VISION AND QUALITY-OF-LIFE*

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ABSTRACT

Objective: To determine the relationship of visual acuity loss to quality of life.

Design: Three hundred twenty-five patients with visual loss to a minimum of 20/40 or greater in at least 1 eye were interviewed in a standardized fashion using a modified VF-14, questionnaire. Utility values were also obtained using both the time trade-off and standard gamble methods of utility assessment.

Main Outcome Measures: Best-corrected visual acuity was correlated with the visual function score on the modified VF-14 questionnaire, as well as with utility values obtained using both the time trade-off and standard gamble methods.

Results: Decreasing levels of vision in the eye with better acuity correlated directly with decreasing visual function scores on the modified VF-14 questionnaire, as did decreasing utility values using the time trade-off method of utility evaluation. The standard gamble method of utility evaluation was not as directly correlated with vision as the time trade-off method.

Age, level of education, gender, race, length of time of visual loss, and the number of associated systemic comorbidities did not significantly affect the time trade-off utility values associated with visual loss in the better eye. The level of reduced vision in the better eye, rather than the specific disease process causing reduced vision, was related to mean utility values.

The average person with 20/40 vision in the better seeing eye was willing to trade 2 of every 10 years of life in return for perfect vision (utility value of 0.8), while the average person with counting fingers vision in the better eye was willing to trade approximately 5 of every 10 remaining years of life (utility value of 0.52) in return for perfect vision.

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Conclusions: The time trade-off method of utility evaluation appears to be an effective method for assessing quality of life associated with visual loss. Time trade-off utility values decrease in direct conjunction with decreasing vision in the better-seeing eye. Unlike the modified VF-14 test and its counterparts, utility values allow the quality of life associated with visual loss to be more readily compared to the quality of life associated with other health (disease) states. This information can be employed for cost-effective analyses that objectively compare evidence-based medicine, patient-based preferences and sound econometric principles across all specialties in health care.

INTRODUCTION

Traditionally, quality in ophthalmic care has been anchored by measures of visual acuity. The Snellen classification is the most widely used clinical visual measurement parameter, but other systems, such as the logMAR chart, are also utilized.[1] Snellen visual acuity can be measured conventionally (eg, 20/20, 20/30, etc.) or by the decimal system (eg, 20/20 = 1.0, 20/40 = 0.5).[1] Despite the method of visual acuity assessment, the vast majority of clinical studies that employ interventional treatments measure results in terms of change, or absence of change, in visual acuity[2-4]

While visual acuity measurements can be compared within the field of ophthalmology, it has not been possible to compare the value of an interventional therapy that improves vision to the value of a medical procedure outside the field of ophthalmology. For example, what is more valuable to a patient? Removal of a 20/100 cataract when the opposite eye has 20/40 vision, or a total hip replacement if the patient is unable to walk? To date, information that facilitates this type of comparison is not available.

A number of methods have been undertaken to measure quality of life issues in medical care. In ophthalmology, methods that produce visual function indices, such as the VF-14[5] and the 51-item National Eye Institute Visual Function Questionnaire,[6] have been developed. Multiple investigators[7-10] have used these instruments to evaluate the degree of disability occurring secondary to pathologic ocular conditions but, again, have been constrained by the inability to make comparisons across nonophthalmologic specialties. To overcome this lack of generalized applicability across specialties, some investigators have incorporated more generalized medical quality of life measurement indices, such as the Medical Outcomes Study Short Form Health Surveys.[9,11-14] Because of the paucity of information at present, it is difficult to ascertain whether such forms, designed more for systemic disease evaluation,[12] will be particularly applicable for ophthalmic abnormalities.[9]

In the 1970s and 1980s, new methods of evaluating cost-effectiveness began to evolve.[15-18] These methodologies incorporated principles of utility theory, a concept that evolved to help quantify uncertainty in various fields.[19]

Utility theory, as applied to the medical field, involves the use of preferences to assess the ability of a person to function in the activities of daily life. In essence, it allows quantification of the quality of life associated with a health (disease) state. By convention, a utility (or utility value) of 1.0 is associated with perfect health, and a utility of 0.0 is associated with death.[15,16,18,20,21] The closer to 1.0 the utility value, the better the ability of a person to function and the better the implied quality of life. Conversely, the lower the utility value, the greater the difficulty a person has functioning in life's daily activities; thus, the less the quality of life. For example, a health state of life with menopausal symptoms has been associated with a utility value of 0.99,[16] mild angina a utility value of 0.90,[16] severe angina a utility value of 0.50[16] and major stroke a utility value of 0.30.[22]

Utility assessment, in contrast to some of the ophthalmic indices of quality of life,[5,6] allows a comparison of utility values associated with various health states. Thus, the quality of life associated with a bilateral visual acuity of 20/200 can be compared by utility evaluation to the quality of life associated with severe angina. The improvement in utility values conferred by therapeutic interventional treatments can also be compared across disease entities that involve different organ systems in the body.[15-18,20,21]

Because of the increasing importance of patient preferences[23-25] and quality of life issues[5-18,20,21] in the medical field, the present study was undertaken to evaluate the quality of life associated with varying ophthalmologic abnormalities. The specific goals of the study were to:

1. Develop and evaluate a quality of life survey questionnaire based on the VF-14 form,[5] but incorporate features that other investigators have found to be of importance as well.[6,10]
2. Measure patient preference-based utility values associated with varying degrees of visual loss.
3. Ascertain whether factors such as patient age, sex, race, education level, time of visual loss, and underlying disease responsible for the visual loss significantly affect mean utility values associated with visual loss.

METHODS AND MATERIALS

STUDY POPULATION AND SETTINGS

Consecutive patients of the author with:

1. Visual loss to a level of 20/40 or worse in at least 1 eye.
2. Visual loss occurring predominantly secondary to the same cause in each eye when the visual loss was bilateral, were selected for entrance into the study group.

The patients were predominantly from a population with vitreoretinal diseases seen in a hospital outpatient setting as well as in peripheral offices. Since many of the patients had more than 1 cause for visual loss (eg, cataract and age-related macular degeneration, glaucoma and age-related macular), only patients who had, in the judgment of the examiner, at least 80% of their visual loss in an eye occurring secondary to one specific ocular disease entity were included. Questionable cases in this regard were excluded. In instances in which there was doubt due to concomitant cataract and a posterior segment abnormality, a potential acuity meter reading was obtained. If the vision could be improved by greater than 20% (eg, from 20/100 to 20/80, a 25% improvement), the patient was excluded.

A vision of 20/40 or less in at least 1 eye was selected as an entrance criterion, because previous focus group data had revealed that patients who have essentially normal vision in each eye have a visual utility value approaching 1.0. They are most often unwilling to trade time or risk immediate death in return for essentially no improvement in vision.[20]

Most ocular abnormalities causing visual loss, such as cataract, retinal vein obstruction, macular hole, macular edema and diabetic retinopathy were readily apparent. Patients were defined as having age-related macular degeneration if the fundus demonstrated macular drusen in conjunction with retinal pigment epithelial abnormalities. If there was choroidal neovascularization or its sequelae in one eye only, drusen and retinal pigment epithelial abnormalities were required to be present in the second eye. Patients with bilateral disciform scars were presumed to have the pathology occurring on the basis of age-related macular degeneration. The presence of macular drusen in this latter group was not required, since they are often not visible in the presence of a large disciform scar.

Patients were also judged by their ability to respond to a series of complex questions in a coherent fashion. If they were unwilling or were unable, despite repeated explanations, to understand the questions, they were excluded. Those with Alzheimer's disease or other forms of dementia were excluded as well.

DATA COLLECTION

Each person underwent a complete ophthalmoscopic examination, which included best-corrected Snellen visual acuity, applanation tonometry, slitlamp biomicroscopy, and dilated fundus examination with both indirect ophthalmoscopy and biomicroscopic evaluation. In those situations in which the visual acuity was improved with a pinhole beyond the best-corrected visual acuity, the pinhole vision was selected as the best visual acuity in the eye under study. This rationale was undertaken because people often squint to improve vision; thus, it was believed that the pinhole vision was more accurate in representing the actual visual potential in a real-world setting.

Snellen visual acuity was selected as the method of visual assessment because it is the most commonly used system in clinical practice, and it was the objective of the study to simulate real-life situations as closely as possible. For the purpose of evaluation of the data, Snellen acuities were converted to the decimal system according to the visual angle subtended by the letters (eg, 20/20 = 1, 20/25 = 0.8, 20/30 = .67, 20 40 = .5, 20 50 = .4, 20/400 = .05). For those visions less than could be measured on the visual acuity chart, a value of 20/800 (.025) was assigned to a vision of counting fingers, while a value of 20/1600 (.0125) was assigned to an acuity of hand motions and a value of 20/3200 (.0062) was given to light perception. No light perception received a value of 0.0

Demographic information, including age, sex, race, and highest level of formal education, was also obtained. The length of time of visual loss to the present level was ascertained as well.

The purpose of the study was explained to patients eligible for participation, who were then asked if they would be willing to answer difficult questions related to their quality of life. The questions were administered by the author using a standard protocol (Appendix) that employed a questionnaire including 3 distinct parts:

1. An evaluation of the general medical status of the patient. Multiple questions involving different organ systems were included. Each positive answer was assigned 1 point, and the total number of points were added to give a measurement index related to the number of serious, systemic medical diseases the patient had.

2. An evaluation of quality of life as measured by a series of questions similar to those on the VF-14 form.[5] The VF-14 form evaluates the ability of a patient with visual loss to function in the activities of daily life. It is not as complete, however, as some investigators would prefer it to be.[6,10] The form used in the present study was therefore changed by including questions that also evaluated the degree of disability caused by ocular pain (See Appendix, Part II. Visual Health, question 19) as well as that caused by depression and frustration (See

Appendix, Part II. Visual Health, questions 14 and 15). An overall subjective evaluation of the degree to which visual loss has decreased quality of life was also included (See Appendix, Part II. Visual Health, question 16).

The form included 10 questions (1-5, 7,9,10,13,18) that evaluated primarily activities that could be readily performed with uniocular vision and 12 questions (6,8,11,12,14-17, 19-22) concerning activities that were thought to be best performed with binocular vision. Eleven questions (1-3,6,9,12,13,19-22) were concerned with primarily basic activities for functioning in life, such as reading and driving, 5 questions (4,5,10,11,18) involved primarily social issues, such as interacting with friends, 3 questions (14-16) involved emotional or psychosocial issues associated with visual loss, and 3 (7,8,17) concerned issues believe to be primarily associated with activities of employment. These classifications are arbitrary, and there is certainly overlap among the categories.

Each question had 6 possible answers, with the last being "not applicable." When the question was not applicable to the patient, it was deleted from the scoring system. When the answer was No. 1 (the visual status did not affect an activity or function), a score of 4.0 was given for that question. If No. 2 was answered (the visual function mildly impaired an activity), a score of 3.0 was given. For No. 3 (moderate impairment), a score of 2.0 was given, and for No. 4 (severe impairment), a score of 1.0 was applied. If the patient was unable to function at all because of the vision, a score of 0.0 was given. The scores of the applicable questions were then averaged and multiplied by 25 to give a final score.

3. Use of the time trade-off and the standard gamble methods for evaluating utility values.[20, 26-30] The time trade-off method of utility evalu ation initially involves asking a person how many years he or she expects to live. The person is then asked how many of those remaining years–if any–he or she would be willing to give up, or trade, in return for a perfect health state. In essence, the person is being asked to trade time of life for quality of life. The utility value itself is then calculated by subtracting the proportion of years traded from 1.0. As an example, a person with 20 theoretical remaining years of life who is willing to trade 8 of those years in return for a perfect health state would have a utility value of 1.0 – 8/20, or 1.0 – 0.4 = 0.6.

With the standard gamble method of utility evaluation, a person is given the scenario that a treatment, when it works, always restores him or her to a perfect health state. The alternative, however, is immediate death (eg, under anesthesia) when the treatment fails. The patient is then asked how high a risk of death (in percent) he or she would be willing to assume–if any–before refusing the treatment. The utility value is calculated by subtracting the highest risk the individual is willing to assume from 1.0. As an example, a person who is willing to assume up to a 40% risk of dying before refusing a treatment would have a utility value of 1.0–0.4 = 0.6.

STATISTICAL METHODS

The patients were divided into groups according to the visual acuity in the worst-seeing eye and the better-seeing eye. The means, standard deviations, and 95% confidence intervals were calculated for pertinent variables.

A paired, two-tailed, Student's *t* test was used to compare mean utility values using the time trade-off and standard gamble methods within visual acuity groups. A heteroscedastic, unpaired two-tailed Student's *t* test was used to compare the utility means of the time trade-off values of the total sample of 325 patients in regard to educational level, sex, race, age, and length of time of visual loss to the present degree. The x^2 test for independence was used to compare numbers of patients trading time or risking death in the time trade-off and standard gamble groups respectively, and multivariate linear regression analysis was performed to assess the correlation of visual acuity with utility values and confounding variables.

RESULTS

Approximately 2,000 patients were screened over a 6 month period to obtain 350 who met the criteria for inclusion into the study. Among the 350 patients, 25 were unwilling or unable to answer the questions posed in the questionnaire (Appendix). Thus, a total of 325 subjects were included in the data reported herein.

Included among the 325 subjects were 120 men and 205 women. There were 313 Caucasians and 12 African Americans. The mean age was 67.5 years, with an age range from 28 years to 87 years. The median age was 70 years. The mean number of years of formal education after kindergarten was 13.2 years, with a range from 3 years to 25 years. The median number of years of formal education after kindergarten was 12.

The disease entities responsible for visual loss are listed in Table I. The most common causes of visual loss in this predominantly vitreoretinal patient population were age-related macular degeneration and diabetic retinopathy, but numerous other ocular disease entities were included. Among those with diabetic retinopathy, 51 of 107 patients (48%) had proliferative disease with high-risk characteristics requiring previous panretinal photocoagulation in both eyes.

VISUAL HEALTH QUESTIONNAIRE RESULTS

The values for the 22 questions were correlated with the visual acuity in the better eye for the group of 325 subjects. The results are shown in Table II. When the visual acuity in the better eye was 20/20, the average patient registered a total score of 91.5, while for a vision in the hand motions to no light perception range in the better eye, the total mean score was 15.4. As each visual acuity level decreased, the corresponding score on the visual function test score decreased as well across all levels.

The greatest absolute decreases in total mean score occurred when the vision in the better eye dropped from the 20/50 level (mean score of 72) to the 20/70 level (mean score of 60.1), from 20/70 (mean score of 60.1) to 20/100 (mean score of 46.7) and counting fingers (mean score of 26.3) to hand motions/light perception (mean score of 15.4).

The scores were also correlated with the visual acuity in the eye with the poorest vision. The results are shown in Table III. Since each person in the total study group had 20/40 vision or worse in the poorer seeing eye, the 20/20/ 20/25 and 20/30 groups are absent in this analysis. The absolute

TABLE I: PRIMARY CAUSES OF DECREASED VISION IN THE 325 PATIENTS

CAUSE	NO. %
Age-related macular degeneration	107 (33)
Diabetic retinopathy	107 (33)
Retinal detachment	27 (7)
Retinal vein obstruction	26 (7)
Cataract	23 (7)
Macular hole	7 (2)
Amblyopia	6 (2)
Macular edema	5 2)
Glaucoma	4 (1)
Macular pucker	4 (1)
Endophthalmitis	3 (1)
Parafoveal telangiectasis	2 (1)
Anterior ischemic optic neuropathy	2 (1)
X-linked retinoschisis	1 (1)
Trauma	1 (1)
Total	325 (100%)

TABLE II: RESULTS OF THE VISUAL FUNCTION QUESTIONNAIRE CLASSIFIED ACCORDING TO THE VISUAL ACUITY IN THE BETTER-SEEING EYE

VISUAL ACUITY	FUNCTION RESULT	SD	95% CI
20/20 (n=32)	91.5	8.6.	88.5-94.5
20/25 (n=50)	88.3	11.6	85.2-91.5
20/30 (n=44)	83.9	15.4	79.4-88.4
20/40 (n=54)	78.6	18.0	73.7-83.5
20/50 (n=31)	72.0	17.3	65.9-78.1
20/70 (n=40)	60.1	17.6	54.6-65.6
20/100 (n=18)	46.7	18.4	38.2-55.2
20/200 (n=16)	43.6	11.3	38.1-49.1
20/300 (n=13)	35.6	13.4	28.3-42.9
20/400 (n=9)	31.6	13.6	22.2-41.0
CF (n=12)	26.3	17.0	16.6-35.9
HM-NLP (n=6)	15.4	8.6	8.5-22.3

CF, counting fingers, HM, hand motions, LP, light perception; n,number of patients in subgroup

range of function values was substantially less in this group, ranging from 44.8 when the vision in the poorer eye was hand motions/light perception to 70.6 when the vision in the poorer seeing eye was 20/50. Additionally, while there was a trend for visual function values to decrease as the vision decreased, there was no direct and consistent correlation between Snellen

TABLE III: RESULTS OF THE VISUAL FUNCTION QUESTIONNAIRE CLASSIFIED ACCORDING TO THE VISUAL ACUITY IN THE POORER-SEEING EYE

VISUAL ACUITY	FUNCTION RESULT	SD	95% CI
20/40 (n=29)	67.9	18.1	61.2-74.6
20/50 (n=19)	70.6	17.1	62.7-78.5
20/70 (n=37)	66.7	18.0	60.9-72.5
20/100 (n=23)	53.1	16.3	46.3-59.9
20/200 (n=45)	53.4	21.9	46.9-59.9
20/300 (n=22)	50.0	22.3	40.5-59.5
20/400 (n=22)	50.9	25.6	40.0-61.8
CF (n=82)	46.0	20.9	41.4-50.6
HM-LP (n=29)	44.8	22.5	36.5-53.1
NLP (n=17)	45.2	21.8	37.0-53.4

CF, counting fingers, HM, hand motions, LP, light perception, n, number of patients in subgroup; NLP, no light perception).

visual acuity and visual function value. As examples, the mean function value of 45.2 in the no light perception group exceeded the mean value of 44.8 in the hand motions light perception group, the opposite of what might be expected. For the 20/40 group, the mean function value was 67.9, less than that of 70.6 in the 20/50 group.

UTILITY VALUES

Utilities Classified According to Vision in the Worst-Seeing Eye

There were 78 patients with good vision (20/20 to 20/25) in 1 eye. These 78 patients were subdivided, according to the visual acuity in the eye with the worst vision, into the following groups: 20/40 to 20/50, 20/70 to 20/100, 20/200 to 20/400, counting fingers to light perception, and no light perception. A summary of the time trade-off and standard gamble utilities found for each of these visual subgroups is shown in Table IV.

There was no discernible correlation between visual acuity in the worst-seeing eye and mean utility values of the 5 visual subgroups using either the time trade-off or standard gamble methods. With the time trade-off method, the group with 20/40 to 20/50 vision in the better eye had a mean utility value of .86 (95% confidence interval, [CI] .78-.94), while those with no light perception in the worst had a mean utility value of .81 (95% CI, .67-.95). The difference between these 2 subgroups was not significant (P=.70) with the heteroscedastic, two-tailed Student's t test). With the standard gamble method, the mean utility value for the

TABLE IV: UTILITY VALUES ASSOCIATED WITH VISUAL ACUITY IN THE WORST-SEEING EYE

VISUAL ACUITY	TIME TRADE-OFF	STANDARD GAMBLE
20/40-20/50	.86 (CI, .78-.94)	.93 (CI, .87-.99)
(n=18)	(SD = .18)	(SD = .13)
20/70-20/100	.90 (CI, .83-.97)	.96 (CI, .93-.99)
(n=12)	(SD = .16)	(SD = .05)
20/200-20/400	.95 (CI, .88-1.00)	.94 (CI, .87-1.00)
(n=13)	(SD = .12)	(SD = .13)
CF- LP	.88 (CI, .81-.95)	.92 (CI, .87-.97)
(n=28)	(SD = .18)	(SD = .14)
NLP	.81 (CI, .67-.95)	.95 (CI, .89-1.00)
(n=7)	(SD = .19)	(SD = .08

CF, counting fingers; LP, light perception; n, number of patients in subgroup; NLP, no light perception.

group with 20/40 to 20/50 vision in the worst eye was .93 (95% CI, .87-.99), while for those with no light perception in the worst eye it was .95 (95% CI, .87-1.00). This difference in the standard gamble subgroups was again not significant (*P*=.65).

Because of the lack of correlation between vision in the worst-seeing eye and mean visual subgroup utility values, the remainder of the relationships in this study were undertaken using the visual acuity in the better-seeing eye for visual classification.

Utilities Classified According to Vision in the Better-Seeing Eye

The utility values obtained when all of the 325 patients were stratified according to the visual acuity in the better eye are shown in Table V. The utility values shown were correlated with 12 different visual stratifications (20/20, 20/25, 20/30, 20/40, 20/50, 20/70, 20/100, 20/200, 20/300, 20/400, counting fingers, and hand motions to no light perception). There was only 1 patient with no light perception vision in both eyes.

Using the time trade-off method, the mean utility values ranged from .92 with 20/20 vision in the better eye to .35 when the vision was in the hand motions to no light perception range in the better eye. Of note is the fact that as the visual acuity in the better eye decreased, the corresponding time trade-off utility value concomitantly decreased at every visual stratification level. The most dramatic decreases in mean utility values occurred when the vision changed from 20/70 to 20/100 (a -0.07 utility change), from 20/300 to 20/400 (a -0.09 utility change), and from counting fingers to hand motions/light perception (a -0.17 utility change).

Utility values obtained with the standard gamble method also generally decreased as the vision in the better eye worsened, but the decrease was not as direct and consistent as with the time trade-off method. At the 20/20 level the mean utility value was 0.96, while at the hand motions to counting fingers range it dropped to 0.49.

Time Trade-off Versus Standard Gamble Utilities

In the time trade-off group, 201 (62%) of 325 of patients were willing to trade time of life in return for normal vision, while in the standard gamble group, 171 (53%) of 325 patients were willing to assume some risk of immediate death. This difference between the numbers of patients willing to trade time or risk death respectively with each of the methods was significant using the x^2 test statistic for independence (*P*=.02, df=1, x^2=5.66).

As the vision in the better eye worsened, the likelihood of the time trade-off patients to trade time in return for improved quality of life

TABLE V: UTILITY VALUES ASSOCIATED WITH VISUAL ACUITY IN THE BETTER-SEEING EYE

VISUAL ACUITY	TIME TRADE-OFF	STANDARD GAMBLE	*P*
20/20 (n=32)	.92 (CI, .87-.97) (SD = .13)	.96 (CI, .94-.98) (SD = .06)	.02
20/25 (n=50)	.87 (CI, .82-.92) (SD = .19)	.92 (CI, .88-.96) (SD = .15)	.01
20/30 (n=44)	.84 (CI, .79-.89) (SD = .19)	.91 (CI, .86-.96) (SD = .18)	.03
20/40 (n=54)	.80 (CI, .74-.86) (SD = .22)	.89 (CI, .84-.94) (SD = .17)	.003
20/50 (n=31)	.77 (CI, .70-.84) (SD = .20)	.83 (CI, .75-.91) (SD = .15)	.15
20/70 (n=40)	.74 (CI, .67-.81) (SD = .21)	.80 (CI, .72-.88) (SD = .25)	.12
20/100 (n=18)	.67 (CI, .57-.77) (SD = .21)	.82 (CI, .72-.82) (SD = .22)	.002
20/200 (n=16)	.66 (CI, .55-.77) (SD = .23)	.80 (CI, .70-.90) (SD = .21)	.004
20/300 (n=13)	.63 (CI, .54-.72) (SD = .16)	.78 (CI, .67-.89) (SD = .21)	.01
20/400 (n=9)	.54 (CI, .43-.65) (SD = .17)	.59 (CI, .47-.71) (SD = .19)	.40
CF (n=12)	.52 (CI, .36-.68) (SD = .29)	.65 (CI, .50-.80) (SD = .26)	.02
HM-NLP (n=6)	.35 (CI, .10-.60) (SD = .29)	.49 (CI, .17-.81) (SD = .37)	.43
Overall (n=325)	.77 (CI, .75-.79) (SD = .23)	.85 (CI, .83-.87) (SD = .21)	< .001

CF, counting fingers; CI, 95% confidence interval; HM, hand motions; n, number of patients in visual straification group; NLP, no light perception; °*P*, value compares the mean utility values obtained using the time trade-off and standard gamble methods using the paired, two-tailed, Student's *t* test.

increased. Among the 18 patients with counting fingers or worse vision in the better eye, 16 of 18 (89%) were willing to trade time for normal vision. In contrast, in the group with 20/20 to 20/25 vision in the better eye, only 35 (43%) of 81 were willing to trade time. In the standard gamble group, 14 (78%) of 18 of patients with counting fingers or worse vision in the better eye were willing to assume some risk of immediate death, while only 32 (40%) of 81 were willing to do so when the vision in the better eye was 20/20 to 20/25. The numbers of patients willing to trade time or risk death in the various visual stratifications are shown in Table VI.

The overall mean time trade-off utility value for the groups of 325 patients was 0.77 (SD =.23, 95% CI = .02). For the standard gamble method, the mean overall utility value for the 325 patients was .85 (SD = .21, 95% CI = .02). When the 2 groups were compared using the paired, two-tailed Student's *t* test, the difference between the means was highly significant (P<.001).

A further comparison of the mean utility values obtained with the time trade-off and standard gamble methods, however, reveals that at every visual stratification level, the value was lower for the time trade-off method than for the standard gamble method. The utility value means of the time trade-off and standard gamble methods were also significantly different in 8 of the 12 visual acuity stratifications (Table V). There was not a significant difference between the mean utility values using the two methods at the 20/50, 20/70, 20/400 and hand motions to no light perception levels.

As noted, the mean time trade-off and standard gamble utility values differed significantly. Since it was the impression of the author, however, that subjects comprehended the time trade-off concepts substantially better than the standard gamble concept, the following comparisons in this paper are made using predominantly the time trade-off method.

Utility Values From Different Ocular Diseases

Utility values obtained from different disease entities were compared using the unpaired, two-tailed, heteroscedastic Student's *t* test. The results are shown in Table VII. There was no significant difference between the mean utility values of 4 of 5 visual strata for the age-related macular degeneration and diabetic retinopathy groups (Table VIIA). For the 20/60 to 20/100 group, however, there was a significant difference between the means (P=.01).

When the mean utilities of cataract patients were compared to those of

TABLE VI. PATIENTS WILLING TO TRADE TIME FOR IMPROVED VISION (TTO METHOD) AND RISK IMMEDIATE DEATH FOR IMPROVED VISION (SG METHOD)

VISION	TTO METHOD	SG METHOD
CF-NLP	16/18 (89%)	14/18 (78%)
20/200-20/400	36/38 (95%)	26/38 (67%)
20/70-20/100	47/60 (78%)	37/60 (62%)
20/30-20/50	77/128 (60%)	62/128 (47%)
20/20-20/25	35/81 (43%)	32/81 (40%)

CF, counting fingers; NLP, no light perception; SG, standard gamble; TTO, time trade-off.

both the age-related macular degeneration and diabetic retinopathy groups, there was no significant difference at any of the visual stratification levels measured (Table VIIB). It should be noted, however, that insufficient numbers of cataract patients were available to allow meaningful comparisons at the 20/200 to 20/400 and counting fingers to hand motions levels.

Age and Utility Values

The patients were arbitrarily divided into groups of those 80 years of age and older and those who were less than 80 years of age. Forty-two patients were 80 years or older. The mean age for this group was 82.9 years (SD=2.4; 95% CI, 82.2-83.6) and the age range was 80 to 89 years. The mean time trade-off utility value for those 80 years and older was 0.74 (SD=.27; 95% CI, .66-.82)

Among 283 patients who were less than 80 years of age, the mean age was 65.2 years (SD=1.0; 95% CI, .63.9-66.5), with a range of 28 years to 79 years. The mean time trade-off utility value for this group was 0.77 (SD=.22; 95% CI, .74-.80). The difference in mean utility values between the group >80 years and that <80 years was not significant with the heteroscedastic, two-tailed *t* test (*P*=.38).

Among the total group of 325 patients, there were 31 patients who were under the age of 50 years, with a range from 28 years to 49 years. The mean age for this subgroup was 41.6 years (SD = 5.1; 95% CI, 39.8-43.4). The mean utility value for this subgroup was 0.83 (SD = .22; 95% CI, .75-.91). When this younger group was compared to the oldest group of patients 80 years of age and older, the difference in the mean utility values was not significant (*P*=.12).

TABLE VIIA. A COMPARISON OF TIME TRADE-OFF UTILITY VALUES FROM·ARMD AND DIABETIC RETINOPATHY

VISION*	ARMD	DIAB RET	*P* VALUE†
20/20-20/25	.86	.84	.77
20/30-20/50	.79	.78	.61
20/70-20/100	.62	.78	.01
20/200-20/400	.58	.66	. 21
CF-LP	.47	.54	.68

ARMD, age-related macular degeneration; Diab Ret, diabetic retinopathy.

* Visual acuity in best-seeing eye.

†*P* value compares the means of utility values using the unpaired, two tailed, heteroscedastic Student's *t* test)

TABLE VIIB: A COMPARISON OF TIME TRADE-OFF UTILITY VALUES FROM CATARACT AND ARMD AS WELL AS CATARACT AND DIABETIC RETINOPATHY

VISION	ARMD	P†1	CATARACT	P‡2	DIAB RET
20/20-20/25	.86	.15	.93	.14	.84
20/30-20/50	.79	.19	.89	.09	.78
20/70-20/100	.62	.47	.71	.57	.78
20/200-20/400	.58	----	IN	----	.66
CF – HM	.47	----	IN	----	.54

ARMD, age-related macular degeneration; Diab Ret, diabetic retinopathy; IN, insufficient numbers

° Visual acuity in best-seeing eye.

† P^1 Values of the ARMD and cataract groups using the unpaired, two tailed, heteroscedastic Student's *t* test.

‡ P^2 Compares the mean utility values of the cataract and diabetic retinopathy groups using the unpaired, two tailed, heteroscedastic Student's *t* test.

A summary of the age groups and their respective time trade-off utility values is shown in Table VIII.

Education Level and Utility Values

When the total group of 325 patients was subdivided into those who had completed 12 years or less of formal education after kindergarten versus those who had completed greater than 12 years of formal education, there were 187 patients in the former category and 138 in the latter.

Among the 187 patients with 12 years of formal education of less, the mean number of years was 11.1 (SD=1.6; 95% CI, 10.9-11.3), with a range of 3 years to 12 years. The mean time trade-off utility value for this group

TABLE VIII: TIME TRADE-OFF UTILITIES AMONG DIFFERENT AGE GROUPS

AGE (YR)	UTILITY°	SD	95% CI
≤ 50 (n=31)	.83	.22	.75 - .91
≤ 80 (n=283)	.77	.22	.74 - .80
≥ 80 (n=42)	.74	.27	.66 - .82

° A comparison of utility value means of the ≥80 group with the ≤80 group using the two-tailed heteroscedastic Student's *t* test reveals no significant difference (P=.38). A comparison of the utility value means of the ≥80 group with ≤50 group also reveals no significant difference (P=.12).

was 0.75 (SD=.23; 95% CI, .72-.78).

In the group of patients with more than 12 years of formal education, the mean number of years of education was 16.0 (SD=2.4; 95% CI, 15.6-16.4), with a range of 12.5 years to 25 years. The mean time trade-off utility value for this group was .79 (SD=.23; CI, .75-.83).

When the mean utility values of the group with 12 years or less of education and the group with more than 12 years of education were compared using the homoscedastic, two-tailed *t* test, no significant difference (P=.14) was found. A summary of the education level groups and their respective, mean, time trade-off utility values is shown in Table IX.

Time of Visual Loss and Utility Values

Separation of the 325 patients according to the time of visual loss to the level present at the time the study questionnaire was administered revealed that 139 patients had visual loss for 1 year or less and 186 patients had visual loss for more than 1 year . Sixty patients had visual loss for 5 years or more (≥ 5 years). A summary of mean time trade-off utility values correlated with the length of time of visual loss is shown in Table X.

The mean number of years of visual loss in the ≤1 year group was 0.60 (SD=.3; 95% CI, .55-.65), with a range from 1 week to 1 year. The mean time trade-off utility value for this group was 0.76 (SD=.24; 95% CI, .72-.80).

The mean number of years of visual loss in the ≤ 1 year group was 4.7 (SD=6.0; 95% CI, 3.8–5.6), with a range of 15 months to 60 years. The mean time trade-off utility value for this group was 0.78 (SD=.22; 95% CI, .75-.81).

The mean number of years of visual loss in the ≥5 year group was 9.4 (SD=9.0; 95% CI, 7.1–11.7), with a range of 5 years to 60 years. The mean time trade-off utility value for this group was 0.80 (SD=.19; 95% CI, .75-.85).

A comparison of utility mean values using the heteroscedastic, two-tailed *t* test revealed no significant difference between the ≤1 year group

TABLE IX: TIME TRADE-OFF UTILITY VALUES AMONG DIFFERENT EDUCATION LEVEL GROUPS*

LEVEL OF EDUCATION	UTILITY	SD	95% CI
<12 years (n=187)	.75	.23	.72 - .78
>12 years (n=138)	.79	.23	.75 - .83

*P=.14, indicating no significant difference between the mean utility values of the two groups using the homoscedastic, two-tailed Student's *t* test.

TABLE X: TIME TRADE-OFF UTILITY VALUES AND LENGTH OF TIME OF DECREASED VISION

TIME OF VISUAL LOSS	UTILITY*	SD	95% CI
≤ 1 year (n=139)	.76	.24	.72 - .80
>1 year (n=186)	.78	.22	.75 - .81
> 5 years (n=60)	.80	.19	.75 - .85

*A comparison of utility value means of the ≤1 year group with the ≥1 year group using the two-tailed heteroscedastic Student's t test reveals no significant difference (*P*=.34). A comparison of the utility value means of the ≤1 year group with ≥5 year group also reveals no significant difference (*P*=.22).

and the >1 years group (*P*=.34). A similar comparison between the means of the ≤1 year group and the >5 year group also showed no significant difference (*P*=.22)

Sex, Race and Utility Values

Among the 205 women, the mean utility value was .77 (SD=.22; 95% CI, .74-.80), while in the group of 120 men, the mean utility value was also .77 (SD=.24; 95% CI, .73-.81). There was no significant difference between the mean utility values in regard to sex (*P*=.87).

Among the 313 Caucasians, the mean utility value was .77 (SD=.23; 95% CI, .74-.80), while in the group of 12 African Americans the mean utility value was .80 (SD=.17; 95% CI, .70-.90). There was no significant difference between the means of these two groups (*P*=.48).

Multivariate Regression Analysis and Time Trade-off Utility Values

Data from the first 237 patients entered in the study were examined using multiple regression analysis. The results have been summarized elsewhere as well.[30] A significant relationship was noted between mean time trade-off utility values and decreasing visual acuity in the better eye (F value = 12.1; $P<.0001$), but there was none between mean utility values and age (*P*=.21), education level (*P*=.14), duration of visual loss (.07), the number of comorbid systemic diseases (*P*= .64), or patient perception of overall health (*P*=.52).

A simple linear regression model has been developed from these same data. The equation is as follows:

$$\text{Utility value} = .37\ (\text{Va}) + .514$$

In this equation, Va = the Snellen visual acuity, in decimal form, in the better-seeing eye. The coefficient of determination for this model was found to be .2255.

DISCUSSION

Conventionally, the results of the vast majority of clinical studies, including prospective randomized trials,[2-4,31-36] involving ophthalmologic patients have concentrated primarily on visual acuity as the parameter to determine whether an interventional treatment is of benefit or not. In many instances, the visual acuity has been measured using the conventional Snellen visual acuity chart, while in others a logMAR chart has been employed.[1] While visual acuity measurement gives an objective clinical number, the relationship of these numbers to quality of life has been studied superficially at best.

Measurements of quality of life issues are becoming increasingly important and prevalent in the medical literature.[5-25] Of particular importance are those tools that allow the incorporation of patient preferences.[23-25] While quality of life can also be measured by physicians, administrators, the general public, or others, their measures often differ from patient preferences.[29,37-39]

I. VISUAL FUNCTION TEST RESULTS

The data in the present study show that the modified VF-14 mean results decrease as the visual acuity in the better eye decreases. While there is a trend toward a decrease in visual function results when the visual acuity in the worst-seeing eye is used, the trend is not linear, and results are inconsistent and unpredictable. As has been previously found with the VF-14,[5] the results appear to be most predictable when the visual acuity in the better-seeing eye is compared with the visual function scores.

The decreases in visual function score results were most dramatic when the vision in the better eye dropped from 20/70 to 20/100 (a loss of 14 points) and from counting fingers to hand motions/light perception (a loss of 11 points). This most likely occurred because the drop from 20/70 to 20/100 makes reading and driving substantially more difficult; both are activities greatly valued by most patients. Similarly, the change from counting fingers to the hand motions/light perception range is probably also important because of the increased difficulty with general navigation that occurs when vision drops to the latter visual level.

While the modified VF-14 study used in the present analysis demonstrated a correlation between vision in the better eye and test results, these results remain unique to ophthalmic disease. They cannot be compared with quality of life results obtained with systemic abnormalities such as cardiac diseases, arthritis, and pulmonary diseases.[40,41] In essence, as has been noted, one may be looking at apples and oranges when comparing quality of life studies that are organ or system specific with those of other systems.[42,43]

II. UTILITY VALUE RESULTS

Utility values provide a direct reflection of the ability of a patient to function in the activities of everyday living and thus provide a measure of the quality of life associated with a health state.[15-18] Those health states with a utility close to 1.0 are associated with a greater ability to function in life's everyday activities, and thus a higher quality of life. As the utility value decreases, so does the quality of life. A sample of utility values that have been obtained for various health states is shown in Table XI.

It should be noted, however, that both time trade-off and standard gamble utility values appear to be most effective for the assessment of chronic disease entities, rather than acute disease states such as pneumonia or sepsis.[15-18,44] Other methods of measurement, such as the willingness to pay, have been developed to deal with more acute diseases.[40,45,46]

The majority of patients are able to effectively answer questions related to utility values. In the present study, 25 (7%) of 350 patients were unable to effectively answer time trade-off and standard gamble utility questions. This percentage is very similar to the 9.6% failure rate noted by

TABLE XI: UTILITY VALUES ASSOCIATED WITH DIFFERENT HEALTH STATES

HEALTH STATE	UTILITY VALUE
Perfect health	1.00
Life with menopausal symptoms[16]	.99
Mild angina[16]	.90
Kidney transplant[16]	.84
Mild stroke state[22,43]	.75
Moderate angina[16]	.70
Home dialysis[16]	.64
Severe angina[16]	.50
Severe depression[16]	.45
Moderate stroke state[22,43]	.39
Bilateral no light perception[27]	.26
Severe stroke state[22,43]	.12
Death	.00

Nease and associates[47] for the same task.

Utility measurement has 2 major advantages over other measures of quality of life:

1. It obviates the problem of comparing quality of life parameters across different specialties.
2. It theoretically takes all confounding factors associated with a disease into account.

Thus, in regard to the first point, the degree of impairment caused by an osteoarthritic hip can be readily compared to the degree of impairment induced by severe cataracts, dyspnea from chronic obstructive pulmonary disease, angina, or other pathologic entities. While there are scales that evaluate disability induced by specific disease entities,[5,12,13,48-50] they are often not comparable with disease entities of other organ systems. This is particularly true of the VF-14.[5] In regard to the second point of taking into account all confounding factors associated with a health state, utility measurement gives an evaluation in its entirety of the degree of disability induced by a disease from the patient point of view. As per Feeny and Torrance,[51] it overcomes difficulties in interpreting results from more narrowly focused psychosocial measures of outcome. With analyses that ask multiple questions, there is always the possibility that areas of importance to the patient's quality of life may be overlooked. This is not the case with utility measurement. Every aspect associated with a disease (functional, social, psychologic, economic) is theoretically taken into account with utility evaluation. The forest itself is examined as a whole, rather than each individual tree.

Time Trade-off Versus Standard Gamble Methods

The standard gamble method has historically been considered the "gold standard" for utility measurement.[52-54] The overall difference in mean utility values in the present study was significantly different ($P<.001$) between the time trade-off and standard gamble methods, when utility values were correlated with vision in the better eye; subdivision of the total group of 325 patients according to visual acuity levels revealed a significant difference between the time trade-off and standard gamble methods for 8 of the12 visual subgroups. This difference in values between the time trade-off and standard gambles has been noted in the past.[52-55]

It is the opinion of the author that patients understand the time trade-off concept more readily than the standard gamble concept. Additionally, as was the case in this study, evidence has accumulated that the standard gamble method overestimates risk aversion.[52,56] At each visual acuity stratification in the present study (Table VI), a lesser percentage of patients was willing to risk death with the standard gamble scenario than trade time of life with the time trade-off scenario in return for perfect vision. Many people simply find the thought of instant death abhorrent and emotional. Despite the technique employed, it is important that the same technique of measurement (time trade-off or standard gamble) be used when comparing utility values among different health states.

Accordingly, it is also key that utility values be kept concordant in regard to the group polled. Utility values in the past have been obtained from patients, physicians, administrators, and the public.[16] It is the opinion of this author, as well as others, that patient preferences are the most important, because patients have experienced a disease and its sequelae firsthand,[23-25,42] In ophthalmology, it has been demonstrated that patient perceptions of their degree of loss of quality of life due to visual impairment differ dramatically from those of clinically active ophthalmologists.[29] At multiple visual acuity stratifications, patients with visual loss secondary to age-related macular degeneration have been demonstrated to have lower utility values than ophthalmologists would estimate, given the same level of visual loss. This discordance has also been demonstrated between physicians and their patients with psychiatric disorders,[38] multiple sclerosis,[39] and other disease.

The time trade-off method, when correlated with visual loss in the better eye, demonstrated a decrease in mean utility value for each of the 12 visual levels measured in the present study (Table VI). While there was also a decreasing trend with the standard gamble method, it was not as uniform as with the time trade-off method. Of note is the fact that mean utility values with the time trade-off method had the greatest decreases when the mean acuity in the better eye decreased from 20/70 to 20/100 (.07 utility points), 20/300 to 20/400 (.09 utility points), and counting fingers to hand motions/no light perception (.17 utility points). Concerning the drops from 20/70 to 20/100 and counting fingers to hand motions/no light perception, these data parallel those from the modified VF-14 function values. The change from 20/70 to 20/100 appears to be a crucial one, again probably since both reading and driving become substantially more difficult after a decrease from the former to the latter visual level. The dramatic change from counting fingers to hand motions/no light perception is again probably accounted for by considerably increased problems with navigation when vision drops from the former to the latter level. The drop in mean utility value from the 20/300 to the 20/400 level is more difficult to explain; it may have to do again with decreased functioning related to general navigation, or perhaps to increased difficulty with reading, even with low vision aids.

Utility Values and Different Causes of Visual Loss

With the exception of the 20/70 to 20/100 visual subgroup comparing mean time trade-off utility values in patients with diabetic retinopathy and age-related macular degeneration, there was no significant difference between utility values at any available measured visual stratification level in patients with diabetic retinopathy, age-related macular degeneration, or cataract as the major cause of visual loss. This strongly suggests that utility values are much more dependent on the level of visual loss in the better-seeing eye than on the underlying ocular disease process itself. Thus, for example, loss to the 20/50 level in the better eye from any of these 3 diseases produces a similar utility value, or the same degree of difficulty in dealing with the daily activities of life.

While formal visual field testing was not obtained in these patients, almost one half (48%) of the diabetic retinopathy patients had had bilateral panretinal photocoagulation therapy for high-risk proliferative retinopathy. Because of the retinal capillary nonperfusion already associated with proliferative diabetic retinopathy, in addition to subsequent panretinal photocoagulation therapy, it is likely that most of these high-risk eyes had substantial impairment of the peripheral visual field.[57] Despite this loss of field, the utility values were not lower in the diabetic patients, as compared to the macular degeneration or cataract patients. This suggests that either peripheral visual field loss does not significantly affect utility values. On the other hand, it is possible that field loss does negatively affect utility values, but the central visual loss at similar visual levels with macular degeneration is more incapacitating that that due to diabetic retinopathy. Unfortunately, the present study cannot differentiate between these two possibilities. Analysis of utility values in glaucoma patients with visual field loss might provide such insight, but such data are not available from the present study.

Length of Time of Disease

Results suggest that the length of time of visual loss to the present level does not substantially affect mean utility values. There was no significant difference in mean utility values in this study among those who had had visual loss for 1 year or less, versus more than 1 year or more than or equal to 5 years. Intuitively, one might think that time would allow a better adaptation and less of an impairment of quality of life, but this did not appear to be the case.

One group that was not evaluated in this study, however, was that with visual loss from a very early age. It is quite possible that these patients, with no previous frame of reference other than their present degree of vision, might be less willing to trade time for better vision, and thus have a higher mean utility value than those with visual loss later in life.

Education Level

The level of formal education of the patients did not appear to affect mean utility value outcomes. Those patients with a high school education or less had a mean utility value that was not significantly different from those with greater than a high school education. While there appears to be little information on this aspect in the literature, it has been noted that difference in preferences between different social groups tends to be small.[58]

Age

Mean utility values did not appear to be dependent on age in the present study. There was no significant difference between mean utility values of those 80 years of age or older versus those who were younger than 80 or those who were 50 years old or younger. Similar to the case with utilities and level of education, little information is available on this topic, although Tsevat and associates[59] found that hospitalized patients who were 80 years or older were willing to give up 2.3 of each 12 remaining months (utility of .81) in return for perfect health. The patients in this group were hospitalized for multiple different reasons and thus are not comparable to a group with a more specific organ disease entity such as described herein. Additionally, it would be expected that a hospitalized population would have a bias toward more acute disease processes, thus perhaps leading to lower utility values than in an age-matched outpatient population. It is of note that the surviving patients of Tesvat and associates[59] traded less time at a later date when they were not hospitalized.

Other Confounding Variables

Male or female gender appeared to have no effect on utility values in the present study. The absence of a difference in patient preference between sexes has been previously noted using time trade-off utility analysis.[60] There also appeared to be no difference in mean utility values in regard to race, although it should be noted that there were only 12 African American patients in the present study group.

III. RELEVANCE OF UTILITY VALUES

Quality-Adjusted Life-Years (QALY's)

It has been written[15-18,61] that the purpose of interventional medical therapy is twofold:

1. To maintain or improve quality of life.
2. To maintain or improve length of life.

Measurement of utility of values addresses the aspect of quality of life, but not length of life or the time over which a change in quality of life exerts its effect. For this reason, the quality-adjusted life-year (QALY) was developed.[15-18,20,21]

Quality-adjusted life-years gained are derived by multiplying the utility value change from an intervention by the length of time over which that change has an effect.[15,26,61] For example, a patient with visual loss due to bilateral cataracts and 20/100 vision in the better eye theoretically has a utility value of 0.67 (Table V). If the vision is improved after surgery to 20/25, the utility value improves to 0.87. Thus, the improvement in utility is 0.20. If the patient has a life expectancy of 20 years and the benefit of the cataract surgery is expected to last for the entire 20 years, the number of QALYs gained from the treatment is 0.20 x 20, or 4.0. Some treatments might be expected to improve length of life alone, in which case the existing utility is multiplied by the number of years gained to yield the number of QALYs gained. An example would be repair of an acutely ruptured aortic aneurysm, which might extend life by 10 years. If both quality of life and length of life are improved, as might occur with coronary artery bypass surgery in which the time of life is lengthened and quality is improved by eliminating congestive heart failure and/or angina, the number of QALYs gained is determined by multiplying the total number of years of anticipated life added by the new utility value for that time. This number is then added to the product of the number of years of estimated life without the surgery, multiplied by the change in utility value conferred by the surgery.

Using the QALY method of incorporating utility values and the length of benefit of an interventional therapy, it can readily be seen that treatment of an infant with threshold retinopathy of prematurity with laser therapy could theoretically yield substantially more QALYs gained than treatment of an 80-year-old patient with exudative age-related macular degeneration.

Decision Analysis

Calculating the number of QALYs gained by a treatment is not as simple as one might expect. For example, after cataract surgery there are complications such as macular edema, posterior capsular opacification, retinal detachment, and endophthalmitis. Furthermore, the quality of the data used in the calculation of a treatment benefit is crucial. The highest quality of evidenced-based data,[62-65] such as prospective, randomized clinical trials[2-4] and meta-analyses,[66] should yield higher-quality, more reproducible information regarding the number of QALYs gained by a therapy than would anecdotal information

In regard to an interventional treatment result, decision analysis is of substantial benefit in ascertaining what is the most probable outcome of the treatment. Decision analysis takes into account the possible results, as well as the complications and probabilities of such, to arrive at the most probable outcome. In the cataract surgery situation, it factors in the incidences of postoperative macular edema, retinal detachment, endophthalmitis, and their respective utility results to yield a final utility value. In instances in which there is recurrent risk of complications or change in therapeutic effect, Markov theory can be employed to allow a more accurate analysis.[67]

Cost-Effectiveness

The final goal of using the highest-quality evidenced-based medical information in conjunction with patient-derived utility data and decision analysis is to amalgamate the benefit obtained by an interventional therapy with the costs associated with that therapy. The final result obtained is expressed in units of $/QALY (cost per quality-adjusted life-year). $/QALY is the common denominator that can be used to compare the cost-effectiveness of one therapy with another disparate therapy.[68-77]

It has been suggested that therapies which yield a $/QALY of less than $20,000 are very cost-effective, while those that yield a $/QALY of greater than $100,000 are probably not particular cost-effective.[71] Nevertheless, these values are quite arbitrary. It is important to appreciate that even if a therapy is expensive in nominal dollars, it may be very cost-effective if it substantially improves quality of life and/or length of life. A list of the $/QALY associated with various medical treatments is shown in Table XII.

It is important to remember that utility theory was developed in the form of an econometric model.[15,19] Inherent in this type of model is the time value of money. The time value of money, in particular, takes into account the fact that money spent on health care could have been earning additional money if it had been invested in another vehicle. Thus, a US dollar spent in 1999 will have more value than a US dollar spent in the year 2009. Costs are therefore discounted by a set rate to account for the changing value of money.[78-80] Alternatively, the number of QALYs themselves could be discounted to arrive at the same end result.[79,80]

There is controversy over the discount rate to employ, whether it be

TABLE XII: COST-EFFECTIVENESS OF THERAPEUTIC INTERVENTIONS ADJUSTED TO CONVERT NOMINAL COSTS TO 1998 REAL COSTS IN US DOLLARS

INTERVENTION	$/QALY*
Laser therapy for threshold ROP	$678[74]
Cryotherapy for threshold ROP	$1801[74]
Coronary artery bypass for left main coronary artery disease	$6,880[16]
Neonatal ICU treatment (1,000-1,499 birth weight)	$11,340[16]
Cochlear implant in deaf individual	$16,900[76]
Chemoprophylaxis after occupational exposure to HIV	$37,000[73]
Treatment of hypertension (diastolic 95-104mm Hg) in males, aged 40	$54,930[16]
Neonatal ICU treatment (500-999 birth weight)	$80,136[16]
Continuous ambulatory peritoneal dialysis	$85,250[16]
Liver transplant	$327,500[74]
Three day chemoprophylaxis for prosthetic joint patients during dental treatment	$1,350,000[77]

ICU, intensive care unit.
* $/QALY, dollars, or cost, per quality-adjusted life-year
All data are adjusted to 1998 US dollars comparing the mid-year consumer price index[78] from the year the study was performed to the mid-year consumer price index from 1998.

3%, 5%, or another rate.[68,72,74] More important than the actual percent of the discount rate is the point that, similar discount rates be used when comparing the results of one cost-effectiveness analysis to another.[68] Sensitivity analysis reveals that using a discount rate of 10%, instead of a discount rate of 3%, over a 20-year period of benefit from a therapy would yield a $/QALY that is 3.72 times greater for the10% rate. Furthermore, while quality of life can usually be discounted over the period during which it exerts its effect, increased time of life is more complex and must be discounted appropriately. For example, 5 years of life gained immediately from repair of a ruptured appendix costs less in nominal dollars, and should be discounted differently, than 5 years added on at the end of another 10 years of remaining life expectancy due to cessation of cigarette smoking. Some investigators[74] have also factored the Fisher equation[80] into the discounting process, therefore equating the nominal interest rate (R) to the sum of the expected inflation rate (i) and the real rate (r).

Methodology of Cost-Effective Analysis
Uniformity is an important aspect of cost-effective analysis. The type of cost-effectiveness system with utility values described here should employ uniform methods of data gathering to obtain valid utility values. The sug-

gestion has been made that different elicitation procedures for utility values may not be directly comparable,[81] and from experience in obtaining hundreds of utility values, this author agrees. Patient responses in regard to utility questions can be altered by using dissimilar interviewing styles.

Additionally, the method of utility evaluation (time trade-off, standard gamble, willingness to pay, or another) should be standardized as well when comparing cost-effective analyses. In the present study, there was generally a marked difference in utility values, with different levels of visual loss, obtained using the time trade-off and standard gamble methods on the same patients.

Patient preferences are an important factor as well. When possible, patient preferences are favored over those obtained from people who are not affected firsthand by the disease (or health) state itself.[23-25,68,82,83] One study suggests that there is a significant difference between utility values obtained from patients with a disease and those obtained by physicians who treat that disease.[29] Thus, cost-effectiveness studies are likely more comparable when utility values are derived from the same population. There is, however, a dearth of information available on the subject of comparison of utility values obtained from different groups.[83]

It would be desirable for the method of decision analysis to be uniform as well when comparing utility outcomes of different disease states. Of key importance also is the use of a standardized economic reference frame. Small changes in discount rates produce vastly different cost-effectiveness values. Therefore, a comparison of one study should include the same discount rate (or appropriate modifications to account for a discount rate discrepancy), currency exchange data if studies are compared across countries, and compensation for the rate of inflation if the studies are performed in different years.

The Future

A system that provides information on the cost-effectiveness of interventional therapeutic modalities would be of great value to many stakeholders in health care. It would allow patients, health care professionals, administrators, and others to objectively assess medical interventional therapies that take into account evidence-based medical data, patient preferences, and sound econometric principles. The common denominator of $/QALY allows such a comparison of disparate therapies.

Overall, highly effective clinical therapies should have a favorable $/QALY, while therapies that have marginally effective clinical benefit would likely have a high $/QALY. In essence, this type of information allows the health care consumer to have a more unbiased idea about what he or she is purchasing.

It should be emphasized that the system described here is in no way one that should be undertaken primarily for rationing. Rather, it should be viewed as a source of information for patients who desire reliable, objective data concerning therapeutic modalities. It favors those procedures that have a more beneficial effect on quality and/or time of life and points out those that have marginal clinical efficacy and need to be improved. With this system, there is the possibility of a rational framework that will allow health care dollars to be spent in the most efficacious manner, just as most individuals and society desire to do in fields other than medicine.

APPENDIX

VISUAL FUNCTION FORM

(Modified from the VF-14)[5]

Patient Name____

Sex__________________Age______________Race__________________

Occupation____

Highest level of education________________________________

Va: (best corrected) OD_____________ph___________

OS_____________ph__________

Anterior segment:	OD	OS
Cornea	__________________	___________________
Lens	__________________	___________________

(PSC, cortical change, or NS - grade each 0-4)

Fundus {if ARMD,
note size of scar
(in disc areas)}

Reason for
decreased vision 1° _________________ 1°_________________
(list % attributable 2°__________________ 2°_________________
to each cause) 3°__________________ 3°_________________

Length of time of decreased
vision to the present level __________________________

PART I - GENERAL HEALTH

Are you aware that you have any of the medical conditions listed below?

	(Circle 1 On Each Line)		
	Yes	No	Uncertain
I. Cardiovascular?			
a. High blood pressure (hypertension)?	1	2	3
b. Heart attack or angina (chest pain)?	1	2	3
c. Heart failure or enlarged heart?	1	2	3
d. Cardiac pacemaker?	1	2	3
e. Blood vessel bypass surgery?	1	2	3
f. Blocked peripheral blood vessels?	1	2	3
g. Amputation of an arm or leg?	1	2	3
II. Cancer?	1	2	3
a. If so, what kind? ______			
b. Is it still active? ______			
III. Diabetes?			
Type I	1	2	3
Type II	1	2	3
For how many years?______			
IV. Kidney or liver disease?	1	2	3
Are you on dialysis?	1	2	3
V. Gastrointestinal?			
a. Ulcer (duodenal, stomach,)?	1	2	3
b. Chronic inflamed bowel, enteritis, colitis?	1	2	3
VI. Respiratory ?			
a. Asthma or other serious lung problems, such as chronic bronchitis or emphysema?	1	2	3
VII. Musculoskeletal?			
a. Arthritis or rheumatism?	1	2	3
b. Back problems (including disk or spine)?	1	2	3

VIII. Neurological?			
a. Paralysis or neurologic problems, such as stroke, epilepsy, multiple sclerosis, or neuropathy?	1	2	3
b. Do you need assistance to walk?	1	2	3
c. Deafness or trouble hearing?	1	2	3
IX. Other major health problem?	1	2	3

Please specify______________________________

In general, would you say your overall health is:
(Circle one)

Excellent	1
Very Good	2
Good	3
Fair	4
Poor	5

How would you rate your overall health, on a scale where zero is worst possible health and 10 is best possible health?

(Circle One)

0	1	2	3	4	5	6	7	8	9	10
Worst										Best

PART II - VISUAL HEALTH

A. VISUAL FUNCTION QUESTIONNAIRE

All of the following questions assume you are using your best correct vision (with glasses, contact lenses, and/or low vision aids if necessary) (Not applicable = stopped doing for non-visual reasons, or not interested in doing)

1. Do you have any difficulty reading small print such as labels on medicine bottles, a telephone book, or stock market quotes?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

2. Do you have any difficulty reading a typical newspaper or a book?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

3. Do you have any difficulty reading a large-print book, a large-print newspaper or numbers on a telephone?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

4. Do you have any difficulty recognizing people when they are within 6 feet from you?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

5. Do you have difficulty recognizing people across the room (20 feet)?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to recognize them at all because of my eyesight
   f. Not applicable

6. Do you have any difficulty seeing steps, stairs, or curbs?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

7. Do you have any difficulty reading traffic signs, street signs, or store signs?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

8. Do you have any difficulty doing fine handwork like sewing, knitting, crocheting, carpentry?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

9. Do you have any difficulty writing checks?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity because of my eyesight
   f. Not applicable

10. Do you have any difficulty playing games such as bingo, dominos, or card games?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal
   e. Am unable to perform the activity at all because of my eyesight
   f. Not applicable

11. Do you have any difficulty taking part in sports like bowling, handball, tennis, golf?
   a. None
   b. A little
   c. A moderate amount
   d. A great deal

e. Am unable to perform the activity at all because of my eyesight
f. Not applicable

12. Do you have any difficulty cooking?
a. None
b. A little
c. A moderate amount
d. A great deal
e. Am unable to perform the activity at all because of my eyesight
f. Not applicable

13. Do you have any difficulty watching television?
a. None
b. 2. A little
c. A moderate amount
d. A great deal
e. Am unable to perform the activity at all because of my eyesight
f. Not applicable

14. Do you feel depressed about your vision?
a. No
b. A little
c. A moderate amount
d. A great deal
e. Am unable to perform most activities because of the depression about my vision
f. Not applicable

15. Are you frustrated by your vision?
a. No
b. A little
c. A moderate amount
d. A great deal
e. Am unable to perform most activities because of the frustration about my vision
f. Not applicable

16. Has your vision decreased your overall quality of life?
a. No
b. A little
c. A moderate amount

e. A great deal
f. Am unable to perform most activities because of my vision

17. Could you operate? Fine machinery (sewing machine) and/or heavy equipment (drill press, electric saw)
a. Yes
b. With a little difficulty
c. With moderate difficulty
d. With great difficulty
e. Not at all because of my eyesight
f. Not applicable

18. Because of your eyesight do you have difficulty in doing your normal activities with your family, friends, neighbors, or groups (including church)?
a. No
b. A little difficulty
c. Moderate difficulty
d. Great difficulty
e. Am unable to do the activities at all because of my eyesight
f. Not applicable.

19. Do your eyes cause you substantial pain or irritation?
a. None
b. A little
c. A moderate amount
d. A great deal
e. So much that I cannot perform most activities

20. How much difficulty do you have driving during the day because of your vision? (both 5 & 6 may be circled for this question)
a. None
b. A little difficulty
c. A moderate amount of difficulty
d. A great deal of difficulty?
e. Am unable to perform the activity at all because of my eyesight
f. Have never driven a car

21. How much difficulty do you have driving at night because of your vision? (both 5 & 6 may be circled for this question)
a. None

b. A little difficulty
c. A moderate amount of difficulty
d. A great deal of difficulty?
e. Am unable to perform the activity at all because of my eyesight
f. Have never driven a car at night

22. Does the loss driving ability from your vision impair your overall functioning in life?
    a. No
    b. A little
    c. A moderate amount
    d. A great deal
    e. Am unable to function in most activies because of it
    f. Not applicable

B. UTILITIES

TIME TRADE-OFF

I'm going to ask you some purely theoretical questions that require careful thought. Please take your time in answering.

1. How many years do you expect to live?________________________
2. Suppose there was a technology that could return your eyesight to perfectly normal in both eyes. The technology always works, but decreases your survival. Essentially, it increases your quality of life, but decreases the length of time you live.

   What is the maximum number of years, if any, you would be willing to give up if you could receive this technology and have perfect vision for your remaining years?______________

STANDARD GAMBLE

Now, a little bit different scenario: Suppose there is a technology that can return your eyesight to normal. However, it doesn't always work. When it works, patients respond perfectly and have normal vision in both eyes for the rest of their lives. When it doesn't work, however, the technology fails and patients do not survive (eg, death under anesthesia). Thus, it either restores perfect vision or causes immediate death.

1. What is the highest risk of death (a percent–if any–you would be willing to accept before refusing to have the technology to treat your visual loss?________________________

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