

Integrating health profile with survival for quality of life assessment

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Abstract

In cohort studies or clinical trials, measurements of quality of life (QoL) were averaged across available individuals for each group at given points in time to produce single measures for comparisons. However, estimates of these single measures may be severely biased if substantial mortality occurs over time. The objective of this study is to develop a method that integrates QoL measurement and survival for long-term evaluation of health services. We defined a mean QoL score function over time for an index population as the average QoL score of all individuals both alive and dead at each time point in the population. While a living subject's QoL can be assessed by asking one's subjective preference, the score of a decedent can be assigned a fixed value depending on the specific facet on health profile. The mean QoL score function over time is reduced to a single measure of expected cumulative QoL score, which is the area under the curve of mean QoL score function over a given time interval and can be estimated by taking a random sample from a cross-sectional survey. For the QoL score function to be extrapolated to life-long, it requires the assumption that the disease causes premature death or a long-term moderate impairment of QoL. We provided methods and computer programs for estimating mean QoL score functions and the reduced single measures for use in comparisons. A cohort of 779 breast cancer patients from Chiangmai, Thailand were followed for 12 years to demonstrate the proposed methods. The data included the 12-year complete survival records and QoL scores on 233 patients collected from a cross-sectional survey using WHOQOL questionnaire and standard gamble method. The expected cumulative QoL scores using utility and psychometric scales were compared among patients in four groups of clinical stages in this cohort for time from onset up to 12 years and life-long. We conclude that such an integration of QoL measurement with survival can be useful for the evaluation of health service and clinical decision.

Key words: Health profile, Monte Carlo method, Quality-adjusted life year, Quality-adjusted survival

Introduction

Health-related quality of life (HRQoL) assessment is increasingly used in clinical trials and other health outcome evaluation [1]. HRQoL is generally defined as the individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns [2]. It is a multidimensional concept incorporating both functional status and the individual's per-

ception of health. Thus, many generic and condition-specific questionnaires have been proposed to assess these effects [3–5]. These QoL measures are similar in that each expresses the effects of medical care in terms that can be reported directly by a patient. However, the rationales for the methods differ considerably. Most of the available psychometric measures include multiple dimensions such as physical functioning, psychological status and social relationships in order to create a profile of patient outcomes. While utility-based methods

assign a value to a specific health state to reflect global impact of that state on the patient's overall QoL [6–9].

Since a patient's QoL continuously fluctuates or changes over time, many HRQoL studies have considered summarizing measurement and analysis from a time perspective. In clinical trials, HRQoL assessments were often conducted by administering profile questionnaires at multiple time points before, during, and after an intervention, with a focus on summarizing or showing the changes in QoL over time (or longitudinally) and across different individuals for group comparison [10]. In practice, the summary measures are often constructed to obtain population mean QoL score estimates at given time points using sampled data from each population. However, it has been a noteworthy problem that the estimates can be biased if there is a substantial proportion, say, 40%, of mortality in a study over time [11]. There is also argument regarding the assignment of scores to those who die in the study. Thus, so far there have been relatively few methods developed for summarizing health profile measures taking account of mortality or survival across time during longitudinal follow-up.

In this study, we first clarify the definition of mean QoL score function over time for an index population, which is a function of average score across all individuals both alive and dead at a given time in the index population. While a living subject's QoL can be assessed by asking one's subjective preference, the score of a decedent can be assigned a fixed value depending on the specific facet on health profile. We then show that the mean QoL score function can be presented in terms of survival function and average QoL score function of the sub population of living individuals. When the survival data are complete, the survival function can be estimated quite accurately using available techniques. The average QoL score function of the sub population of living individuals can be estimated by kernel-smoothing the data of a random sample from a cross-sectional survey of QoL on the living individuals, which was demonstrated in a previous simulation study by Hwang et al. [12]. When the data are not complete such as in follow-up studies with heavy censoring, the mean QoL score functions can be accurately estimated over time only up to the end of the follow-

up. Then, the lifetime score for the whole population can also be extrapolated by a Monte Carlo method proposed by Hwang and Wang [13]. Therefore, we can obtain relatively accurate mean QoL score function estimates, which can be further plotted against the whole life span for specific QoL domain or item scales in different treatment groups. When the QoL score function is replaced by utility function, the area under the whole life span is the expected quality-adjusted life expectancy (QALE).

Data from a cohort of 779 cases of breast cancer from Chiangmai, Thailand followed for 12 years were used as an example to illustrate the proposed methods [14]. The cohort was stratified into four groups with different clinical stages. To the end of the follow-up, June 30, 1997, the survival and mortality of the 779 patients were well recorded. Measurements of QoL were obtained through a cross-sectional survey on 223 patients during 1996–1997 using utility measurement of standard gamble and the questionnaire of World Health Organization quality of life (WHOQOL). We computed and compared expected QALYs in utility and psychometric scores for the four groups of cancer patients for time up to 12 years and life-long.

Methods

In this section, we first clarify the definition and interpretation of mean QoL function over time for an index population and then introduce methods for estimating the function. Let $q_i(t)$ be the unobserved QoL score at time t since the onset of a specific disease or health condition on the i th individual patient in an index population. The QoL score can be measured using the utility or health profile instrument. In most QoL measurement, we often can rescale the QoL score to a value between 0 and 1, in which 0 represents the worst health status and 1 represents the perfect health. If a patient dies during the study, a constant value between 0 and 1, denoted by δ , could also be assigned after that time point for the patient. The population mean QoL score at each time t is constructed straightforwardly by the population average, $Q(t) = \frac{1}{N} \sum_{i=1}^N q_i(t)$, where N is the size of the index population. Let $G(t)$ denote the set of

subjects in this index population who are still alive at time t . The size of $G(t)$ is denoted by $M(t)$. Note that in the beginning of time 0, $M(t) = N$. The mean QoL score function over time t for the index population can be rewritten as the sum of scores of those who are still alive plus those who die:

$$\begin{aligned} Q(t) &= \frac{1}{N} \left(\sum_{i \in G(t)} q_i(t) + \sum_{i \notin G(t)} q_i(t) \right) \\ &= \frac{M(t)}{N} \times \frac{1}{M(t)} \sum_{i \in G(t)} q_i(t) + \frac{N - M(t)}{N} \times \delta. \end{aligned}$$

Note that $M(t)/N$ is the survival rate at time t for the index population, denoted by $S(t)$. We may denote $\frac{1}{M(t)} \sum_{i \in G(t)} q_i(t)$ by $Q_s(t)$ representing the average QoL score for the sub population of individuals still alive at time t . We then obtain the following simple equation

$$Q(t) = S(t) \times Q_s(t) + [1 - S(t)] \times \delta$$

which establishes the relationship between population mean QoL score function and survival function. Note that when QoL score is assigned with a constant value of 1 for all living individuals and $\delta = 0$, $Q(t)$ is the survival function for the index population. Therefore, we can interpret the mean QoL score function as quality-adjusted survival function when the QoL score is in the 0–1 scale. More importantly, this equation provides an alternative way of estimating $Q(t)$ by separately estimating the survival function and the mean QoL score function for the sub population of the living individuals. The area under the curve of the mean QoL score function $Q(t)$ plotted against time t over the period $[a, b]$, presented by

$$Q[a, b] = \int_a^b S(t) Q_s(t) dt + \delta \int_a^b [1 - S(t)] dt,$$

is a common single measure of QoL, with a unit of psychometric score-time, which is conceptually the same as quality-adjusted life year (QALY) for the time period except substituting the utility measurement with health profile scores. This useful measure $Q[a, b]$ is the expected cumulative QoL score, which can be also interpreted as expected quality-adjusted survival time adjusted for the specific score/utility for an index population over

the time period $[a, b]$. If the QoL score is a utility measurement, then the measure $Q[0, \infty]$ is exactly the QALE with the unit of QALY. When the QoL is a score from psychometric measurement, then the unit is a score-time, say, score-month or score-year, etc. Namely, it is a psychometric score adjusted by survival function and should specify the time unit for comparative purpose. The proposed formula is a generalization from that derived by Hwang et al. using integration techniques in which δ is restricted to be 0 [12].

To estimate the expected cumulative QoL score $Q[a, b]$, we can conduct on discrete time by dividing the entire time period $[a, b]$ into K disjointed short intervals $[t_{k-1}, t_k]$, $k = 1, 2, \dots, K$, where $t_0 = a$ and $t_K = b$. The estimate of survival at time t_k , denoted by $\hat{S}(t_k)$, can be easily obtained using common approaches such as Kaplan–Meier method when complete survival data are available. To obtain the estimate of mean QoL for the sub population, $\hat{Q}_s(t_k)$, we only need measurements from a cross-sectional survey on the living individuals, instead of the costly repeated measures, and using kernel smoothing techniques or fitting a non-linear curve to the interviewed scores. The estimate of population mean QoL at time t_k is $\hat{Q}(t_k) = \hat{S}(t_k) \times \hat{Q}_s(t_k) + [1 - \hat{S}(t_k)] \times \delta$. The expected quality-adjusted survival time over the period $[a, b]$ can be estimated using a trapezoidal approximation:

$$\hat{Q}[a, b] = \frac{1}{2} \sum_{k=1}^K (t_k - t_{k-1}) [\hat{Q}(t_k) + \hat{Q}(t_{k-1})].$$

Extrapolation to lifetime with censored follow-up data

When the data are complete, simulation studies conducted by Hwang et al. showed the estimator is quite accurate [12]. However, especially for follow-up studies with heavy censoring, the mean QoL score function $Q(t)$ for the index population can be accurately estimated only over time up to the end of follow-up. Hwang and Wang have proposed a Monte Carlo extrapolation approach to provide estimate of $Q(t)$ for t beyond the close of follow-up [13]. The main idea of that approach is to borrow information of long-term survival from a reference population matched with the same age and gender

for every individual of the index population. In other words, we can generate a hypothetical reference population composed of exactly the same age and gender distribution through Monte Carlo simulation method from the vital statistics. Then, fit a simple linear regression to the logit of the ratio between $Q(t)$ of the index population and the simulated survival function of the reference population for a certain point in time to the end of the follow-up. Finally, use the predicted line to extrapolate $Q(t)$ beyond the follow-up. On this approach, one must assume that the mean QoL score function $Q(t)$ for the index population at time t should be no greater than that of the reference population [13], which only holds for any disease that results in premature death or affects QoL moderately on a long-term basis. A feedback plot to check the linearity assumption is also provided to assure the validity. Simulation studies have shown that this is a potential approach for estimating mean QoL score function and survival function beyond the follow-up with a certain degree of accuracy. The Bootstrap approach was also proposed to estimate standard errors of the estimates [15]. The authors have provided a free package of S-Plus functions for computing the estimates and standard errors of the estimates for $Q[a, b]$ and other applications [16]. Users only need to input files of survival data, cross-sectional survey data of QoL score, and sample of age and gender from the index population, in addition to a file of life table if extrapolation is needed.

Example of a breast cancer cohort

The detailed information of a cohort of 779 cases of breast cancer who were first diagnosed during 1985–1994 were followed regularly at Chiangmai cancer registry for 12 years was described elsewhere [14]. Briefly, the Chiangmai cancer registry is a population-based registry, co-sponsored by the Chiangmai University Faculty of Medicine and WHO, which actively collected data on cancer patients from one university hospital, 10 private hospitals, and 26 public hospitals in Chiangmai province, Thailand [17]. The cohort has been stratified into four groups with different clinical stages with group sizes 81, 330, 226 and 142, respectively. The average onset age of these 779 pa-

tients were 50.3 ± 13.0 years old with a range of 22–95. By the time of censoring, June 30, 1997, there were 75, 244, 106, and 28 patients still alive for stages I–IV, and the 12-year survival rates were 93, 74, 47, and 13%, accordingly. To establish the QoL function curve through time for each stage, we needed to obtain a random sample of 50 in size [12]. In addition, we added 15–25 patients whose duration-to-dates were less than 2 years, because the original cohort no longer collected patients by the end of 1994 and the QoL function was relatively unstable during the first 2 years after diagnosis. A cross-sectional survey was then implemented and the response rate was about 80%. In total, we collected 64, 72, 69 and 28 patients in stages I–IV for HRQoL interview during 1996–1997. Patients were asked to fill out the WHOQOL-100 questionnaire followed by standard gamble method conducted by an interviewer to elicit the utility value of her current health state [8].

The WHOQOL-100 was originally designed by the WHOQOL group, which intended to assess detailed health profile on four domains with 25 facets inquiring about physical/independent, psychological/spiritual, social relationship and environment [2, 18]. Each facet consists of 4 items in which a five point Likert scale (1–5 score) is used. The facet score, given by the sum of its four item scores, ranges from 4 to 20. The domain score is obtained by averaging the facet scores in that domain. In this study we rescaled the domain score by subtracting 4 and then dividing by 16 to a value between 0 and 1 corresponding to the worst and best health status of that domain, respectively. The rescaled score is still a preference measure. But it can be treated as a psychometric QoL score for comparison with the utility measurement obtained from standard gamble method, which also ranges between 0 and 1.

Results

Figure 1 shows the estimated survival, average scores of physical domain of WHOQOL obtained from living patients and the physical domain score-adjusted survival functions over the 12-year follow-up period for the four stages of breast cancer patients. The plots were produced from the free package in which the survival functions were

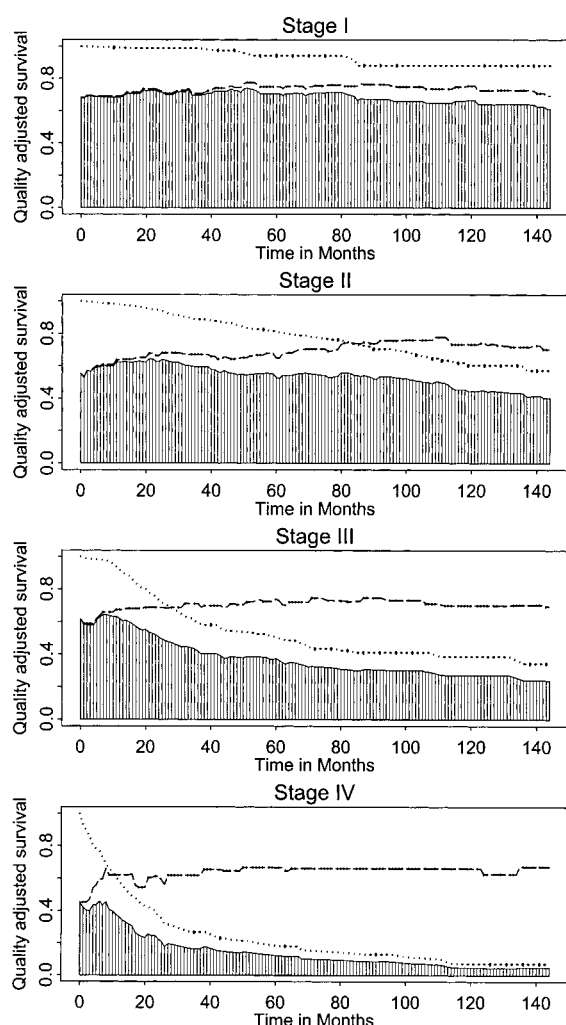


Figure 1. The estimated quality of life adjusted survival functions (solid curves) for stages I–IV breast cancer patients after 144 months of follow-up. Scores from the physical domain of WHOQOL were used for demonstration. The dotted curve is the estimated survival functions. The dashed curve is the estimated average quality of life score of living patients. The shaded area is the expected cumulative physical score-months over the 144 months of follow-up.

estimated using Kaplan–Meier method on the survival data of the breast cancer cohort. The estimated score function for physical domain of each subgroup of living individuals was obtained using kernel smoothing method on the sampled patients with different duration-to-dates. The shaded area under the estimated physical domain score-adjusted survival function in each plot was the expected cumulative physical domain score-time or

physical domain adjusted survival time over the 12 years of follow-up. The average QoL scores of physical domain in living patients were usually lower in the first months of follow-up and then slowly increased to stable levels. Because only five stage IV patients survived for more than 5 years, the curve was over-smoothed after 5 years. However, the survival rates were very low for stage IV patients, and the estimated QoL adjusted survival function would not be greatly affected. Table 1 summarizes the results of estimated expected survival in months, expected quality-adjusted survival time adjusted for standard gamble utility, and for physical, psychological, social, and environmental domain scores, respectively, over the 12 years of follow-up and life-long. The estimated 12-year mean survival times are 134, 112, 77 and 33 months for the four stages, accordingly. The expected quality-adjusted survival time adjusted for utility, were higher than those adjusted with the psychometric scores in all the four stages. The 12-year cumulative psychometric adjusted survival for social domain seemed to be the worst domain compared with other QoL domains in WHOQOL, which indicates that social life is the most severely affected.

To extrapolate the mean QoL score function beyond the follow-up of 12 years, we have checked the linearity assumption for logit of the ratio between $Q(t)$ of the index population and the simulated reference population. As examples shown in Figure 2, the assumption seemed to be largely fulfilled for four stages for the last 60 months of 144-month follow-up. Figure 3 shows the estimated QoL adjusted survival functions up to 30 years for the stage I group. The curves against time beyond 144 months were extrapolated using the Monte Carlo approach on a reference group with age and gender matched for stage I group, which were generated from the general population using 1990 vital statistics of Thailand. The patterns of QoL adjusted survival functions over time were similar for utility measure, and psychometric scaling for physical and psychological domains, which shared a constant decreasing rate during this time period. The QoL adjusted survival functions for social and environmental domains behaved to have less decreasing rates. The lower half of Table 1 summarizes the results of estimated expected survival time, quality-adjusted survival

Table 1. The estimates of expected survival time (in months), quality-adjusted survival time (QAST) adjusted for standard gamble utility and psychometric scores obtained from physical, psychological, social and environmental domains during 144 months of follow-up and life-long for breast cancer patients in the four clinical stages

| QoL scale | Stage I | | Stage II | | Stage III | | Stage IV | |
|-------------------------------------|----------|------|----------|------|-----------|------|----------|-----|
| | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| <i>Over 144 months of follow-up</i> | | | | | | | | |
| Survival time | 134.2 | 3.8 | 111.9 | 2.7 | 76.9 | 4.1 | 33.1 | 3.8 |
| QAST adjusted for | | | | | | | | |
| Standard gamble | 117.7 | 3.6 | 92.4 | 2.9 | 62.1 | 3.5 | 26.7 | 3.3 |
| Physical score | 98.5 | 3.3 | 77.0 | 2.9 | 53.5 | 3.1 | 20.2 | 2.5 |
| Psychological score | 93.4 | 3.1 | 74.1 | 2.2 | 50.8 | 3.0 | 20.9 | 2.4 |
| Social score | 87.4 | 3.4 | 75.1 | 2.2 | 49.8 | 3.0 | 20.5 | 2.2 |
| Environmental score | 91.1 | 2.9 | 74.1 | 2.2 | 51.3 | 2.9 | 20.9 | 2.5 |
| <i>Extrapolated to life-long</i> | | | | | | | | |
| Survival time | 277.5 | 59.8 | 166.2 | 15.3 | 118.6 | 17.1 | 36.9 | 6.1 |
| QAST adjusted for | | | | | | | | |
| Standard gamble | 274.6 | 39.5 | 144.0 | 17.5 | 104.9 | 16.5 | 29.9 | 5.4 |
| Physical score | 215.5 | 33.2 | 122.3 | 16.0 | 84.0 | 13.3 | 22.8 | 4.1 |
| Psychological score | 203.5 | 30.6 | 111.9 | 12.0 | 74.6 | 10.4 | 23.5 | 4.3 |
| Social score | 213.5 | 42.4 | 122.9 | 14.2 | 82.7 | 12.3 | 23.2 | 3.9 |
| Environmental score | 221.8 | 31.7 | 118.7 | 12.9 | 77.6 | 12.1 | 23.5 | 4.3 |
| Survival time for reference group | 379.5 | 1.8 | 361.3 | 1.7 | 326.8 | 1.8 | 313.6 | 1.9 |

The standard errors were estimated using the Bootstrap approach. The reference group was created by matching onset ages of patients in each clinical stage group using female Thai vital statistics in 1990.

time adjusted for utility and for the four domain scores of WHOQOL after extrapolation to 50 years or life-long. The estimated life expectancies were 278, 166, 119 and 37 months for the four clinical stages of breast cancer patients. While the survival times for the four reference groups of people with perfect health (or QoL = 1) were 380, 361, 327 and 314 months, accordingly. The results revealed that psychological domain has the smallest life-long score-time for stages I–III, which implies that breast cancer patients need a long-term psychological care.

The results shown in Table 1 were based on the assumption of assigning the dead 0 score. To explore the sensitivity of assigning the death score, we calculated the expected psychological score-time adjusted survival time for the four stages with death score 0.1 and 0.2, respectively. We have chosen 0.2 because of the minimum psychological score of 0.22 found in the 233 sampled patients. The results are summarized in Table 2. The expected adjusted survival time increased as death scores increased. There were limited increased adjusted survival time for stage I patients because of a high survival rate. But the expected life-long

adjusted survival time for psychological domain increased from 23.5 score-months with death score 0 to 130.3 score-months with death score 0.2 for the stage IV patients. The result indicates that expected quality-adjusted survival time was very sensitive to the assignment of death score for a disease with high mortality rate.

Discussions

In clinical trials, measured QoL scores using utility or psychometric health profile methods were usually compared for available patients at specific time points: before, during, and at the end of the trials. Summary measures over time were usually used for comparisons and reports. However, patient's survivorship is either ignored or considered separately from the observed QoL scores [19]. The ignorance of mortality has caused a serious problem of bias in the summarized QoL measures. In this study, we proposed a clear definition of mean QoL score function over time for an index population, which is the average score of all patients both alive and dead at a given time. Moreover, we

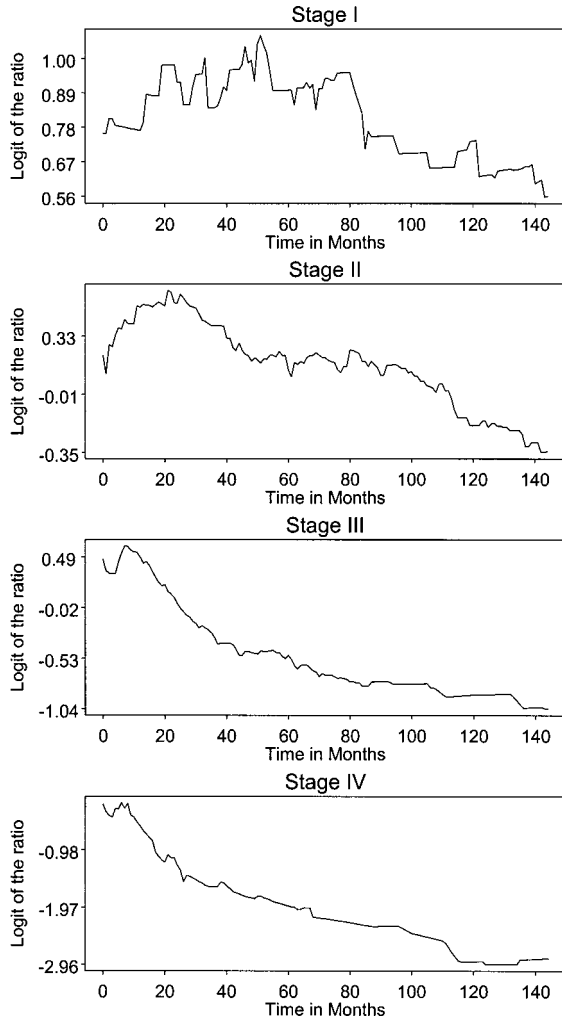


Figure 2. The logit of the ratio between the estimated mean physical QoL score function and survival function for reference population by clinical stages plotted against time over the 144 months of follow-up.

have also shown that the mean QoL score is the sum of following two products: the average score of surviving patients multiplied with population survival rate, and the mortality rate multiplied with the average score of decedents after assigning a fixed value. The survival of the population is then naturally integrated with QoL measure so that we can interpret the mean QoL score function as the QoL adjusted survival function. The QoL adjusted survival function is further extended to define the cumulative QoL score for an index population over a time duration, which can sup-

plement the drawback of only comparing one or several specific time points. When the QoL score is rescaled to 0–1, life-long cumulative QoL score is equivalent to the commonly used expected quality-adjusted survival time in cost-effectiveness analysis [20]. We have provided a general form and procedures for calculating expected quality-adjusted survival time using both utility and health profile measures. Most HRQoL studies have assigned 0 score to the dead, although many people may disagree and there seems to have no consensus. Our proposed method allowed researchers to assign different constant values to the decedents according to different items or domains in health profile assessment. We propose that such a value had better be less than the lowest value of those alive during sensitivity analysis. Since the lowest possible score in our study for different domains was 0.22, we decided to assign scores of 0, 0.1 and 0.2 for sensitivity analysis of scoring the dead subjects, which therefore can be implemented to provide additional information for a more delicate clinical decision-making.

Although we have provided a clear interpretation of the combination of QoL with survival through the definition of population mean QoL, some practical problems are worth further clarification. The major critique on the combination of QoL and survival is the potential dependence of QoL on survival [19]. In general, patients who are about to die or to be lost to follow-up tend to have worse current scores, whereas those who survive longer tend to have somewhat better current scores [11, 20]. It indicates that the average scores obtained from a sample of the surviving patients might produce a positive bias because patients with worse scores may be less represented in the sample. Hence, a (stratified) random sample of currently surviving patients, which cover all different duration-to-dates or times-after-diagnosis, should be essential to an accurate measure for the combination of QoL measures and survival. In other words, our current approach of conducting a cross-sectional survey with kernel-smoothing the data to estimate the mean QoL function at different duration-to-dates may not be very accurate. It can be further improved by repeated measurements for the same cohort followed by constructing a mixed-effects model and adding more predictors of QoL as fixed factors.



Figure 3. The estimated quality of life adjusted survival functions for stage I breast cancer patients using physical, psychological, social and environmental measures of WHOQOL and standard gamble utility.

By doing so, we can actually improve the estimates of QALE as well as lifetime psychometric scores.

Another concern is the choice of an appropriate reference population. While it is very convenient to use the life table of general population on vital

statistics, one can only match with the index population on age and gender. A more accurate estimation may be achieved through a more deliberate selection of a reference population that are comparable with the index population on other determinants of outcome [21], because then the

Table 2. Results of sensitivity analysis for assigning scores of 0, 0.1 and 0.2 to the state of death on the estimates of expected cumulative psychometric score-months obtained from psychological score of four clinical stages of breast cancer for 144 months of follow-up and life-long

| Time duration | Death Score | Stage I | | Stage II | | Stage III | | Stage IV | |
|---------------|----------------|----------|------|----------|------|-----------|------|----------|-----|
| | | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| 144 months | $\delta = 0$ | 93.4 | 3.1 | 74.1 | 2.2 | 50.8 | 3.0 | 20.9 | 2.4 |
| | $\delta = 0.1$ | 94.4 | 3.0 | 77.3 | 2.0 | 57.5 | 2.6 | 32.0 | 2.2 |
| | $\delta = 0.2$ | 95.4 | 2.5 | 80.6 | 1.8 | 64.2 | 2.2 | 43.1 | 1.7 |
| Life-long | $\delta = 0$ | 203.5 | 30.6 | 111.9 | 12.0 | 74.6 | 10.4 | 23.5 | 4.3 |
| | $\delta = 0.1$ | 213.3 | 27.4 | 135.2 | 11.0 | 111.3 | 8.4 | 76.9 | 2.7 |
| | $\delta = 0.2$ | 216.1 | 29.1 | 156.5 | 8.6 | 148.1 | 6.5 | 130.3 | 1.6 |

linear assumption of logit of $W(t)$ may be more easily fulfilled.

The QoL adjusted survival functions may provide more detailed information for different choices of diagnoses and/or treatments, because different patients may have different preferences in different facets and domains. Both patients and doctors or nurses can look at the figures and numerical values of score-time for different facets or domains of their future QoL adjusted lives at any time point from the $Q(t)$ score functions, which can be used to facilitate decision-making. The measure of life-long cumulative QoL score can also be applied to the general population to calculate a nation's psychometric health life expectancy.

The results of this breast cancer study show that expected quality-adjusted survival time calculated from the utility measurement was generally higher than the rescaled psychometric score-adjusted survival time. This may indicate HRQoL measure in terms of utility is really higher than the 0–1 scaled psychometric scores for the breast cancer patients. However, it is also possibly caused by the scale construction difference. The simple 5 points ordinal scale representing increasing or decreasing severity may be enough for patients to mark their perception. But the descriptors for the lowest and highest scale points are often too extreme so that patients tend not to mark these points even when their health conditions are close to these ends. Moreover, most psychometric scores coming from the Likert scale may not be directly transformed into a ratio scale of between 0 and 1. These problems need to be resolved before the rescaled scores can be used to compare with other utility measures. Hence, the interpretation on direct comparison between expected quality-adjusted survival times using different measures must be cautious. Further refinement of psychometric instruments such as conducting a more detailed descriptor study before use will probably improve the accuracy and feasibility of our method.

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