Establishing Levels of Indications for Cataract Surgery: Combining Clinical and Questionnaire Data into a Measure of Cataract Impact

Colm McAlinden,[1] Marina Jonsson,[2] Maria Kugelberg,[2] Mats Lundström,[3] Jyoti Khadka,[1] and Konrad Pesudovs[1]

Purpose. To develop a model for establishing indications for cataract surgery that incorporates clinical and questionnaire data on a single linear scale using Rasch analysis.

Methods. In this prospective study, 293 preoperative cataract surgery patients (mean age, 72.8 ± 10 years; age range, 33–98 years; 174 female, 119 male; 49% with ocular comorbidity) completed two questionnaires, and visual acuity was measured in each eye. A *cataract impact* model was developed using Rasch analysis incorporating questionnaire scores and visual acuity. Participants were ranked from 1 to 293 based on the order in which they presented (first in first out [FIFO]) and then were ranked based on the cataract impact model. The main outcome measure was the number of participants moving 49 (16.7% change) rank positions, which represented a likelihood to change priority category.

Results. The cataract impact model was unidimensional (fit statistics within 0.66–1.68) and had adequate precision (person separation of 2.58), and the components were well targeted to the population (0.05 logits between the mean item difficulty and person ability). Two hundred twenty-seven (77.5%) patients moved by at least 49 rank positions.

Conclusions. It is possible to combine clinical and questionnaire data and rank patients on a single linear scale. This approach modifies the ranking that occurs with the FIFO model and can be used for prioritizing patients for surgical intervention. More sophisticated models incorporating more clinical information may provide a better measure of the cataract impact latent trait. (*Invest Ophthalmol Vis Sci.* 2012;53: 1095–1101) DOI:10.1167/iovs.11-8102

Cataract is the leading cause of world blindness and as such is a major public health issue.[1–3] The number of cataract operations has increased in recent years along with increased waiting times. With factors such as an aging population, lowered threshold for surgery, reduced risks and complications, the number of patients who will require cataract surgery is predicted to grow considerably.[4]

From the [1]National Health and Medical Research Council Centre for Clinical Eye Research, Flinders Medical Centre and Flinders University, Bedford Park, South Australia, Australia; [2]St. Erik Eye Hospital, Karolinska Institutet, Stockholm, Sweden; and [3]EyeNet Sweden, Blekinge Hospital, Karlskrona, Sweden

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Corresponding author: Colm McAlinden, Flinders Medical Centre and Flinders University, Bedford Park, South Australia, 5042, Australia; colm.mcalinden@gmail.com.

There is a need to develop fair and equitable systems for cataract surgery according to the severity of the impact of the disease on the person.[5] Many health care systems use a fundamental principle that health care to all citizens should be on an equal basis. Using such principles should lead to treatment of those in the greatest need of help and should result in the greatest overall benefit for the community for a given allocation of resources.[6]

Many systems for setting indications for cataract surgery are based on a first in first out (FIFO) basis, whereby patients receive surgery in the order in which they were evaluated.[7] An alternative to FIFO is to develop a prioritization schema that attempts to order people by need (i.e., severity of the disease). Prioritization schema typically seek to model clinical acumen using a formula with various clinical variables. However, this is difficult to do with validity, in terms of weighting variables, especially when many variables are involved. There have been a number of attempts, including some simplistic clinical schema heavily weighted by visual acuity,[8] to more developed approaches such as the Clinical Priority Assessment Criteria,[9] the Western Canada Waiting List Project,[10] and the Nationell Indikationsmodell för Kataraktextraktion (NIKE).[11] None of these systems include all the complexity a clinician uses in evaluating a patient.

An elegant approach would be to derive a model based on both clinical data and patient-reported information (questionnaires) where the variance in each input determines its role in the model. Such an approach is possible using Rasch analysis[12] to combine the inputs into a mathematical model of a latent trait; if the common feature of all the inputs is that they reflect the impact of cataract, the latent trait would be *cataract impact*. The quality of the fit of the variables with the model can be assessed ensuring only variables that contribute effectively to describing cataract impact are included. There is no arbitrary weighting of inputs; the relative contribution of each input to the latent trait depends on the input's fit with the model.

The aim of this study was to develop a model for establishing indications for cataract surgery that incorporates clinical and questionnaire data on a single linear scale using Rasch analysis. To test the effect of including the different variables in the model, the full model was compared to prioritizing patients for cataract surgery on the basis of FIFO.

Methods

Clinical Data and Questionnaire Measures

Two questionnaires were used in this study, the Catquest-9SF questionnaire[13] and the Priquest questionnaire,[11] both of which are used in Sweden.[14] The Catquest-9SF is a Rasch-scaled questionnaire consisting of nine items, and it provides an interval level measurement of visual disability. There are two global items and seven difficulty items. The Priquest questionnaire contains eight items, three of them similar to items in the Catquest-9SF. The remaining five items span two content areas. The first content area (items 1 and 2) is cataract symptoms, and the second content area (items 3, 4, and 5) assesses patients' ability to work and drive and the extent to which others depend on them (Table 1). The Catquest-9SF questionnaire is used during the month of March in approximately 40 clinics in Sweden to assess surgery outcomes. The Priquest questionnaire is used all year round by approximately 75% of all clinics in Sweden as part of the NIKE instrument[11] to help sort patients into four indication groups for surgery. Therefore, the nine items of the Catquest-9SF and the five items of the Priquest questionnaire were used. Visual acuity was organized on the log minimum angle of resolution (logMAR) linear scale and reported for the eye undergoing surgery, the fellow eye, and the better eye. Different methods of organizing visual acuity data were chosen to explore the fit to the cataract impact model.

Subjects

The original Swedish versions of the Catquest-9SF and Priquest questionnaires were self-administered preoperatively by 293 cataract surgery patients (mean age, 72.8 ± 10 years; age range, 33–98 years; 174 female, 119 male; 49% with comorbidity). All patients were 18 years of age or older, spoke Swedish, and were without severe cognitive impairment. The study was approved by an ethics committee in accordance with the tenets of the Declaration of Helsinki and by the Swedish data inspection board. Patients were informed about the study in accordance with Swedish law.

Rasch Analysis

Rasch analysis is used across a wide range of disciplines, including health studies, education, psychology, marketing, economics, and social sciences. In ophthalmology, it has principally been used in the development of new questionnaires[15–18] and in the analysis of preexisting questionnaires.[19–21] Rasch analysis is a mathematical model based on relationships between items (e.g., questions or visual acuity) and persons (e.g., patients). It has two important features: it enables the estimation of interval-scaled measures (like a ruler) from raw data, and it enables the assessment of properties such as measurement precision, whether a single construct is being measured (item-fit statistics) and in the order intended (response category ordering), and how well the items target the population assessed. These are known as the psychometric properties.

In this study, questionnaire responses (14 items) and measures of visual acuity (three items: surgery eye, other eye, and better eye) were organized into a Rasch measurement model with the purpose of creating a latent variable of cataract impact on a single linear scale. Questionnaire responses are categorical (four response options), whereas visual acuity represents quasi-continuous measurement (50 steps). The logMAR visual acuity scale ranged from 0.00 to 1.00 in the data set (in 0.02 steps), which was recoded into four categories. Four categories were used for all variables to avoid distortions of the model that may occur in the presence of scales of different sizes. A polytomous Andrich rating scale model using joint maximum likelihood estimation was applied using commercially available software (Winstep, version 3.70.0.2; Winstep Software Technologies, Chicago, IL). An Andrich rating scale was used for each set of inputs with a common scale; therefore there was one rating scale for the three visual acuity items, two rating scales for the Catquest-9SF, and two rating scales for the Priquest. The psychometric properties of the cataract impact latent trait measurement were assessed with response category ordering, precision, item-fit statistics, and targeting.

Category Threshold Ordering

Performance of response categories in terms of use in the order intended was evaluated by observing whether the category calibration increased in an orderly fashion in the category probability curves (a graphical display of the likelihood of each category being selected over the range of the latent trait).

Precision

Precision is a fundamental aspect of measurement; it is the extent to which a measure can discriminate along its scale. Rasch-derived person separation

Table 1. The Nine-Item Catquest-9SF and the Five Items from the Priquest Questionnaire

	Response Options				
Catquest-9SF Questionnaire					
1. Do you experience that your present vision is giving you difficulty in any way in your everyday life?	Yes, very great difficulties	Yes, great difficulties	Yes, some difficulties	No, no difficulties	Cannot decide
2. Are you satisfied or dissatisfied with your present vision?	Very dissatisfied	Rather dissatisfied	Fairly satisfied	Very satisfied	Cannot decide
Do you have difficulty with the following activities because of your vision? If so, how much?	Yes, very great difficulties	Yes, great difficulties	Yes, some difficulties	No, no difficulties	Cannot decide
3. Reading text in the daily paper					
4. Recognizing the faces of people you come across					
5. Seeing prices when shopping					
6. Seeing well enough to walk on uneven ground					
7. Seeing well enough to do handwork, woodwork, etc.					
8. Reading text on TV					
9. Seeing well enough to carry out an activity/hobby you are interested in					
Priquest Questionnaire					
1. Do you feel that headlights, lamps, sunlight, or other lights dazzle you, reducing your vision?	Yes, very great difficulties	Yes, great difficulties	Yes, some difficulties	No, no difficulties	Cannot decide
2. Do you experience visual disturbances from differences (clarity, color, poor depth perception) between the two eyes?					
3. If you have a job, does your present vision cause any problems?	Yes, very great difficulties	Yes, great difficulties	Yes, some difficulties	No, no difficulties	Not applicable
4. If you drive a car, or recently stopped driving, does/did your present vision cause any difficulties in driving?					
5. If you look after yourself or care for someone at home, does your present vision cause any problems with those responsibilities?					

These questionnaires were completed in Swedish; therefore, the information presented represents a translation.

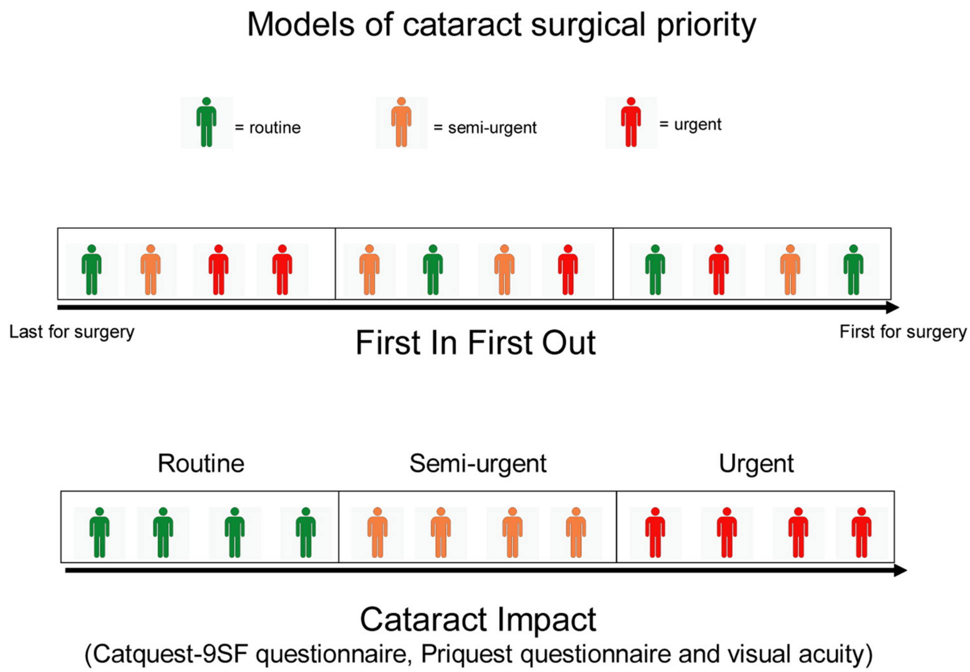

FIGURE 1. The two priority models. *Colors* indicate the level of need for cataract surgery based on the cataract impact model. The FIFO priority model assigns patients cataract surgery in the order in which they present. The FIFO model illustrates that patients who require urgent surgery (*red*) may receive surgery after patients requiring semiurgent (*green*) or nonurgent (*amber*) surgery. The cataract impact model uses questionnaire scores (Catquest-9SF and Priquest) and visual acuity data with patients potentially moving up or down in rank position, depending on these data.

statistics indicate the overall precision of the instrument. Person separation equates to the ratio of the true variance in the estimated measures to the observed variance: the greater the value of person separation, the greater the precision of the model. A minimal acceptable cutoff value for the person separation ratio was set at 2.0 for this study.[22]

Item-Fit Statistics

Item-fit statistics indicate whether the model measures a single concept (unidimensionality). The analysis produces two fit statistics, infit and outfit mean square (MNSQ), with expected values of 1. The infit statistic is less sensitive to distortion from outliers and is thus considered the more informative fit statistic. The MNSQ residual statistic is normalized to the average expected variance such that a residual of <0.50 indicates at least 50% less variance than expected, suggesting a high level of predictability or possible redundancy. Residuals greater than 1.70 indicate at least 70% more variance than expected, suggesting items may be measuring something different to the overall scale. A reasonable fit range for clinical observations is 0.50 to 1.70,[23] which was applied in this study. This is more lenient than typically used for questionnaire evaluation[22] and reflects the diverse nature of clinical data.

Targeting

Targeting refers to the extent to which the difficulty of the items matches the abilities of the persons; ideally, they should center on the same mean. This can be assessed visually by observing the person-item map, a graphical representation of persons and items along the logit scale. This map also shows item hierarchy and enables the identification of redundant items or large gaps between items. Inadequate targeting occurs when items are clustered at certain points along the logit scale, leaving large gaps, and when many persons have a higher or lower ability than the most or least difficult item threshold. Targeting may be measured by comparison of the person and the item mean values. A perfect targeting instrument would have a difference of 0, whereas a difference of more than 1.00 logit indicates significant mistargeting.

Testing the Model

Patients were ranked from 1 to 293 based on FIFO. Patients were then ranked again based on their cataract impact as derived from the model scores. Although both FIFO and the cataract impact model effectively order people along a continuum, for the purposes of comparison, the continuum was considered to consist of three categories. The comparison between the two ranking models was based on a standard prioritization system that ranks patients into three groups depending on urgency: urgent, semiurgent, and routine. The midway point of these tertile intervals corresponds to 16.7%. Therefore, a 16.7% change in rank position of patients was considered significant because it represented a 50% probability of changing tertile. With 293 rank positions, a 16.7% change equates to approximately 49 rank positions. Hence, the number of patients moving 49 rank positions on the cataract prioritization list was considered the main outcome measure (Fig. 1).

RESULTS

Rasch Analysis

The response categories functioned as intended, as illustrated by category structure calibration and observed averages increasing in an orderly fashion for all rating scales. Figure 2 shows the category probability curves for the visual acuity rating scale displaying an ordered progression. The model was found to be unidimensional, with fit statistics within the acceptable MNSQ range of 0.50 to 1.70. The mean infit statistic was 1.00 ± 0.27 (range, 0.68–1.50), and the mean outfit statistic was 1.00 ± 0.33 (range, 0.66–1.68). Specific infit and outfit statistics for each item are displayed in Table 2. Item infit against item calibration is displayed in the bubble plot, with the bubble size indicating the size of the SE of the item calibration (Fig. 3). The model was found to provide adequate precision with a person separation of 2.58. Targeting of the model components to person ability was good; the minimal difference was 0.05 logits between the mean item difficulty and person ability (Fig. 4).

Testing the Model

Patients were ranked from 1 to 293 based on FIFO. Patients were then ranked again from 1 to 293 based on their cataract impact as derived from the model scores (questionnaires and visual acuity); worst cataract impact was ranked 1, and least cataract impact was ranked 293. On the logit scale, the more positive the score, the worse the visual disability or cataract

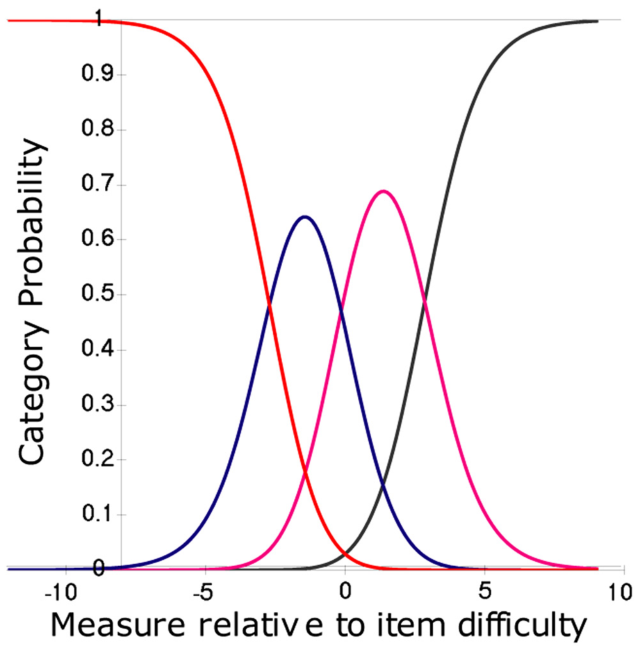

Figure 2. Response category probability curves. The *x*-axis represents the difference between item and person calibration, and the *y*-axis represents the probability of the category being chosen.

Table 2. Item Infit and Outfit MNSQ Statistics for the 17-Item Cataract Impact Model

Item	MNSQ	
	Infit	Outfit
Visual acuity		
Surgery eye	1.50	1.68
Other eye	1.44	1.54
Better eye	1.26	1.24
Catquest-9SF		
Item 1	0.76	0.73
Item 2	1.11	1.10
Item 3	0.75	0.73
Item 4	0.90	0.89
Item 5	0.68	0.66
Item 6	0.81	0.83
Item 7	0.67	0.64
Item 8	0.76	0.73
Item 9	0.80	0.78
Priquest		
Item 1	1.34	1.41
Item 2	1.34	1.46
Item 3	0.93	0.91
Item 4	0.87	0.79
Item 5	1.15	0.94

impact latent trait; 227 (77.5%) patients moved by at least 49 rank positions (>16.7% change).

Discussion

This study found that it is possible to combine patient-reported measures and clinical measures on the same interval level linear scale, measuring a latent trait termed cataract impact. The patient-reported measures consisted of two questionnaires, the Catquest-9SF and the Priquest, whereas the clinical measures consisted of three measures of visual acuity. Rasch analysis was used in the development and assessment of this cataract impact model, finding it to be unidimensional and precise and to have adequate targeting. Item-fit statistics were within the predetermined acceptable range, and an excellent person separation of 2.58 was found. This indicates that all the items used were contributory to the measure and that the model is effective in discriminating in terms of cataract impact.

It is hypothesized that a model that measures the cataract impact latent trait may provide a more sophisticated form for prioritizing patients for cataract surgery. In other words, prioritizing patients to the urgency for cataract surgery with a model that incorporates more clinical information than solely relying on the order in which a patient presents (FIFO) better represents clinical acumen. Previous attempts at combining patient-reported measures and clinical measures, such as the NIKE model, have used arbitrary scoring methods for visual acuity and questionnaires.[11] Arbitrary scoring introduces noise

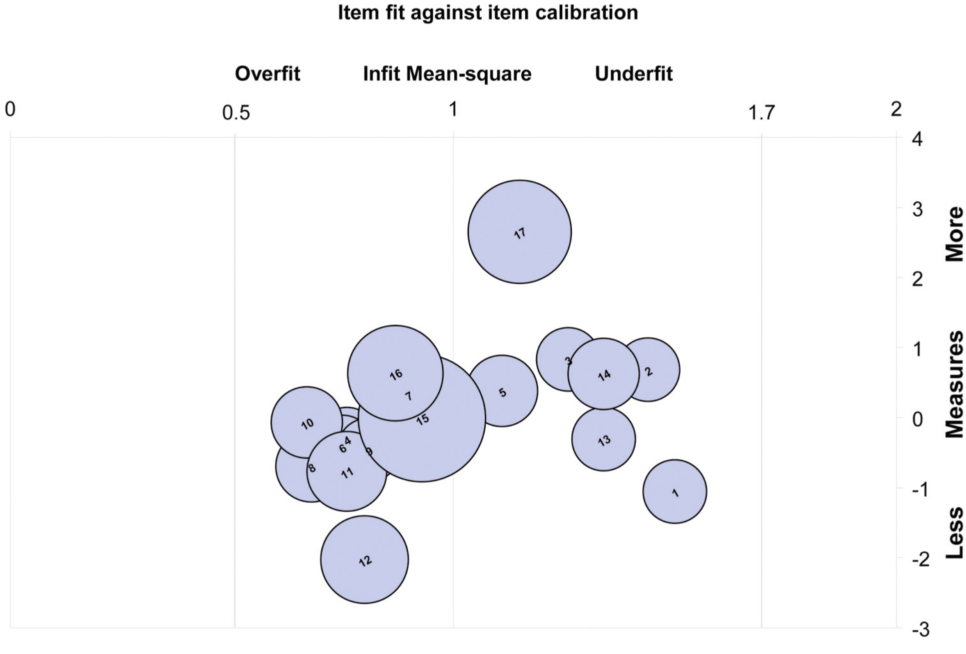

Figure 3. Bubble plot displaying the item infit against item calibration, with the bubble size indicating the size of the SE of the item calibration. The numbers in the bubbles denote the items: 1–3, visual acuity; 4–12, Catquest-9SF questionnaire; 13–17, Priquest questionnaire.

```
                    PERSON - MAP - ITEM
      <More cataract impact>|<Easier>
 5                  .  +
                       |
                       |
                       |
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                       |
 4                     +
                    #  |
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                       |
 3                .##  +
                       |
                    #  |  Priquest 5
                    #  |
                      T|
                  ###  |
 2                     +T
                  .##  |
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                  ###  |
               .#### S|
 1             .####   +S
              #######  |  VA best eye
                #####  |  VA other eye    Priquest 2    Priquest 4
           .#########  |
             ########  |  Catquest 4      Catquest 6
            #########  |
 0           ######## M+M Catquest 9      Priquest 3
            .########  |
              .######  |  Catquest 3      Priquest 1
          .##########  |  Catquest 8      Catquest 5
             ########  |  Catquest 7
            .########  |  Catquest 1
-1              #####  +S VA surgery eye
                .####  |
                ##### S|
               .#####  |
                   .#  |
                   .#  |
-2                 .#  +T Catquest 2
                   .#  |
                   ##  |
                    . T|
                    .  |
                    .  |
-3                  .  +
                       |
                       |
                       |
                       |
                       |
-4                  .  +
                       |
                       |
                    .  |
                       |
                       |
-5                     +
      <Less cataract impact>|<More difficult>
      EACH "#" IS 2. EACH "." IS 1.
```

FIGURE 4. Person-item map for the cataract impact model. Persons are represented on the *left*. (*#*) Two persons; (*dot*) One person. Items are represented on the *right*. Person and item means are denoted by M, with minimal difference between means (0.05 logits).

and nonlinearity to the score; therefore, it is not an efficient representation of the underlying latent trait. This is overcome with the use of Rasch analysis, which enables the estimation of interval-scaled measures from raw data and uses fit to the model to determine the role of variables.

The cataract impact Rasch-scaled model was tested in comparison with ranking based on FIFO. This comparison involved comparing the rank prioritization of each method. Although arbitrary in approach, the test was to determine whether the two models provided different rank orders. This comparison was based on a hypothetical prioritization system that ranks patients into three groups, depending on urgency: urgent, semiurgent, and routine. For a patient to move from the midpoint of one group to the next group would require a 16.7% change in rank position. In this study with 293 patients, this percentage change correlated to 49 rank positional changes. Two hundred twenty-seven (77.5%) patients were found to move by at least 49 rank positions. The significance of these changes on patient waiting times would depend on waiting list length and scheduling factors. This is important because the challenges involved in implementing a prioritization system must be demonstrably worthwhile. In addition, whether this cataract impact model ranks patients better than FIFO must be tested by a randomized controlled clinical trial. This would involve two cohorts of patients, one ranked according to FIFO and the other ranked according to the cataract impact model, and postoperative outcomes compared. Alternatively, an ideal system for establishing indications for cataract surgery would be for all patients to be examined by the same clinician and for the same clinical acumen to be used to rank patients for surgery urgency. Although this process is underpinned by clinical acumen, a system that evades quantification, all the elements entering the process are quantifiable. To enable this type of prioritization to function in a clinical setting, clinical and questionnaire data could be entered into a computer algorithm that would produce a Rasch-scaled score. Then an automated lookup table, or something similar, could be used by which a specific score would correspond to a specific waiting time period. For example, on a cataract impact scale of 0 to 100, scores within 80 to 90 could correspond to waiting times of 4 weeks. Alternatively, patients could be block ranked from most to least in need for surgery, which would correspond to specific waiting times or surgery sessions.

Such models are welcomed because delays in cataract surgery have been shown to result in decreased quality of life, heightened likelihood of falls, vision loss, and depression.[24–26] A recent study based in Spain found that patients ranked for surgery by the FIFO system are disorganized in terms of visual problems.[27] The authors also found that longer waiting times resulted in smaller postoperative gains in visual acuity and suggest that rational and homogeneous criteria should be applied to enable patients who require surgery most receive it soonest. When the demand for cataract surgery exceeds the immediate ability to perform it, patients deserve a more rational approach than the FIFO system. Prioritizing patients who require cataract surgery based on a robust model represents a fairer way to manage waiting lists.[28]

One limitation of this study is that only one form of clinical measure—visual acuity—was included in the derivation of the cataract impact model. The infit statistic of visual acuity in the eye waiting cataract surgery tended to misfit the model the most, with an infit MNSQ of 1.50. Although this was within the predetermined acceptable boundaries, it indicates that at least 50% more variance was present in the variable than expected. This may, in part, be due to the known poor correlation between visual acuity and visual disability[29] and likely influenced by the small number of clinical variables within the model. Including additional clinical measurements such as contrast sensitivity and objective measures of cataract grading may improve item fit to the model. This may also provide a more accurate measure of the cataract impact latent trait and deserves further investigation.

In conclusion, it is possible to combine both clinical and questionnaire measures on a single linear scale. Possible applications of such models include prioritizing patients for cataract surgery. More sophisticated models incorporating more clinical measures may provide a better measure of the cataract impact latent trait. Similar models could be developed for organizing waiting lists for other conditions.

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