Study of Optimal Perimetric Testing In Children (OPTIC): Development and feasibility of the Kinetic Perimetry Reliability Measure (KPRM)

Dipesh E Patel [1,2,3,4] BMedSci, PGDip

Ananth C Viswanathan [3] PhD, FRCOphth

David Garway-Heath [3] MD, FRCOphth

Phillippa M Cumberland [1,2] BA, MSc

Bronwen C Walters [4,2] BMedSci

Isabelle Russell-Eggitt [2] FRCOphth

Mario Cortina-Borja [5] MSc, PhD

Jugnoo S Rahi [1,2,3,4] PhD, FRCOphth

For the OPTIC study group (members listed in the acknowledgement)

[1.] Life Course Epidemiology and Biostatistics Section, UCL Institute of Child Health, London, UK
[2.] Ulverscroft Vision Research Group, London, UK
[3.] NIHR Biomedical Research Centre at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology, London, UK
[4.] Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK
[5.] Clinical Epidemiology, Nutrition and Biostatistics Section, UCL Institute of Child Health, London, UK

Word count: 1137

Corresponding author: Jugnoo S Rahi, UCL Institute of Child Health, 30 Guilford Street, London, WC1N 1EH. Email: j.rahi@ucl.ac.uk

Keywords: kinetic perimetry, Octopus, Goldmann, reliability, visual fields, perimetry, kinetic perimetry reliability measure, KPRM, children, paediatric ophthalmology

ABSTRACT

Introduction: Interpretation of perimetric findings, particularly in children, relies on accurate assessment of test reliability, yet no objective measures of reliability exist for kinetic perimetry. We developed the Kinetic Perimetry Reliability Measure (KPRM), a quantitative measure of perimetric test reproducibility/reliability and report here its feasibility and association with subjective assessment of reliability.

Methods: Children aged 5 to 15 years, without an ophthalmic condition that affects the visual field were recruited from Moorfields Eye Hospital and underwent Goldmann perimetry as part of a wider research programme on perimetry in children. Subjects were tested with two isopters and the blind spot was plotted, followed by a KPRM. Test reliability was also scored qualitatively using our Examiner Based Assessment of Reliability (EBAR) scoring system, which standardises the conventional clinical approach to assessing test quality.

The relationship between KPRM and EBAR was examined to explore the use of KPRM in assessing reliability of kinetic fields.

Results: 103 children (median age 8.9 years (IQR = 7.1-11.8 years)) underwent Goldmann perimetry with KPRM and EBAR scoring. A KPRM was achieved by all children. KPRM values increased with reducing test quality (Kruskal-Wallis, p=0.005), indicating greater test-retest variability, and reduced with age (linear regression, p=0.015). 1/103 child (0.97%) demonstrated discordance between EBAR and KPRM.

Conclusion: KPRM and EBAR are distinct but complementary approaches. Though scores show excellent agreement, KPRM is able to quantify within-test variability, providing data not captured by subjective assessment. Thus, we suggest combining KPRM with EBAR to aid interpretation of kinetic perimetry test reliability in children.

INTRODUCTION

Clinical assessment of the visual field (VF) in children is commonly performed using either static or kinetic perimetry.[1] Interpretation of results relies on an understanding of the variability of responses in normal subjects,[2] normative (reference) values,[3-5] and accurate assessment of test reliability.[6] Modern static algorithms incorporate measures of false positive/negative responses and fixation losses to assess reliability. No equivalent quantitative measures exist for reporting reliability of kinetic perimetry.

We have developed the Kinetic Perimetry Reliability Measure (KPRM) to aid interpretation of kinetic test reliability. VF test results that are highly reproducible are considered to be reliable.[7] One approach to assess reproducibility/repeatability is to examine the variability of within-test responses. The KPRM has been developed based on this approach, as a quantitative measure for fast, visual representation of reliability, applicable to children. We report here an investigation of the feasibility of KPRM and its relationship with a qualitative examiner-based assessment of test reliability.

METHODS

Children aged 5-15 years, with no previous experience of perimetry and no history of ophthalmic disease that affects the visual field were recruited from patients and their siblings attending Moorfields Eye Hospital, as part of a wider research programme investigating perimetry in children. Subjects underwent Goldmann kinetic perimetry and had 2 kinetic isopters (randomised between III4e, I4e and I2e), a blind spot and a KPRM plotted (described below). Test quality was rated qualitatively using our previously reported Examiner Based Assessment of Reliability (EBAR) score, with ratings of either ‘good’, ‘fair’ or ‘poor’ quality, with a good quality test being one that is expected to represent true visual field sensitivity. EBAR scores are derived from matching observed behaviours to pre-defined criterion, and take into account key components that affect test reliability such as fatigue, loss of fixation, poor concentration and behaviour.[6] It was developed to standardise conventional qualitative examiner assessments and is judged independently to the test outcome.

The Kinetic Perimetry Reliability Measure (KPRM)

Deriving a KPRM involves assessing additional test points at the end of a kinetic assessment. If both eyes are being assessed in a single sitting, the KPRM is plotted at the end of testing each eye, to avoid repeated alternation of occlusion.

Four points are tested using the largest/brightest (i.e. most peripheral) isopter stimulus used in the test. One point is plotted in each quadrant along a meridian selected from those already used for plotting that isopter. KPRM points are not repeated if the subject loses concentration during this phase of the test.

Taking a median value of the un-signed distance (in degrees) between these four KPRM points and the corresponding points previously plotted on the same meridian (with the same, outer isopter stimulus, Figure 1) gives a KPRM score, with higher scores indicating greater test-retest variability.

Feasibility of the KPRM was assessed as the proportion of children in whom KPRM plotting was completed.

Associations between EBAR and KPRM

EBAR scores reflect the effect of behaviours that affect test quality. KPRM examines within-subject/test variation. These two complementary measures assess the same underlying construct i.e. degree to which the test can be considered reliable, by capturing different data. The relationship between KPRM and EBAR was examined quantitatively and additional examiner comments were scrutinised to explore any discrepancy between the measures. The maximum 'normal' test-retest variability for good quality assessments was taken as 5 degrees.[8] Thus, KPRM and EBAR scores were deemed discordant if a child rated with good EBAR scored >5 on KPRM and, conversely, if those rated as poor EBAR had an associated KPRM score of <5.

Statistical methods

Co-ordinate points were extracted using Engauge digitizer software (open-source, www.digitizer.sourceforge.net) and distances between points were calculated using the R package `'kineticF'`[9] (The R Project for Statistical Computing (R v3.2.0, www.r-project.org)). The KPRM score was found by ordering the 4 values of the distance between points and calculating the median (mean (average) of the two middle numbers) in Stata (StataCorp; 2011: Stata Statistical Software: Release 12. College Station, TX).

Informed written consent for participation was sought from parents/guardians, whilst children gave verbal assent. The study was approved by the National Health Service Research Ethics Committee for London - Bloomsbury and followed the tenets of the Declaration of Helsinki.

RESULTS

103 children with median age 8.9 years (IQR = 7.1-11.8 years) underwent Goldmann perimetry with KPRM and EBAR scoring. Median spherical equivalent of tested eyes was 0 dioptres (IQR: 0, 2.4), with median visual acuity of 0.0 LogMAR (IQR: -0.1, 0.0). All were able to perform the KPRM. A sample individual KPRM calculation (Figure 1) shows distances (degrees), starting in the supero-temporal field, and working clockwise of: 12.91, 1.82, 0.23 and 2.25, thus giving a KRPM score of 2.0 (i.e. a median of these four values).

Table 1 shows the distribution of KPRM by EBAR (test quality) category. The median KPRM score increases with decreasing test quality (Kruskal-Wallis, p=0.005).

Table 1. KPRM score by Examiner Based Assessment of Reliability (EBAR) rating

Examiner Based Assessment of Reliability (EBAR) rating	Number of subjects	Median Kinetic Perimetry Reliability Measure (KPRM) score (IQR)	Number (%) of subjects with a KPRM score >5
Good	91	1.5 (1.0 - 2.1)	1 (1.1)
Fair	10	3.4 (0.9 - 4.7)	2 (20)
Poor	2	18.3 [6.8 - 29.8]*	2 (100)

** Values indicate data range*

In those with ‘good’ quality assessments, KPRM scores reduce with increasing age (n=91, linear regression, p=0.015). Figure 2 illustrates KPRM points for subjects with varying test quality, showing an increase in KPRM score with reducing test quality (poor EBAR).

DISCUSSION

Accurate assessment of VF test reliability is essential to interpretation of findings. Here, we report that an increasing KPRM score is indicative of poorer test reliability as evaluated by EBAR scores, thus providing a novel indicator of reliability for kinetic perimetry in children. The KPRM is simple to implement and interpret and can be used in children as young as 5 years. Our data suggest that within-test variability reduces with increasing age – a feature that is not captured by assessment with EBAR alone.

Median values are less susceptible to the effects of outliers. Thus using the median of four values to define the KPRM provides a more robust quantification. The score is presented as a summary value, although the individual points within the KPRM score have a descriptive value for indicating fatigue (all points within the original isopter) or learning effects (consistent plots outside the original isopter (Figure 2b)), and they can provide information on variability of responses within each quadrant. Notably, a visible difference in isopter appearance is evident with decreasing test quality (Figures 2a-c), emphasising that, in these normal subjects, VF tests of fair/poor reliability fail to represent a subjects' true visual function.

Our programme focuses on children, i.e. the population in whom there is a higher likelihood of unreliable results. It is challenging to recruit to, and undertake, perimetric research in children. Our study, although the largest of its kind, has limited power for complex statistical methods/models to define expected KPRM values for different test quality levels. Nonetheless, higher KPRM scores are associated with poorer test quality based on EBAR scores, demonstrating that within-test repeatability is poorer with reducing overall test reliability.

We describe a concise method of quantifying within-test variability that could be used in future studies as a proxy to assess perimetric test reliability. Currently, there is no 'gold-standard' quantitative measure of reliability of kinetic perimetry in children against which we can formally validate our KPRM.

However, we have shown that when implemented alongside our examiner rating of test quality (EBAR), the KPRM may prove useful in interpreting serial VFs over a number of visits. The KPRM can describe small fluctuations in test reliability that cannot be captured solely by qualitative judgement. Thus, we recommend the routine implementation of EBAR and KPRM when assessing children with kinetic perimetry.

ACKNOWLEDGEMENTS

OPTIC study group members: Peng Tee Khaw, Bronwen Walters, Phillippa Cumberland, Isabelle Russell-Eggitt, Chris Timms, John Brookes, Anthony Moore, Maria Papadopoulos, David Garway-Heath, Ananth Viswanathan, Alki Liasis, David Crabb, Mario Cortina-Borja, Dipesh Patel, and Jugnoo Rahi.

We are grateful to Haag-Streit (AG, Switzerland) for the loan of an Octopus perimeter to Great Ormond Street Hospital for this study.

Funded by The Guide Dogs for the Blind Association (GBDA) (grant no. OR2009-04e). The sponsor or funding organization had no role in the design or conduct of this research. The research was supported by the National Institute for Health Research (NIHR) Biomedical Research Centre based at Moorfields Eye Hospital NHS Foundation Trust/UCL Institute of Ophthalmology and UCL Institute of Child Health/Great Ormond Street Hospital NHS Foundation Trust. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.

REFERENCES

1. Walters BC, Rahi JS, Cumberland PM. Perimetry in children: survey of current practices in the United Kingdom and Ireland. Ophthalmic epidemiology 2012;**19**(6):358-63 doi: 10.3109/09286586.2012.718027
2. Bengtsson B, Heijl A. Inter-subject variability and normal limits of the SITA Standard, SITA Fast, and the Humphrey Full Threshold computerized perimetry strategies, SITA STATPAC. Acta Ophthalmologica Scandinavica 1999;**77**(2):125-29
3. Egge K. The visual field in normal subjects. Acta ophthalmologica. Supplementum 1984;**169**:1-64
4. Patel DE, Cumberland PM, Walters BC, Russell-Eggitt I, Cortina-Borja M, Rahi JS. Study of Optimal Perimetric Testing In Children (OPTIC): Normative Visual Field Values in Children. Ophthalmology 2015;**122**(8):1711-7 doi: 10.1016/j.ophtha.2015.04.038
5. Vonthein R, Rauscher S, Paetzold J, et al. The normal age-corrected and reaction time-corrected isopter derived by semi-automated kinetic perimetry. Ophthalmology 2007;**114**(6):1065-72 doi: 10.1016/j.ophtha.2006.09.030
6. Patel DE, Cumberland PM, Walters BC, Russell-Eggitt I, Rahi JS. Study of Optimal Perimetric Testing in Children (OPTIC): Feasibility, Reliability and Repeatability of Perimetry in Children. PloS one 2015;**10**(6):e0130895 doi: 10.1371/journal.pone.0130895
7. Bengtsson B. Reliability of computerized perimetric threshold tests as assessed by reliability indices and threshold reproducibility in patients with suspect and manifest glaucoma. Acta Ophthalmol Scand 2000;**78**(5):519-22
8. Grobbel J, Dietzsch J, Johnson CA, et al. Normal Values for the Full Visual Field, Corrected for Age- and Reaction Time, Using Semiautomated Kinetic Testing on the Octopus 900 Perimeter. Translational vision science & technology 2016;**5**(2):5 doi: 10.1167/tvst.5.2.5
9. Patel DE, Cortina-Borja M. kineticF: Framework for the Analysis of Kinetic Visual Field Data. R CRAN 2015. http://cran.r-project.org/web/packages/kineticF/index.html.

Figure legends

Figure 1. KPRM points (triangles) and an example distance (arrow) between a KPRM and corresponding point (cross). The overall KPRM score for this subject is 2.0.

Figure 2. KPRM (triangles) plotted for good quality (top), fair quality (middle) and poor quality (bottom) VF tests.