health status and TTO denotes the certainty-equivalent number in full health for the health profile (Q, T).

The healthy-years equivalent (HYE) was developed as "an alternative to the most commonly-used measure of preference, the QALY" by Mehrez and Gafni (1989). According to them, "HYEs fully represent patients (or other individuals) preferences, as a result of the way they are calculated from each individual's utility function". The HYEs are assessed with a two-stage procedure to find a healthy years equivalent satisfying the relation: (Q, T)~ (Q*, HYE).

The assessment procedure of the TTOs and HYEs is explained in the "interview protocol" part of this

study. Regarding the theoretical difference between the TTOs and HYEs, Mehrez and Gafni (1993) pointed out that the time-tradeoff deals with indifference curves under crenate and the two-stage lottery method deals with indifference curves under uncertainty, although both methods aim to identify points on an individual's indifference curve. From this claim, they inferred that the equivalent healthy years obtained from the two different methods would be different in general.

On the other hand, it has been argued by many researchers that the two-stage method of assessing the certainty-equivalent numbers in full health is not a different way of assessing them with the time-tradeoff method, and that both HYEs and TTOs do not represent risk attitudes of an individual (Johannesson *et al.*, 1993; 1994; Buckingham, 1993; Culyer & Wagstaff, 1993; Gafni *et al.*, 1993). Wakker claimed that the HYEs are theoretically identical to the TTOs, and demonstrated a theorem that states: If two expected utility maximizes exhibit the same riskless preferences but have different risk attitudes (i.e., they exhibit different preferences over gambles), then they exhibit the same HYE values. Their HYE values are also identical to their TTO values (Wakker, 1995). Rittenhouse also pointed out that "HYE first add and then remove the element of uncertainty so that ultimately the technique does not measure preferences under uncertainty. This makes the HYE, at best, a cumbersome equivalent of the TTO" (Rittenhouse, 1997).

Although the theoretical characteristics of TTOs and HYEs could be identical as argued by many researchers, the empirical performance of outcome measures may well be different if they are obtained from different assessment methods. Furthermore, there would be advantages and disadvantages of using a particular outcome measure and the corresponding assessment method in practice. Thus, the study was undertaken to empirically compare the performance of HYEs and TTOs.

2. Methods

We have conducted face-to-face interviews to compare the relative performance of HYEs and TTOs. End stage renal disease (ESRD) was selected as a chronic health state with which the certainty-equivalent numbers in full health were assessed. The health state was assumed to be constant throughout the survival duration and to be preferred to death. The HYEs and the TTOs were assessed with the survival duration of 1, 5, and 10 years. Each survival duration was assumed to represent the expected life of an individual. The study applied a two-stage design. The first stage experiment was conducted as a pilot study with healthy subjects. The second stage experiment was performed with ESRD patients in Wisconsin.

2.1 Participant selection

Face-to-face interviews were conducted with a convenience sample of 33 subjects in the stage 1 experiment: undergraduate and graduate students at the university of Wisconsin - Madison. The subjects were asked to consider hypothetical health profiles, and to state their preferences. For the assessment of quality of-life, a health scenario for dialysis was taken from Sackett and Torrance's (1978) study and was updated for this study.

In the stage 2 experiment, a total of 54 ESRD patients were interviewed. The interview took place at the dialysis clinic at the University of Wisconsin Hospital and Clinics, and at the Froedtert dialysis center at the Medical College of Wisconsin.

2.2 Interview protocol

The health scenario for dialysis was explained to each healthy subject for the pilot interviews to familiarize him or her with the health state. ESRD patients were asked to state their preferences with their current health as the health state in assessing the TTOs and the HYEs.

For the assessment of the TTOs, subjects were asked to directly state the certainty-equivalent numbers in full health that make two health profiles equally preferable:

$$(\text{Dialysis, T}) \sim (\text{Excellent health, TTO})$$

, where T denotes a life expectancy, and TTO denotes the time-tradeoff measure.

For the assessment of the HYEs, the elicitation procedure was divided into two stages to elicit the certainty-equivalent numbers in full health making two health profiles equally preferable:

$$(\text{Dialysis, T}) \sim (\text{Excellent health, HYE})$$

, where HYE denotes the healthy years equivalent.

The elicitation procedure for HYEs is explained in Figure 1. In the first stage, a subject was asked to

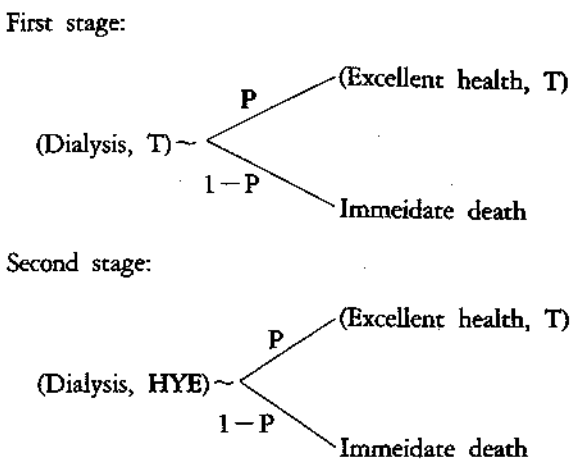


Figure 1. Two-stage method of eliciting the healthy years equivalents.

state the probability that makes the choice between two options equivalent. The subject was then asked, in the second stage, to state the certainty-equivalent number in full health that makes the two choices indifferent with the probability P elicited in the first stage as the probability of living T years in excellent health (Mehrez & Gafni, 1991).

2.3 Statistical Analysis

Both the TTOs and the HYEs were assessed with the survival duration of 1, 5, and 10 years in the health state of end-stage renal disease requiring hemodialysis. Thus the comparisons between the two measures were made with three different survival duration. Scatter plots were generated to see whether there is linear association between the two measures and how much one measure deviates from the other. The Pearson correlation coefficients between the two measures were calculated with each survival duration. The differences between the HYEs and the TTOs were calculated, and paired t-tests were performed to test the null hypotheses with different survival duration that average differences between the two measures are equal to zero.

3. Results

3.1 Demographics and the feasibility of assessment techniques

The TTOs and the HYEs were compared to see whether or not they lead to same quantities representing individual's preferences. Among the 33 subjects interviewed in the pilot study, 3 subjects preferred immediate death to any length of survival on dialysis. Thus the data collected from those subjects were excluded from the analysis, since we have assumed throughout the study that the health state Q on dialysis is no worse than death. One subject was not able to complete the interview because he could not state his preferences clearly. One subject refused to continue the interview and was excluded from the study. So the data collected from 28 subjects were analyzed in the pilot study.

A group of 61 outpatient hemodialysis patients were contacted at the University of Wisconsin Hospital and Clinics of whom 29 agreed to participate in the interview. A group of outpatient hemodialysis patients at Froedtert dialysis center at the Medical College of Wisconsin were also interviewed. Of 39 patients contacted, 25 agreed to participate. For a total of 54 participants in the second stage of the experiment, the demographic information from each group is given in Table 1.

Of those 54 hemodialysis participants interviewed for the study, 3 patients preferred immediate death to any length of survival on dialysis. Three participants were excluded due to termination of the interview prior to obtaining the required data. Among 51 hemodialysis patients(excluding the 3 patients who preferred immediate death to any length of survival), 18 patients could not understand the two-stage elicitation method and thus could not state their preferences. They were not able to understand the certainty-equivalent as well as the probability-equivalent standard gamble questions.

Table 1. Demographic information of hemodialysis patients.

	UW hospital, Madison	Froedtert, Milwaukee
Age		
0~19	0	0
20~44	4	6
45~64	13	10
65~74	8	6
75 +	4	3
Race		
White	24	12
Black	4	13
Hispanic	1	0
Gender		
Male	13	14
Female	16	11
Total	29	25

Of those patients who could not follow the two-stage elicitation procedure, 9 patients could not understand the time-tradeoff method as well. They were not able to make trade-off between two different health profiles. The age was one of the factors that differentiated between those who could and could not understand the assessment procedures. 28.6% and 42.9% of the patients who were older than 65 years could not understand the time-tradeoff method and the two-stage method, respectively. The corresponding figures for patients who were under the age of 65 were 9.1% and 27.3%, respectively.

Each patient was also asked which method was easier for him/her to understand and answer questions between the time-tradeoff method and the standard gamble methods (probability-equivalent and certainty-equivalent standard gamble techniques). Thirty patients, out of the total of 54 patients interviewed, were able to answer all the questions in the questionnaire. The time-tradeoff method was easier to understand for 17 patients. For 6 patients, the standard gamble (SG) method of elicitation was easier. Eight patients understood the two methods equally well. Figure 2 summarizes the feasibility of each assessment method applied in this study with hemodialysis patients.

3.2 TTOs versus HYEs

The scatter plots between the two measures are provided in Figure 3 (For pilot group) and Figure 4 (For hemodialysis patients). Correlation coefficients and t-tests are given in Table 2 (For pilot group) and Table 3 (For hemodialysis patients), along with the

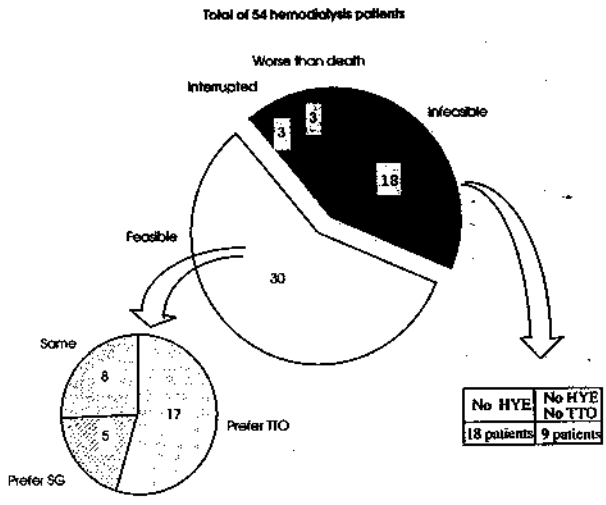
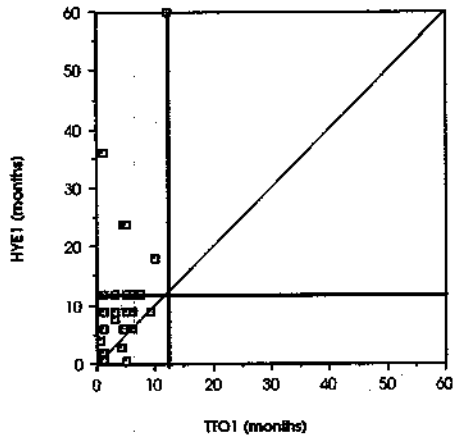
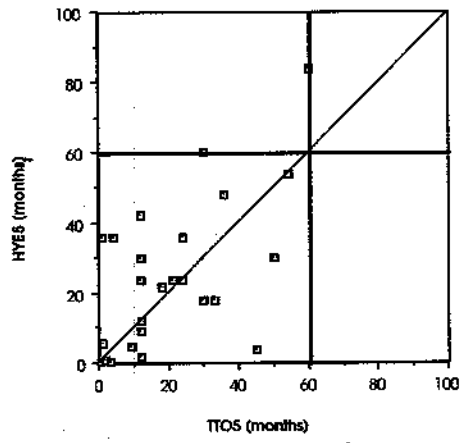


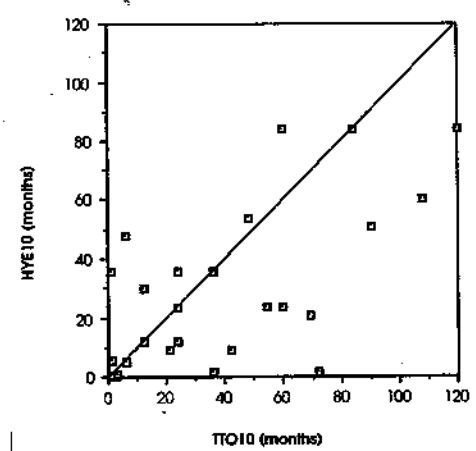
Figure 2. Feasibility of each assessment method with hemodialysis patients.



(a) 1 year time horizon



(b) 5 year time horizon

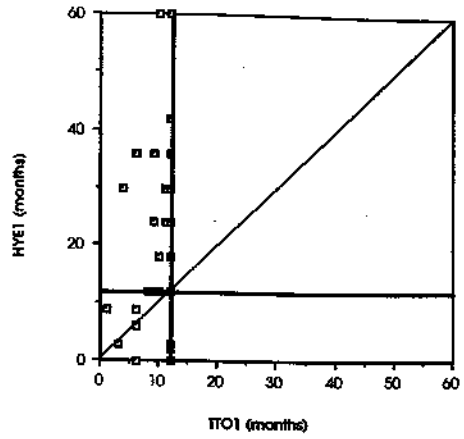


(c) 10 year time horizon

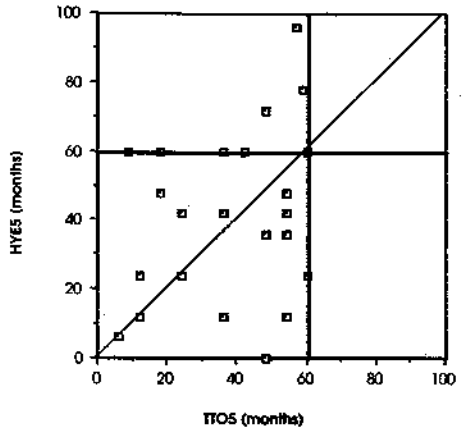
Figure 3. Scatter plots between the TTOs and the HYEs (Pilot Group): Dashed lines represent the time horizon.

mean values of the TTOs and the HYEs.

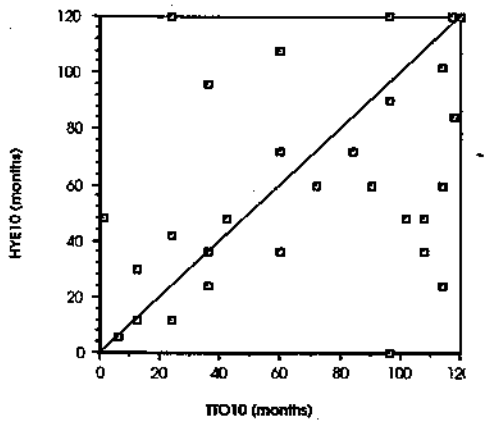
The t-tests show that the TTOs and the HYEs did not coincide in general for representing patient's preferences. The correlation coefficient between the TTOs and HYEs were not high in general, although



(a) 1 year time horizon



(b) 5 year time horizon



(c) 10 year time horizon

Figure 4. Scatter plots between TTOs and HYEs (Hemodialysis patients): Dashed lines represent the time horizon.

two measures were closer in terms of linear association when the survival duration was longer. Figure 3 and 4 show that the HYEs involve more inconsistencies than the TTOs. Both the TTOs and the HYEs should be less than the survival duration on dialysis, since both quantities represent the

Table 2. Paired t-tests and correlation coefficients between TTOs and HYEs (Pilot Group)

Survival Duration	Mean TTO	Mean HYE	Paired t-test			Correlation coefficient
			p-value	Mean	SE†	
12 months	4.29	11.93	0.001**	−7.64	2.10	0.48
60 months	19.77	23.64	0.23	−3.87	3.17	0.61
120 months	38.02	27.82	0.049**	10.20	4.95	0.65

Approximate power of the tests is 0.95.
The number of observation is 28.
The numbers are reported in the unit of months.
** Reject with 90% and 95% confidence level.
† Standard error: Standard deviation divided by the square root of n.

Table 3. Paired t-tests and correlation coefficients between TTOs and HYEs (Hemodialysis patients)

Survival Duration	Mean TTO	Mean HYE	Paired t-test			Correlation coefficient
			p-value	Mean	SE†	
12 months	9.35	20.39	0.001**	−10.85	2.84	0.24
60 months	40.10	40.07	0.86	−0.83	4.66	0.31
120 months	70.93	60.97	0.30	8.17	7.74	0.42
N of cases	40	31	30	30	30	30

Approximate power of the tests is 0.6.
The numbers are reported in the unit of months.
** Reject with both 90% and 95% confidence level.
† Standard error: Standard deviation divided by the square root of n.

certainty-equivalent numbers of life years in "full" health. However, as shown in Figure 3 and 4, many of the HYEs assessed from subjects (the data points above the dotted horizontal line) were not reliable since those quantities were greater than the survival duration on dialysis. An example of such inconsistencies can be seen in Figure 4a, which showed 2 hemodialysis patients rated one year on dialysis equivalent to five years of excellent health. 50% and 10% of hemodialysis patients assessed HYEs that were greater than the time on dialysis with the survival duration was 1 year and 5 years, respectively, while 18% and 4% of the student subjects stated inconsistent HYEs. Table 3 shows that the mean value of HYEs assessed from renal patients was 20.39 months for the 12 months of survival on dialysis. The HYEs that made an individual indifferent

Table 4. t-tests between patients and healthy subjects

Patients vs. healthy subjects	Survival duration					
	12 months		60 months		120 months	
	t-value	p-value	t-value	p-value	t-value	p-value
TTOs	6.73**	.001†	4.66**	.001†	3.62**	.001†
HYEs	2.49**	.007	3.04**	.001†	4.26**	.001†

The numbers represent the t-values.
Independent t-tests with certainty-equivalent numbers assessed by patients and healthy subjects, respectively.
** Reject with both 90% and 95% confidence level.
† Less than 0.001.

to a life of 1 year on hemodialysis were sometimes 5 years. The above findings suggest that the HYEs are less reliable outcome measures than the TTOs.

3.3 Patients versus healthy subjects

It was examined whether there were differences between patients and healthy subjects in assessing the certainty-equivalent numbers. Independent t-tests were conducted to test the null hypothesis that the mean values of the certainty-equivalent numbers (both TTOs and HYEs), that were assessed from patients and healthy subjects, respectively, were equal to zero. The t-tests were conducted with the survival duration of 1 year, 5 years, and 10 years. Table 4 summarizes the results of the t-tests.

The results show that there were differences between patients and healthy subjects in assessing the TTOs and the HYEs. The certainty-equivalent numbers assessed by the patients were significantly greater than those assessed by the healthy subjects, indicating that the quality of life in the health state of ESRD was perceived better on average by the patients than by the healthy subjects. This finding implies that quality of life measures assessed by general public may not represent real patient's quality of life. It discords with the study finding conducted by Sackett and Torrance (1978) that health status perceived by the general public can be good approximation of quality of life of real patients.

4. Discussion

Throughout the interview, the subjects exhibited wide indifference Intervals in assessing the certainty-equivalent numbers and the probabilities. It was not easy for them to state their preferences with much accuracy. Many of the subjects had hard time in stating preferences with *imaginary* health profiles and scenarios. For example, it did not make sense for an 80-year-old patient to think of a health profile of living 10 more years in excellent health. We presumed that uneasiness of stating preferences with imaginary health conditions was one of the major reasons that many patients could not follow the elicitation procedures. Most of the patients, who could not state their preferences in this study, showed no interest and were sometimes upset about the unreal questions.

Another finding was that individuals seemed to have reference points both for life years and probabilities in assessing numerical quantities. The reference points serves as a boundary that distinguishes gains from losses, and is known to be zero for most individuals with a monetary outcome measure (Tversky & Kahneman, 1992). We recorded subjects' comments and any interesting findings during the interviews. The existence of reference points for life years and probabilities was identified from the records of 20 and 15 subjects (including 13 and 8 patients), respectively. Many patients seemed to have a reference point of 1 year or 2 years, which can be interpreted as the minimum duration of survival they would require if a bad outcome should happen. In general, subjects had a tendency to choose the longer life in worse health condition rather than the shorter life in excellent health when the lengths of survival were shorter than the reference point, while they were willing to sacrifice the same proportion of life for better health state when the lengths of survival were greater than the reference point. This behavioral tendencies seemed to cause the violation of the assumption of constant-proportional risk posture over life years which is required for a construction of an outcome measure when we assume a functional utility curve (Pliskin *et al.*, 1980).

There seemed to be also reference points for probabilities around which the choice behavior of a subject changes significantly. Take for example, an individual who is expected to live 5 years from now on hemodialysis. Suppose he/she is offered an innovative treatment option that he/she can live 5 years in excellent health if the treatment is successful, but dies immediately if it is not. With a reference point of .33 in terms of the success probability of the innovative treatment, the individual is likely to feel the difference between treatment options with success probability of, say, .30 and .35, while he/she

may not feel the same difference between the treatment options with success probability of .20 and .25. The above behavioral patterns were identified from subjects' comments like: "The success probability of .45 and .5 seems to me about the same, but the probability of .42 feels different.", "I don't see much difference between the probability of .25 and .30, but it's different between the probability of .3 and .34.", "I know that .25 is greater than .2, but I don't feel difference", etc.

Overestimation of HYEs was identified from this empirical study. One explanation for the overestimation of HYEs is that both the probabilities and the certainty-equivalent numbers are overestimated when they are assessed with the probability-equivalent and the certainty-equivalent standard gamble method, respectively (Tversky *et al.*, 1990; Delqui, 1993). Another possible explanation for the overestimation of HYEs seems to be the complex assessment procedure of the two-stage method. To assess the HYEs a subject was given two options: One of the options involved uncertain health profile, and the other option was a sure health profile. The uncertain health profile was identical, but the sure health profiles were different in the first and the second stage of the two-stage method. In the first stage, the sure health profile was (Dialysis, T), a life of T years in the health state of ESRD. In the second stage, the sure health profile was (Excellent health, T*), a life of T* years in excellent health. We found that many subjects confused the two sure health profiles in the first and the second stage. In the second stage of the two-stage method, the study interviewer had to emphasize that the sure health profile involved excellent health and was different from the one with the health state of ESRD in the first stage. However, it seemed that the subject's attention was more on the survival duration rather than on the health condition in the health profiles. In effect, the sure health profile in the first stage seemed to affect subject's choices in the second stage like the anchoring and adjustment type of bias (Tversky & Kahneman, 1974). Noticing that the sure health profile in the first stage involved worse state of health than the profile in the second stage, we presumed that the overestimation of HYEs was caused by the complex procedure of two-stage method as well as by subject's confusion with it.

Subjects, especially the patients, had hard time in making choices between different health profiles with the standard gamble questions. The outcome of *immediate death* seemed to make subjects more difficult to make decisions. We presume that the use of *near corner points* (e.g., survival of 1 day or 1 week) instead of using the immediate death as the corner point in the outcome space would relieve the difficulties of the quality of life assessment. The idea of using the *near corner* points instead of the corner points for the construction of a multiattribute utility function was introduced by Fryback and Keeney (1983), and will be of much practical value in assessing quality of life in practice. In fact, the outcome of immediate death was considered an infinitely undesirable outcome for most of the subjects in this study, although a few subjects considered the health state of being on dialysis worse than the immediate death. This problem then relates to the Archimedean axiom for the construction of a multiattribute utility function that there is no infinitely desirable or undesirable outcome (Keeney & Raiffa, 1976). If the immediate death is used as the worst health outcome and is considered an infinitely undesirable outcome by an individual, then the Archimedean axiom would be violated and in turn the assessment of quality of life itself would not be theoretically valid. More studies and discussions would be required to solve this problem.

The study was limited in that it did not account for the reliability of each outcome measure and the corresponding assessment technique. The findings of the proposed empirical study may be disease-specific and thus may not be generalizable to other problems. Due to lack of sample size, the study did not analyze effect of patient age and their disease duration on the assessment of TTO and HEY. Age and disease duration may influence patient's quality of life perception, and analysis of this influence could provide valuable insight.

When HYEs were assessed from the two-stage method, subjects were not given a chance to resolve inconsistencies that the assessed HYEs are greater than the survival duration on dialysis. The inconsistencies in assessing HYEs were recognized in the process of data analysis. If subjects had given chances to resolve these inconsistencies, then the assessed HYEs from subjects could have been more consistent.

5. Conclusion

This study compared the TTOs and the HYEs. The study suggests that a patient's assessment of quality

of life could be quite different from that of a healthy subject. There was significant difference between patients and healthy subjects in assessing the TTOs and HYEs, implying that the health status perceived by general public should be used cautiously for quality of life of real patients.

The results of the study also showed that the TTOs and the HYEs did not coincide empirically although they should be identical in theory. The certainty-equivalent numbers assessed by the patients were greater than those assessed by the healthy subjects in general. The time-tradeoff method was perceived as easier to implement than the two-stage method. It was observed that the assessed HYEs were sometimes greater than the life years in the health state of ESRD, implying that the HYEs involved larger inconsistencies than the TTOs. The inconsistent assessments of HYEs were observed more often when the survival duration in a health profile was short.

The fact that those two outcome measures did not coincide may well be due to errors intruded in the assessment process in the form of random error. However, the inconsistency of HYEs seemed to be caused by the complex elicitation procedure of the two-stage method and the preference assessment bias brought on by the probability heuristics associated with responses. The study findings confirm Rittenhouse's (1997) claim that the more complicated method of the HYE would appear to have no practical advantage to offer over the TTO.

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