

INVITED REVIEW

Assessment of age-related maculopathy using subjective vision tests

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This paper reviews non-standard, clinical vision tests that may be used to detect the earliest visual loss in age-related maculopathy (ARM), before fundus changes are detected. We recommend a clinical test battery for all patients aged 60 years and older, comprising low luminance/low contrast (SKILL) VA or low contrast VA, desaturated D-15 colour vision assessment, flicker perimetry, glare recovery and dark adaptation if possible, together with conventional assessments of case history, ophthalmoscopy and high contrast visual acuity (VA) for the detection and diagnosis of ARM. Reading rate is also discussed as a potential indicator of early visual loss. For monitoring the progressive visual loss in age-related macular degeneration (AMD) and determining the requirements for optometric vision rehabilitation, we recommend more conventional clinical vision tests of distance and near visual acuity, reading rate, the effects of varying illumination and a functional central visual field assessment.

Key words: age-related maculopathy, macular degeneration, subjective assessment

A paper published by the first author in this journal almost 25 years ago¹ on the assessment of 'senile macular degeneration' reviewed the standard tests of clinical vision according to three criteria:

1. Were the tests effective in detection and diagnosis of the condition?
2. Were they adequate for monitoring the progression of the disease?
3. Could the tests predict patients' functional disabilities and indicate their rehabilitation needs?

It is timely to examine what else has changed apart from the name and to ask again those same questions about our assessment of vision in age-related maculopathy (ARM) and age-related macular degeneration (AMD) as the early and late forms of the condition are now classified.²

In 1981, Kitchin¹ predicted that there would be many patients with ARM in the future—little did we realise that the condition would be approaching epidemic proportions now. Despite a better understanding of the risk factors and the evolution of some modestly effective treatments,^{3,4} AMD remains the leading cause of visual impairment among white persons in Australia and other developed countries.^{5–10} The incidence and prevalence of AMD is increasing at a rate faster than can be explained by the ageing population.¹¹

The Melbourne Visual Impairment Project¹² found the overall five-year incidence of ARM (soft distinct or indistinct drusen and/or pigmentary abnormalities) for Australians aged 40 years and older to be 17.3 per cent (95 per cent confidence

interval, 8.7 to 26.0 per cent). Their findings are higher than those from the Blue Mountains Eye Study¹³ because of different definitions for ARM and different age ranges in the study populations. However, both Australian studies indicate that the highest incidence rate is in persons aged 70 years and older; between one in five and one in three people aged 70 years and older will develop ARM over a five-year period and the disease will progress to a more severe form after 80 years of age.^{12,13} Thus, there will be between 370,000 (one in five) and 620,000 (one in three) new cases of ARM over the next five years among older Australians (estimated from Australian Bureau of Statistics 2004 population figures—AusStats: 3201.0 Population by Age and Sex, Australian States and

Territories, June 2004 <http://www.abs.gov.au/ausstats/abs>).

The economic and social impacts of this major public health issue are enormous.¹⁴⁻¹⁷ Hopley, Salkeld and Mitchell¹⁷ estimated that the cost of AMD to the health system in Australia exceeds \$AUD290 million per year. Bonastre and colleagues¹⁵ similarly estimated the annual budget impact of AMD in four European countries to be between 51.3 and 101.1 million euros (\$AUD85 to 168 million). The impact of AMD on activities of daily living, self-care, emotional well-being and overall quality of life can be profound and appears to be directly related to the severity of the condition.¹⁸⁻²³

Treatment of neovascular AMD by photodynamic therapy for subfoveal lesions (the majority) or thermal laser photocoagulation for extrafoveal lesions may stabilise or occasionally improve visual function^{24,25} and quality of life^{26,27} but only small numbers of AMD patients can actually benefit from these treatments.^{24,28} Given that there are limited options for treatment of AMD, early detection of the disease and prevention of progression are most important public health goals. Hopley and co-workers²⁹ determined that screening people aged 55 years and older for early ARM and then treating them with zinc and antioxidants could be considered cost-effective and these were highly cost-effective compared with no screening or treatment. Zinc and antioxidants have been shown to be effective for slowing the progression of visual loss in patients with large, soft drusen, unilateral moderate AMD or advanced AMD in the fellow eye.³⁰ Thus, the roles of the optometrist in both the early detection and diagnosis of ARM and the management of the visual impairment due to AMD are paramount.

PURPOSE OF ASSESSMENT OF VISION

The purpose of any visual assessment depends on the patient and the current visual status. The purpose may be:

1. to detect visual loss
2. to diagnose the cause of a visual loss
3. to monitor progressive visual loss, and/or

4. to predict functional impairment and inform vision rehabilitation.

The important, initial purpose is to determine if any visual loss is physiological, that is, due to refractive error or normal ageing, or pathological and if the latter, to detect the disease as early as possible and to determine appropriate treatment and/or referral.

The subjective tests of vision reviewed in 1981 by Kitchin¹ were: visual acuity (VA), visual fields, colour discrimination, contrast sensitivity and illuminance effects. Of course, the visual functions of the eye have not changed, so most of the tests of vision available today still fall under those general headings but the tools at our disposal have greatly increased in number and sensitivity.

We now know that our conventional, subjective clinical tests of vision, administered under optimal lighting and contrast conditions, detect neither 'normal' age-related losses in visual function³¹⁻³³ nor the transition from normal ageing to early ARM. Similarly, by the time examination of the retina by ophthalmoscopy or fluorescein angiography reveals visible abnormalities, visual function is already compromised.³⁴ In addition objective measures of cone- and rod-mediated functions in ARM have shown that impairment exceeds the funduscopically affected area.³⁵⁻³⁷ Fine⁴ commented that 'Remarkably, psychophysicists now can detect subtle disturbances in macular function before there are visible macular abnormalities'. This is an important and challenging role for optometrists: to detect changes in retinal function before ophthalmoscopic changes are apparent and before the traditional measures of vision (for example, high contrast VA) show impairment.

DETECTION AND DIAGNOSIS OF ARM

The fact that retinal function is compromised in ARM before high contrast VA is reduced is not surprising, as we know now that the disease starts parafoveally,³⁸⁻⁴¹ that rods are affected before cones in early ARM^{42,43} and that the distributions of soft drusen, depigmentation of the retinal pigment epithelium and early ARM all

increase at parafoveal locations.⁴⁴ A wide variety of studies has investigated changes in visual functions with normal ageing, ARM and AMD, under photopic and scotopic conditions. Table 1 lists the functions affected by ARM and some of the relevant publications (this list is by no means exhaustive).

Many of the psychophysical functions listed in Table 1, assessing both cone and rod function, can be impaired before high contrast VA deteriorates. However, some of these tests are not clinically available, require expensive equipment, are not standardised or validated, do not have normative data available and/or are time-consuming to administer. Ideally, for efficient and effective screening and diagnostic purposes, optometrists need a small battery of practical, validated tests that can detect and monitor visual loss in early ARM. As yet, there is no such proven battery of tests but based on research over the past 20 years, a range of subjective vision tests has been reviewed and various recommendations have been made for the detection of early age-related visual changes, to monitor vision in early ARM and/or assess visual loss in AMD.^{33,40,49,52,56,61,63,89,95-97}

Multiple tests of visual functions are required to detect early dysfunction because of physiological and pathological variations among patients and the variants of the condition.^{63,96} Therefore, we propose a set of clinically applicable subjective tests, which have been the most commonly recommended^{33,40,52,56,61,63,89,96,97} for detecting early changes in visual (retinal) function and have been repeatedly shown to be impaired in ARM. We recommend two measures of steady state visual functions (SKILL VA or low contrast VA and desaturated D15) and two tests of adaptation dynamics (flicker perimetry and glare recovery) for routine clinical use. Two additional tests (dark adaptation and reading rate) are suggested for possible use. Some or all of the proposed tests should be applied to all patients 60 years and older to determine individual baseline values and thereby identify and monitor those patients at risk of subsequent visual problems.^{33,89,98} Of course, these tests should be

Visual function	Publications
Colour discrimination	Bowman 1980, ⁴⁵ Bowman and Cameron 1984, ⁴⁶ Collins 1986, ⁴⁷ Applegate et al 1987, ⁴⁸ Collins and Brown 1989a, ⁴⁹ Sunness et al 1989, ⁵⁰ Haegerstrom-Portnoy and Brown 1989, ⁵¹ Eisner et al 1992, ⁵² Cheng and Vingrys 1993, ⁴⁰ Feigl et al 2004 ⁵³
Colour matching	Smith et al 1988, ⁵⁴ Eisner et al 1987a and b, 1991, 1992 ^{34,52,55,56}
Contrast sensitivity: spatial/temporal/colour	Sjostrand 1979, ⁵⁷ Brown and Lovie-Kitchin 1987, ³⁶ Kleiner et al 1988, ⁵⁸ Collins and Brown 1989a, ⁴⁹ Owsley et al 1990, ⁵⁹ Frennerson et al 1995, ⁶⁰ Midena et al 1997, ⁶¹ Phipps et al 1999, 2003, ^{62,63} Arden and Wolf 2004 ⁶⁴
Visual fields	Hart and Burde 1983, ³⁸ Swann and Lovie-Kitchin 1991, ³⁹ Cheng and Vingrys 1993, ⁴⁰ Tolentino et al 1994, ⁴¹ Midena et al 1994, 1997, ^{61,65} Sheu et al 2002, ⁶⁶ Phipps et al 2004, ⁶⁷ Goldstein et al 2005 ⁶⁸
Cone adaptation dynamics/glare recovery	Brown et al 1986, ⁶⁹ Collins and Brown 1989a and b, ^{49,70} Brown and Lovie-Kitchin 1989a, ⁷¹ Eisner et al 1987a and b, 1991, 1992 ^{34,52,55,56} Cheng and Vingrys 1993, ⁴⁰ Sandberg and Gaudio 1995, ⁷² Sandberg et al 1998, ⁷³ Midena et al 1997, ⁶¹ Owsley et al 2000, ⁷⁴ Phipps et al 2003 ⁶³
Foveal sensitivity	Sunness et al 1988, 1989, ^{75,76} Massof et al 1989 ⁷⁷
Flicker sensitivity	Mayer et al 1992a, b, and c 1994, ⁷⁸⁻⁸¹ Phipps et al 2004 ⁶⁷
Short wavelength perimetry	Remky et al 2001, 2005 ^{82,83}
Low contrast distance visual acuity	Lovie-Kitchin and Bowman 1985, ⁸⁴ Greeves and Cole 1988, ⁸⁵ Kleiner et al 1988, ⁵⁸ Lovie-Kitchin 1989, ⁸⁶ Brown and Lovie-Kitchin 1989b, ⁸⁷ Abadi and Pantazidou 1996, ⁸⁸ Schneck et al 2004, ⁸⁹ Feigl et al 2004 ⁵³
Dark adaptation	Brown and Lovie-Kitchin 1983, ³⁵ Brown et al 1986, ⁹⁰ Eisner 1992, ⁹¹ Steinmetz et al 1993, ⁹² Owsley et al 2000, 2001, ^{74,93} Haimovici et al 2002 ⁹⁴

Table 1. Subjective visual function tests investigated in ARM

used in conjunction with conventional assessments including case history, direct and indirect ophthalmoscopy and high contrast VA.

Steady state thresholds tests

LOW LUMINANCE/ LOW CONTRAST VA

The value of a number of ‘non-standard, yet clinically-practical’⁸⁹ tests of visual function for predicting future loss of visual acuity has been examined in the longitudinal phase of the SKI (Smith Kettlewell Institute) study involving a large sample (n = 537) of older adults (58 years and older) with good initial visual acuity.^{31,33,89,99} Schneck and associates⁸⁹ found that for those observers with habitual high contrast VA of 6/12 or better at baseline and retested an average of 4.4 years later, tests of low contrast spatial vision were stronger predictors of a loss of high contrast VA of

0.3 log units/decade (three lines or a doubling of the visual angle) at follow-up than either age or retinal disease status. The odds ratio for low contrast spatial vision was 2.35 (95 per cent CI 1.32-4.18) compared to 1.44 (95 per cent CI 0.74-2.80) and 1.04 (95 per cent CI 0.83-1.29) for retinal disease status and age, respectively. This indicates that for every unit change in performance the likelihood of subsequent acuity loss more than doubled.⁸⁹

The best predictor of future (high contrast) VA loss was a measure of low luminance/low contrast near letter VA using the Smith-Kettlewell Low Luminance (SKILL) card,¹⁰⁰ although Schneck and associates⁸⁹ acknowledged that other measures of low contrast spatial vision gave similar results. The SKILL card consists of two near letter charts designed on the Bailey-Lovie principles,¹⁰¹ one side with a chart of black letters on a dark grey background

(reflectance and contrast approximately eight and 14 per cent, respectively), while the reverse side has a conventional high-contrast, black-on-white letter chart.¹⁰⁰ The SKILL score is the acuity loss (number of letters) between the light and dark sides of the card and this varies with age, particularly after age 50 years. For 20-year-olds the SKILL score was a mean of 15 letters (three lines) and for 80-year-old participants (with high contrast VA of 6/9.5 or better), 25 letters (five lines).^{33,100} Schneck and associates⁸⁹ showed that reduced low luminance VA (increased SKILL score) at baseline increased the likelihood of future visual loss by three times. While their findings were not specific to ARM, a significant proportion of their participants had diagnoses of early ARM at baseline. In our laboratory, we have found significantly reduced SKILL scores in people with early ARM (and high contrast VA of 6/12 or better) compared to an age-matched control group.⁵³ The SKILL card provides a quick, robust and reliable measure of the effect of reduced luminance and contrast on VA,¹⁰⁰ which appears to be useful for detecting sub-clinical pathology.^{53,89} Practitioners should establish normal values in their own consulting rooms for individual patients through repeat measures.⁹⁸ The test is available from The Smith-Kettlewell Eye Research Institute; details on how to order it are available at their website http://www.ski.org/Rehab/JABraby_n_lab/skistudy.html.

LOW CONTRAST VISUAL ACUITY

An alternative to the SKILL test is a more conventional measure of low contrast (high luminance) visual acuity. There have been conflicting reports on the usefulness of low contrast VA for diagnosing early ARM.^{40,58,86,88} Kleiner and colleagues⁵⁸ reported that low contrast VA was significantly reduced in a group of 52 eyes with drusen and pigmentary changes but normal high contrast VA, compared to 27 healthy control eyes. The difference between the groups increased with increasing drusen severity. Lovie-Kitchin,⁸⁶ Cheng and Vingrys⁴⁰ and Abadi and Pantazidou⁸⁸ have concluded that while low contrast VA was reduced in ARM, its measurement

gave no additional information over that provided by high contrast VA for those with ARM. In all of these studies, including that of Kleiner and colleagues,⁵⁸ the ARM subjects already had slightly reduced high contrast VA, thus the conclusion is logical. However, reduced low contrast VA before high contrast VA loss may indicate early macular dysfunction. Greeves⁸⁵ and Lovie-Kitchin⁸⁶ independently found that a pass-fail criterion of 6/12 for low contrast VA distinguished between subjects with early ARM and age-matched subjects with normal retinas. This provides a useful guide for practitioners in monitoring the low contrast VA of their older patients.

The findings of Schneck and associates⁸⁹ indicated that a measure of low contrast VA would be as good as the SKILL score at predicting future visual loss. Again, there are significant changes in low contrast VA with age, particularly for observers older than 70 years,^{100,102} although the rate of change with age is not as great as for the SKILL score.³³ This suggests that a significant change in low contrast VA over repeated visits for an individual is more likely due to disease than age. Again, the practitioner would need to establish normal baseline low contrast VA for each patient to monitor for this change.⁹⁸ High and low contrast Bailey-Lovie^a charts for use at a three-metre test distance are available from the National Vision Research Institute of Australia <http://www.optometry.unimelb.edu.au/nvri/equipment.html>.

COLOUR VISION

ARM is characterised by a reduction in short-wavelength cone (S-cone) sensitivity,^{34,51,52} which probably is reflected clinically as a tritan defect on the Panel D-15 and/or desaturated D-15 tests, depending on the stage of the condition.^{40,45,47,49,53,64,103} Reduction in S-cone function discriminates between age-matched observers and eyes with good acuity (6/7.5 or better) but a fellow eye with AMD^{34,56} and is associated with progression to exudative AMD.⁵² Simi-

larly, the desaturated D-15 has been shown to discriminate between age-matched normal observers and participants with retinal pigmentary changes and/or drusen and normal VA.^{47,49,53} Schneck and associates⁸⁹ investigated the D-15, but not the desaturated D-15, for predicting future visual loss. While reduced D-15 colour discrimination was associated with subsequent visual loss, it was not as good a predictor as the tests of low contrast spatial vision.

The desaturated D-15 test has a high rate of false positives in discriminating between early ARM and normal vision observers,⁴⁰ probably because of the normal reduction in blue-yellow sensitivity with age.⁵⁵ However, the desaturated D-15 detects a greater functional loss in ARM than does the D-15 test,⁴⁶ so might be expected to detect earlier loss. In addition, we have found that poorer desaturated D-15 discrimination correlated significantly with lower objective visual function measured with the multifocal electroretinogram in early ARM (VA 6/12 or better).⁵³ Therefore, we suggest that the desaturated D-15 be included in a battery of tests to detect early colour visual loss in ARM. Once ARM is established funduscopically, the D-15 colour vision test is probably more useful for monitoring loss of colour vision.^{45,103}

Tests of adaptation dynamics

FLICKER PERIMETRY

Different versions of flicker perimetry are available with the Medmont (Medmont Pty Ltd, Camberwell, Victoria, Australia) and Octopus (Interzag AC, Schlieren, Switzerland) perimeters.¹⁰⁴ Recently, Phipps and colleagues⁶⁷ assessed macular visual fields with both static and flickering stimuli using the M-700 Medmont automated perimeter in participants with or at risk of early AMD (greater than five soft drusen with or without pigmentary changes or an end-stage choroidal neovascular lesion in the fellow eye) and age-matched control subjects, all with visual acuity of 6/12 or better. They found that flicker thresholds were significantly more affected than steady state thresholds in early AMD. Using the criterion of a flicker loss of 10 dB or more at any location in the foveal (one

degree to three degrees) rings gives high specificity (92 per cent) and sensitivity (84 per cent) for AMD. These results agree with those of Mayer and colleagues, who similarly found reduced foveal flicker sensitivity in eyes at risk of developing AMD^{78,79} and found it to be a good predictor of the development of exudative AMD.^{80,81}

Flicker perimetry is an easy and quick (four to seven minutes) procedure but it is essential to give clear instructions to the patient to avoid a high number of false positive responses.¹⁰⁵ Patients are required to respond only to the flicker or shimmer of the target, so practice is needed to reinforce instructions and to give positive reinforcement for correct responses. Further investigations are needed to confirm the usefulness of flicker perimetry for detecting ARM before fundus changes are visible but with careful administration, we recommend flicker perimetry for detecting and monitoring ARM, especially in those patients at risk.

GLARE RECOVERY

Glare recovery, also called photostress recovery, is impaired in ARM or in patients at risk of developing ARM.^{40,49,63,70,73,106} When the normal macula is exposed to an intense light source for a specified time, it will recover a defined level of function in a known time. Any deviation from normal retinal function will manifest as a prolonged recovery time. Lovie-Kitchin and Bowman⁸⁴ and others^{40,96,107,108} have described similar clinically-applicable approaches: the time to recover high or low contrast VA to one line above threshold after exposure to a glare source of known illuminance, usually viewed through a translucent opal filter, for a set exposure time is recorded. It is relatively easy for practitioners to establish a quick, easy and reproducible protocol to measure glare recovery for their own use and to determine normal values to validate their measurements with older patients.

The usefulness of the assessment of glare recovery for detecting early visual loss in older observers has been investigated by Haegerstrom-Portnoy and colleagues.^{31,33,89,99} From the range of visual

a. The first author has no proprietary interest in these charts.

functions assessed, glare recovery showed one of the greatest changes with increasing age. While glare recovery was significantly associated with future VA loss, it was no better than increasing age itself at predicting future loss of high contrast VA.⁸⁹

In contrast, the results of many studies^{40,49,63,70,72,97} indicate that glare recovery is a valuable tool for detecting early adaptational changes in ARM. The results of Collins and Brown^{49,70} suggest that assessment of parafoveal glare recovery detects dysfunction in ARM earlier than do tests of foveal adaptation. Thus, a clinical test of parafoveal glare recovery needs to be developed.⁴⁰ In the absence of a standardised, commercially available test (to the knowledge of the authors) or a validated procedure, further development and longitudinal clinical investigations are needed to determine the effectiveness of glare recovery for discriminating between normal age-related changes and early ARM before fundal changes are apparent and high contrast VA is reduced.

DARK ADAPTATION

Several studies have shown that dark adaptation in the central and peripheral retina is compromised in ARM and AMD^{35,90,91,93,109} and in eyes at risk of developing AMD.^{92,94} Evidence that rods are affected first in early ARM^{42,43} would suggest that dark adaptation should be performed routinely on older patients. However, given its time-consuming nature, investigations on its efficacy and cost-effectiveness at discriminating between normal age-related loss and early ARM would be needed before we would recommend it for routine clinical use.

Additional possible assessments

READING RATE

Recent research and the clinical experience of the first author suggest that a reduction in reading rate is often noticeable among older patients before significant visual loss.^{33,110-112} Lott and co-workers¹¹² found that reading ability declined with age among participants aged 58 years and older with good high contrast VA; this decline reflected reduced reading rate but

not accuracy. When measures of vision, some of which included significant cognitive demand, were taken into account, age was no longer a significant predictor of reading ability. This agreed with the findings of the Salisbury Eye Evaluation (SEE) study, in which measures of vision and health but not age predicted self-reported visual task difficulties.¹¹³ Thus, we speculate that while reduced reading rate may reflect early cognitive changes in some older people, it may also relate to the first symptoms of visual impairment and would be worth assessing in older patients as a possible means of detecting ARM. As ARM progresses, it is important to monitor reading rate with respect to future low vision management, as it becomes severely impaired with visual loss in AMD (see below).

Reading rate can be measured directly with a stop-watch for decreasing print sizes using either lines of unconnected words, for example with Bailey-Lovie word charts,¹¹⁴ or short sentences, such as with the MNRead chart¹¹⁵ or at least some assessment of fluency can be made by listening to the patient read print of decreasing sizes.¹¹⁶ As the patient approaches threshold print size (normally three point (N3) print at 40 cm when best corrected), their reading rate will slow. It is valuable to record the print size one line above the size at which the first noticeable decrease in reading rate is heard. That print size, the smallest giving maximum reading rate, is referred to as the Critical Print Size¹¹⁷ and on average is three lines above threshold, although this varies among older observers with and without visual loss.^{116,118}

CONTRAST SENSITIVITY

Tests of contrast sensitivity have often been investigated and/or recommended for the evaluation of visual performance in ARM.^{57,63,95,96,119} While these studies have found reduced contrast sensitivity in ARM, in the opinion of the authors, its value for early detection of ARM has not been established.¹¹⁹ A number of easily administered chart-based tests of contrast sensitivity have been developed¹²⁰⁻¹²² but these are not used commonly in clinical practice. Schneck and associates⁸⁹ found the Pelli-Robson letter contrast sensitivity test¹²¹ was

not as good as the SKILL score or low contrast VA for predicting future visual loss, so we do not recommend a test of contrast sensitivity for routine clinical use.

AMSLER GRID

The Amsler grid does not provide reliable or precise, quantifiable measures of visual field defects and is not recommended for clinical, diagnostic use.¹²³ Cheng and Vingrys⁴⁰ found that a low contrast (18 per cent) Amsler grid was more sensitive than the conventional Amsler grid for detecting central visual field defects in early ARM but this is not commercially available. The take-home Amsler grid is a simple and easy method for older patients to self-monitor their visual status and has been commonly recommended. Its efficacy for the early detection of patients who will benefit from treatment for exudative AMD is limited¹²⁴ but if it detects even one person with early central visual loss that is treatable or who will benefit from more regular vision care, it is worth recommending.

The steady state visual function tests we have recommended above are essentially low contrast tests that detect subtle sub-clinical visual loss that conventional VA measures do not detect. Older persons with good high contrast VA who score at the low end of the range on SKILL VA or low contrast VA have a nearly 50 per cent chance of significant VA loss in the next four to five years.^{33,89} To our knowledge, the effectiveness of the desaturated D-15 and reading rate at predicting subsequent visual loss has not been examined in longitudinal studies. Tests of glare recovery and flicker perimetry are likely to prove valuable for detecting early macular dysfunction and ideally a test of dark adaptation should be performed given that rods are first affected in ARM.^{42,43} The battery of clinical tests recommended above agrees well with the recommendations of Phipps, Guymer and Vingrys⁶³ to include combinations of cone-mediated tests of adaptation, temporal, spatial and colour functions, which for their small sample of subjects correctly identified 88 per cent of ARM eyes (with early fundal changes), while in their study, a test of glare recovery plus one other test correctly classified

75 per cent of ARM eyes.

The routine use of these tests of vision also gives a better understanding to both the optometrist and the older patients of the visual impairment experienced in real world conditions of low contrast, low luminance or glare.^{31,33,89}

Until clinical trials prove the efficacy of a battery of tests such as we and others have proposed and the effective use of preventative treatments in patients with early (sub-clinical) visual loss, the role of the optometrist is to monitor closely those patients who are at risk of ARM. We suggest that patients with impaired function on one or more of the tests we have recommended, in the absence of funduscopic changes, should be assessed every 12 months. Patients with AMD in the fellow eye or a family history of AMD, smokers and those with other cardiovascular risk factors such as hypertension or diabetes should also be monitored closely.¹²⁵⁻¹²⁸

While antioxidants and zinc have been shown to be effective at slowing the progression of visual loss in patients with large, soft drusen, unilateral moderate AMD or advanced AMD in the fellow eye, a preventative use has not been proven.³⁰ Similarly, with our current knowledge of the disease, referral for ophthalmological investigation and intervention (fluorescein angiography, laser therapies et cetera) is not indicated until there are visible retinal changes at the earliest. The future goal is the prevention of the development of ARM. Whether this can be achieved by a healthy diet combined with antioxidants and/or a stricter medical treatment regime, similar to that for general cardiovascular diseases, for patients identified to be at risk by these more sensitive visual function tests still needs to be investigated.

MONITORING PROGRESSION OF VISUAL LOSS IN AMD AND PREDICTING ACTIVITY LIMITATIONS

For the majority of patients with ARM, the condition will progress to AMD which, especially for the atrophic form, will not be amenable to medical or surgical treatment. As indicated above, only a small proportion of those patients with the

neovascular form of AMD will receive laser therapy, which may stabilise vision^{24,25} but most will experience little or no improvement in vision. Hopefully the optometric care of these patients is a continuum over many years, from the time of normal vision, to the first sub-clinical dysfunction, to symptoms and fundal changes (ARM) and then, unfortunately for many, to progressive visual loss (AMD). The role of the optometrist becomes one of monitoring visual loss and gradually introducing low vision care, especially magnification and advice on lighting and contrast, in conjunction with other vision rehabilitation professionals. To monitor progressive visual loss in AMD and to determine activity limitations and the need for vision rehabilitation, more conventional subjective tests of vision are used than those proposed above.

High contrast distance visual acuity

The Bailey-Lovie letter chart¹⁰¹ has become accepted as the standard for VA measurements in clinical research,¹²⁹ although perhaps not in clinical practice.¹³⁰ Practitioners should be encouraged to use charts of this design to improve the precision of VA measurements for all patients but especially patients with progressive visual loss. Brown and Yap¹³¹ showed that for any individual patient a difference in visual acuity between right and left eyes, or a loss of VA, of greater than five letters (one line) is indicative of pathology. When measuring VA, the patients should be encouraged to guess as they approach their limit of resolution to ensure that a threshold measure is taken. Scoring VA letter-by-letter doubles the sensitivity of the VA test to detect changes in vision compared to scoring row-by-row.¹³² If VA is reduced in AMD, the position of letters missed gives an indication of the presence and position of scotomas.^{1,84,95}

Distance VA is not a strong predictor of everyday performance of people with AMD on tasks such as mobility^{133,134} or face recognition¹³⁵ but it can be used as the basis for advice for some everyday tasks. The easiest way to compensate for reduced distance VA is to recommend a reduction in the viewing distance for the task (proxi-

mal magnification), if it is safe to do so. For example, if a person with AMD reports difficulty seeing the television, they should be reassured that a closer seating position is safe and they should sit to the side of the worse eye. The recommended viewing distance can be determined from the VA, remembering that the linear size of detail that can be resolved is proportional to the viewing distance. For example, a person who reads the 60 m line on the VA chart at 6.0 metres can be expected to resolve detail equivalent to the 30 m line from 3.0 metres, the 15 metre line from 1.5 m and so on. From this, a 1.5 metre or 1.0 metre viewing distance might be recommended for television viewing for the AMD patient with a distance VA of 6/60. The linear extent of any scotoma is also reduced with a decreased viewing distance.⁸⁴

Near (reading) visual acuity and reading rate

As indicated above, one of the first signs or symptoms of visual loss in ARM may be a reduction in reading rate. Near VA is a good predictor of reading rate.^{112,118,136-138} As ARM progresses to AMD, both near VA and reading rate will reduce and both should be assessed. To detect the early reduction in near VA, the patient must be encouraged to read to the limit of resolution and the optometrist must use a reading acuity chart (preferably with words or text, rather than letters) with print small enough to determine threshold size. The smallest print size read, the clearest viewing distance and the current near addition should be recorded. If the near addition is not equal to the dioptric equivalent of the clearest distance, this may indicate a need for refractive change, for example, a clearest distance of 25 cm with a +2.50 D addition suggests that either the distance prescription is excess plus or the patient may be tolerating blur to give an enlarged retinal image with the closer distance (proximal magnification). If near VA is a lot worse than distance VA,^b a scotoma is

b. For a 40 cm test distance the Snellen denominator is approximately two times the N point, for example, N8 at 40 cm is approximately 6/15.

probably impeding near vision.¹¹¹

At first, a reduction in near VA and reading rate may be compensated by an increase in illumination (see below) but an increase in the near addition will probably be the start of vision rehabilitation for most patients with AMD. With progression of AMD, higher levels of magnification will be needed for reading tasks. Recommended procedures for determining the magnification, which needs to be high enough to provide sufficient acuity reserve to enable a useable reading rate, have been described previously.^{110,116,139}

Reading performance with AMD is impeded by more than reduced VA; the visual field loss also has a significant impact.^{118,136} Magnification can compensate for reduced VA and reading rate but not for the effects of a scotoma.¹¹⁸ The position and size of the scotoma and the adaptation to eccentric viewing¹⁴⁰ mean that maximum achievable reading rate with magnification (using large print, optical or closed-circuit television systems) for people with AMD is usually between 30 and 100 words per minute.^{118,136} Thus, with moderate or severe AMD, patients will never return to their 'normal' (pre-AMD) reading fluency using any magnification devices. Extensive training may improve some patients' reading rates, although well-controlled studies have not proven the efficacy of such training programs.¹⁴¹ In our laboratory, we have found that provided sufficient magnification is prescribed, patients with AMD using illuminated stand magnifiers do not need extensive training to achieve their maximum, albeit slow, reading rate.¹⁴² Despite the relatively slow reading rate achievable with central visual loss, many patients are satisfied with this for short term, 'survival' tasks. Other non-visual ways of accessing information can be used for work or recreational tasks if necessary.^{143,144}

Visual field assessment

In 1981, the first author suggested using a tangent screen to assess the visual field defect in AMD.¹ For the purposes of vision rehabilitation that instrument is still appropriate but the recommended method of assessment has been modified.¹⁴⁵

Automated static perimetry can be used in early or moderate AMD^{146,147} but visual field assessment is not necessary or practical for monitoring visual loss in AMD. Once a diagnosis of AMD is confirmed, the main purpose of visual field assessment is to determine the size and position of any scotoma, as these impact on tasks such as reading and mobility; these characteristics of the scotoma can be readily assessed with a tangent screen. Binocular visual field loss is the strongest predictor of mobility performance in low vision patients with AMD.^{133,134} Thus, for determining the impact on mobility, visual fields should be assessed binocularly. Similarly, the presence, size and position of a central scotoma are very strong predictors of reading performance in AMD.^{117,118} As most patients with AMD read monocularly, the central visual field should be assessed monocularly to determine the effect on reading performance.¹⁴⁵

Most patients with well-established AMD develop one (or more) parafoveal preferred retinal locus (PRL).^{148,149} As indicated above, the position, size and stability of this eccentric viewing position have significant effects on reading in particular.¹⁴⁰ Using a one-metre tangent screen and instructing patients with AMD to fixate (eccentrically) so that they can clearly see a large fixation target will enable most patients to maintain stable fixation. Threshold assessment of the central field is not needed, so a large test target, for example, 10 or 20 mm can be used to plot the size and position of the scotoma.¹⁴⁵ If the scotoma is positioned to the left and/or above fixation, that is, the right and lower visual fields are open, reading (in English) will not be severely impeded by the scotoma. If the right field is not open, eccentric viewing training may be needed for reading but many patients spontaneously learn to position their scotoma appropriately for the task. For mobility also, it is desirable that fixation is below any binocular scotoma so that the inferior field is open.¹⁵⁰ Patients often adopt different eccentric fixation positions for these different tasks or for different conditions.¹⁵¹

Effects of increased illumination

Adaptation is abnormal in ARM and AMD. Knowing this, from the functional point of view the optometrist can advise patients on appropriate lighting conditions for safety and maximum visual performance. Various studies have shown that the effect of varying illumination differs among individuals with AMD, especially for reading.^{84,152,153} Bowers, Meek and Stewart¹⁵³ recommended that near VA and reading rate be assessed at low (5 to 20 lux), medium (100 to 300 lux) and high (2,000 to 5,000 lux) illuminances, using dim room lighting, normal room lighting and a reading lamp 20 cm or less from the reading material, respectively. Using these results, optometrists can advise on appropriate, adjustable lighting for reading and writing, positioned to the side away from the writing hand, to avoid glare and shadows. Some patients with AMD show best VA and reading performance at very high light levels, while a few show marked reductions in VA and reading rate at moderate and high illuminances,^{84,153-155} indicating that each patient's own response to varying illumination needs to be assessed.

Contrast sensitivity

In many studies, contrast sensitivity has been shown to be useful for monitoring the progression of visual loss in AMD and its treatment¹⁵⁶⁻¹⁵⁸ and as a predictor of performance on many everyday activities. In AMD, contrast sensitivity is a strong predictor of reading performance,¹⁵⁹ face recognition,¹³⁵ mobility^{133,134} and other visual discrimination tasks.¹⁶⁰ As indicated above, contrast sensitivity can be assessed using a number of easily administered chart-based tests¹²⁰⁻¹²² but they are not commonly available in clinical practice. Low contrast visual acuity is strongly correlated with contrast sensitivity measures^{87,99} and while this does not mean that these measures should replace contrast sensitivity measures,⁸⁹ for the purposes of monitoring visual loss and predicting difficulties with daily activities, the SKILL or low contrast VA test would be satisfactory and in fact, for predicting performance on tasks such as reading may be preferred.¹⁵⁹

When contrast sensitivity is reduced,

there are limited strategies to improve performance. Optimum lighting (see above), minimising glare and reversing or increasing print contrast, commonly using video devices such as closed-circuit television or computer based devices, are the only interventions for enhancing contrast. If contrast sensitivity is severely impaired, non-visual techniques (for example, books on tape) may be required.¹⁵⁹

Multidisciplinary vision rehabilitation

Recent well-controlled studies have not been able to prove conclusively the value of multidisciplinary vision rehabilitation services compared to other low vision services^{141,161,162} but there is good evidence that optometric vision rehabilitation is effective in improving task performance and quality of life.¹⁶¹⁻¹⁶⁶ The best battery of clinical tests to predict functional abilities with low vision on a range of everyday tasks has not yet been determined,¹¹² although there have been attempts to do so.¹⁶⁷ Meanwhile, use of the results of the subjective tests of vision described above will enable optometrists to respond to recent calls to improve the management of AMD patients¹⁶⁸⁻¹⁷⁰ by regularly and accurately assessing their vision using the (mostly) standardised and validated clinical measures described above. The results can be used to give appropriate advice and/or optometric low vision care to improve the functional ability and quality of life of patients with AMD.

CONCLUSIONS

There are now more effective subjective tests of vision available for detecting and diagnosing ARM than those available 25 years ago. We recommend a battery of clinical tests comprising SKILL VA or low contrast VA, desaturated D-15 colour vision assessment, flicker perimetry, glare recovery and dark adaptation if possible, for the detection and diagnosis of ARM. These should be administered, in conjunction with conventional assessments of case history, ophthalmoscopy and high contrast VA, to all patients aged 60 years and over and certainly anyone exhibiting risk factors for AMD. The more conventional sub-

jective tests of distance VA, near VA, reading rate, central visual field assessment and the effects of increased illuminance, with some modifications to the methods of assessment, are still adequate for monitoring the progression of ARM and AMD. Considerable research has shown that the results of these tests are useful for predicting limitations of patients' activity and indicating their rehabilitative needs, although case history will always be the most important assessment for this purpose.

Early detection of ARM and referral for medical or surgical treatment if indicated, together with prompt implementation of optometric vision rehabilitation will help to minimise the visual disability experienced by many people with AMD. Optometrists have a crucial role in assessing visual function and providing appropriate advice and management, over the whole range of visual performance in patients with ARM and AMD, from prior to the first symptoms and retinal signs to the time when all useable central vision may be lost. Appropriate use of available practical, subjective, clinical tools can improve greatly our management and care of patients with macular disease.

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