Comparison of stereoscopic digital imaging and slide film photography in the identification of macular degeneration

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ABSTRACT • RÉSUMÉ

Background: This study compared the sensitivity and specificity of stereoscopic digital photography of the retina through a dilated pupil with a 45° nonmydriatic camera and Joint Photographic Experts Group (JPEG) compression of the images with the sensitivity and specificity of 35-mm slide film photography in the identification of age-related macular degeneration (AMD).

Methods: Consecutive patients with a diagnosis of AMD were enrolled. Stereoscopic retinal images of the disc, macula and temporal macula were captured with a digital 45° nonmydriatic camera (then compressed into JPEG format) and with a standard fundus camera and slide film. A single retinal specialist graded both image formats in masked fashion, at least 1 month apart, using a modified Age-Related Eye Disease Study (AREDS) severity scale. The digital images were displayed on a monitor and viewed with the use of liquid crystal display shutter glasses and stereo imaging software. The film images were mounted on a light box and graded with the use of a stereoviewer. Primary outcome measures included the presence or absence of AMD pathological features. Positive and negative predictive values (PPVs and NPVs), sensitivity, specificity and weighted $\kappa$ statistics were calculated.

Results: We photographed 203 eyes (of 103 patients) with both digital and slide film cameras. Correlation of the 2 image formats was substantial in identifying AREDS level 3a or greater ($\kappa = 0.64$, standard error = 0.08, PPV = 0.95, NPV = 0.66, sensitivity = 0.93, specificity = 0.74) and excellent in identifying level 4b or greater ($\kappa = 0.83$, standard error = 0.05, PPV = 0.81, NPV = 0.98, sensitivity = 0.94, specificity = 0.94).

Interpretation: High-resolution stereoscopic, mydriatic, 45° digital images captured with a nonmydriatic camera and JPEG compressed correlate well with stereoscopic slide film photographs in the identification of moderate to advanced AMD (AREDS level 3a or greater).

Contexte : Cette étude compare la sensibilité et la spécificité de la photographie numérique stéréoscopique de la rétine, avec pupille dilatée, avec une caméra non

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This article has been peer-reviewed.

Age-related macular degeneration (AMD) is the most common cause of irreversible blindness in North America.\(^1\) Currently, AMD patients are evaluated by means of clinical examination with slit-lamp biomicroscopy coupled with adjuncts such as stereoscopic slide film photography, fluorescein angiography and optical coherence tomography. These patients face several difficulties: a disease in evolution between referral and specialist assessment, limited treatment options and delay in diagnosis. A method to screen patients for treatable AMD would be beneficial.

Photographic screening is a method used to identify retinal diseases.\(^2\)\(^–\)\(^5\) Previous studies have shown that slide film photography is both sensitive and specific when compared with slit-lamp examination in the identification of AMD.\(^6\) It also has the advantage of providing a more permanent and objective record. For this reason, most AMD-related research studies have used standard stereoscopic slide film photography of the retina to identify macular disease.\(^7\)\(^–\)\(^9\)

Outside of a research setting, standard stereoscopic slide film fundus photography is not ideal when compared with clinical examination. First, slide film is expensive to purchase and develop. Second, standard fundus cameras are technically difficult to operate, requiring an experienced photographer to capture subtle retinal detail. To overcome these disadvantages, many eye care specialists now incorporate a digital nonmydriatic fundus camera as part of an eye examination for efficient photo documentation of the retina.

Digital retinal imaging provides certain advantages when compared with slide film photography. Images can be reviewed for quality and content at the time of capture, both by the photographer and by the patient. This helps patients to better understand their eye disease. Furthermore, digital images can be transferred electronically, thereby improving access to medical information. Although many teleophthalmology applications\(^10\)\(^–\)\(^15\) do not incorporate stereopsis, advances in both software and hardware have made it easy to integrate stereoscopic photography into a basic teleophthalmology system.\(^16\)\(^–\)\(^20\)
Our study was designed to answer 2 questions. First, when compared with 30° stereoscopic slide film photography, is stereoscopic 45° digital imaging of the retina with 16:1 Joint Photographic Experts Group (JPEG) compression as sensitive and specific in the identification of treatable AMD? Second, is there significant agreement between these 2 modalities? In answering these questions, we hoped to determine whether compressed stereoscopic digital images could be used to identify patients who would benefit from oral antioxidant therapy or further testing with fluorescein angiography. In particular, we were interested to see whether stereoscopic digital imaging could identify eyes with AMD of Age-Related Eye Disease Study (AREDS)21 level 3a or greater and AREDS level 4b or greater.

Methods

Ethics approval was obtained through the Health Research Ethics Board of the University of Alberta. A formal power calculation could not be performed because of the descriptive nature of the study, comparing correlative data in the form of weighted kappa ($\kappa_w$) statistics, sensitivity, specificity, predictive values and likelihood ratios. A review of the medical literature revealed 2 studies that compared digital imaging and slide film photography for identifying macular degeneration.22,23 These studies provided information regarding the sensitivity, specificity, and positive and negative predictive values (PPVs and NPVs) of digital imaging. Both studies enrolled fewer than 100 patients. Other studies comparing digital imaging and slide film photography for identifying other retinal disorders, such as diabetic retinopathy, have typically enrolled approximately 50 to 100 volunteers.18,19 We therefore selected the higher end of the “standard” as our sample size and recruited approximately 100 subjects. Eligibility requirements included new referral for all types of AMD, ability to undergo retinal photography and age 50 years or greater. Exclusion criteria included any confounding retinal abnormality if it precluded a diagnosis of macular degeneration.

Consecutive new patients referred to a group retina practice for AMD evaluation were invited to participate in the study. Based on the average number of AMD referrals per month to the practice, an enrollment period of 4 months was chosen. Patients were enrolled consecutively between June 1 and Sept. 1, 2004. After informed consent was obtained, their pupils were dilated with 2.5% phenylephrine and 1% tropicamide eye drops, and they underwent stereoscopic retinal imaging with both digital and slide film photography.

Digital fundus photographs were taken with a 45° nonmydriatic camera (Topcon TRC-NW6S, Paramus, NJ) linked to a digital camera (Nikon D100, Melville, NY) (resolution 3008 × 2000 pixels). Patients were instructed to focus on a green fixation target, which could be manipulated by the office technician to capture various areas of the retina. Nonsimultaneous stereoscopic 45° paired images were captured of the optic disc (standard field 1), macula (standard field 2) and temporal retina (standard field 3) through a cornea-induced parallax. The photographs were assessed for quality at the time of capture and retaken if necessary.

Once captured, each 17.2-MB (24 bits/pixel) Tagged Image File Format (TIFF) image was 16:1 lossy-compressed to a 1.1-MB (1.5 bits/pixel) JPEG image with the Microsoft GDI+ graphics library. Each image set was then uploaded onto a secure Web server (Secure Diagnostic Imaging Inc., Edmonton, Alta.) for review and grading.

The digital stereoscopic images were viewed with the use of liquid crystal display (LCD) shutter glasses (StereoGraphics Corporation, San Rafael, Calif.) and stereo imaging software (SDI Stereoviewer, Secure Diagnostic Imaging Inc.) on a 21-in. (53-cm) monitor (P260, IBM, New York, NY). The screen resolution was set to 1024 × 768 pixels, and the minimum threshold (100 Hz) for the refresh rate required by the LCD goggles was set. Monitor brightness and contrast were set to the factory default. Ambient light levels in the room were similar to those used for clinical funduscopic examination. The grader had the option of zooming in to view the image at the maximum pixel resolution, as well as increasing or decreasing gamma correction.

Images were graded according to a modified AREDS protocol (Table 1). Retinal areas were calculated following image calibration using the distance between the central fovea and the edge of the disc as a standard 3840 $\mu$m. The grader was able to outline single or multiple areas of retina. The area of involved retina was then transformed into numerical disc areas by the calibrated software.

Stereoscopic 30° film photographs of the optic disc, macula and temporal retina were captured with a mydriatic camera (Zeiss FF450, Carl Zeiss Meditec,
Jena, Germany) on slide film (Ektachrome, Eastman Kodak, Rochester, NY). The film was mounted on a light box and graded with the use of a +5.00 stereoviewer, according to the same modified AREDS protocol. Area measurements were performed with the AREDS standard area circles.\textsuperscript{24}

The grading of digital and film photographs was separated by a minimum of 1 month and was done in masked fashion by a single grader (M.T.). Intrareader variability was assessed by having the same grader, in masked fashion, 1 month after the original grading, regrade a subset of digital images from 20 patients (40 eyes) randomly selected from the group. Both formats were evaluated for maximum drusen size and area, geographic atrophy, retinal pigment epithelium (RPE) depigmentation or hyperpigmentation, subretinal fibrosis, evidence of previous laser photocoagulation, serous retinal or hemorrhagic detachment, subretinal or sub-RPE hemorrhage and fibrovascular or serous pigment epithelial detachment (PED). The reader received extensive training by a consultant formerly employed at the Wisconsin Reading Center, Madison, Wis. Results from the digital and slide grading forms were compiled and assigned a corresponding modified AREDS level.

The extent of agreement between digital and slide gradings for right and left eyes was evaluated with $\kappa_w$, a linear-weighted version of the intraclass correlation coefficient $\kappa$.\textsuperscript{25} The value was determined assuming a dichotomous variable, that is, the presence or absence

\[\begin{array}{|c|c|c|c|}
\hline
\text{AREDS level} & \text{Modified Alberta criteria} & \text{Imaging technique; no. of eyes} \\
\hline
0 & No signs of age-related macular degeneration (AMD) & Digital & Slide film \\
1 & Drusen maximum size < C-0 (63 $\mu$m in diameter) and total area < C-1 (125 $\mu$m) & 6 & 0 \\
2 & Presence of 1 or more of the following: & & \\
2a & Drusen maximum size $\geq$ C-0 but < C-1 & 2 & 4 \\
2b & Drusen total area $\geq$ C-1 & 11 & 9 \\
2c & Retinal pigment epithelium (RPE) pigment abnormalities consistent with AMD, defined as 1 or more of the following in the macula: & & \\
2c1 & Depigmentation & 3 & 10 \\
2c2 & Increased pigment $\geq$ C-1 & 3 & 5 \\
2c3 & Increased pigment and depigmentation at least questionable & 4 & 3 \\
3 & Presence of 1 or more of the following: & & \\
3a & Drusen maximum size $\geq$ C-1 & 11 & 17 \\
3b & Drusen maximum size $\geq$ C-0 and total area $> l$-2 & 17 & 11 \\
3c & Drusen maximum size $\geq$ C-0 and total area $> o$-2 & 74 & 79 \\
4 & Presence of 1 or more of the following: & & \\
4a & Geographic atrophy within the macula & 9 & 16 \\
4b & Evidence of neovascular AMD & & \\
4b1 & Fibrovascular or serous pigment epithelial detachment (PED) & 9 & 5 \\
4b2 & Serous or hemorrhagic sensory retinal detachment & 15 & 11 \\
4b3 & Subretinal or sub-RPE hemorrhage & 26 & 24 \\
4b4 & Subretinal fibrosis & 7 & 8 \\
4b5 & Evidence of previous laser photocoagulation & 1 & 1 \\
\hline
\end{array}\]
of AMD pathological features. This process is more accurate than calculating separate $\kappa$ values for the right and left eyes and pooling them or calculating $\kappa$ as if the left and right eyes were independent.\(^{26}\) In addition, $\kappa_w$ provides a single global measure of agreement for the 2 eyes, and the standard error (SE) formulas still apply to the calculations.\(^{27,28}\) Pairs of eyes yielding the same diagnoses from the 2 image formats were assigned a full weight of 1, indicating perfect agreement for both eyes. Pairs of eyes for which there was agreement for only 1 eye were given a weight of 0.5, indicating partial agreement. The guidelines for evaluating the coefficients were as follows: $\kappa_w \leq 0.4$ indicated marginal reproducibility, $0.4 < \kappa_w \leq 0.6$ indicated fair reproducibility, $0.6 < \kappa_w \leq 0.8$ indicated substantial reproducibility and $\kappa_w > 0.8$ indicated excellent reproducibility.\(^{29}\) Approximate 95% confidence intervals (CIs) were constructed for the $\kappa_w$ values calculated for each of the diagnoses. In addition, tests of the hypothesis $\kappa_w = 0$ were carried out at a 5% level of significance.

Sensitivities, specificities, PPVs and NPVs were calculated for features of AMD and AREDS levels. Sensitivities and specificities were calculated with film imaging, considered the gold standard. Corresponding PPVs and NPVs were then derived. Sensitivities, specificities, PPVs and NPVs for stereoscopic digital imaging were calculated separately for left and right eyes. Overall estimates obtained by combining the left and right eye readings and treating them independently were also calculated. The overall estimates were biased, as they ignored the correlation between the eyes. Overall likelihood ratios and CIs were also calculated.\(^{30,31}\)

To compare the ability of digital and film imaging to identify the presence or absence of choroidal neovascularization (CNV), we performed McNemar’s test. The “true” diagnosis of CNV was defined as either the presence of CNV on fluorescein angiograms or a notation of no CNV on follow-up clinical records. Two separate analyses were conducted: the first defined the ability to identify CNV, and the second assessed the ability to identify the absence of CNV.

**RESULTS**

Over the 4-month period 103 patients (63 women and 40 men) with AMD were recruited. They ranged in age from 50 to 92 (median 78) years. There was a family history of AMD in 17%, a history of smoking in 8% and a history of hypertension in 5%; 6% had undergone previous treatment for AMD.

Digital photographs were not captured for 1 eye, for which slide film photography showed subretinal fibrosis consistent with a disciform scar; without digital images for comparison, this eye was excluded from the study. Slide film images were not captured for single eyes of 2 patients; digital photography revealed macular drusen in both eyes, and they were excluded. As calculation of $\kappa_w$ relies on paired data, the 3 patients with monocular data were excluded, thereby eliminating a further 3 eyes from the comparison study. Thus, 200 eyes of 100 patients were included in the final analysis. Concordance between digital and film imaging was calculated for features of AMD and for treatable AREDS level.

All eyes photographed were considered to be gradeable by the reader. Submacular hemorrhage or subretinal fibrosis precluded accurate grading of certain features associated with macular degeneration in 6 eyes, but a final AREDS grading level was still assigned to all 6 eyes.

Certain features associated with early AMD were not well delineated by stereoscopic digital photography (Table 2). These included small (< 63 µm in diameter) and intermediate (63–125 µm) drusen and small total area of drusen (< I-2). Although this technique was insensitive in identifying small and intermediate drusen (sensitivity 0% and 31%, respectively), it was highly specific (specificity 97% and 87%, respectively). Predictably, correlation was poor for both small ($\kappa_w = 0.09$) and intermediate ($\kappa_w = 0.18$) drusen. For the smallest drusen area (< C-1), stereoscopic digital photography had 0% sensitivity, 10% specificity and poor correlation ($\kappa_w = 0.09$). The next stratum of drusen area (C-I ≤ x < I-2), however, was better delineated, with 72% sensitivity, 82% specificity and fair correlation ($\kappa_w = 0.46$).

Other features of early AMD, such as pigmentary changes, were identified more clearly by stereoscopic digital photography. The technique was slightly more sensitive in detecting RPE hyperpigmentation than in detecting RPE depigmentation (sensitivity 76% vs. 67%); the specificity was 92% for both conditions. For pigmentary abnormalities, there was fair (depigmentation, $\kappa_w = 0.56$) to substantial (hypermelanization, $\kappa_w = 0.62$) correlation between imaging formats.

To identify patients who would benefit from oral antioxidant therapy (those with AREDS level 3a or greater) a system must be able to identify and grade...
several abnormalities: large drusen (> C-1), moderate overall area of drusen (> I-2), geographic atrophy and features of neovascular AMD. For the detection of large drusen, stereoscopic digital photography had 90% sensitivity but only 55% specificity; there was fair correlation ($\kappa_w = 0.49$) between the photographic formats. For the detection of large areas of drusen (> O-2), stereoscopic digital photography had 80% sensitivity and 86% specificity, and there was substantial correlation with identification from film photography ($\kappa_w = 0.65$). For the detection of drusen areas from moderate to large (I-2 ≤ $x$ < O-2), stereoscopic digital photography had only 14% sensitivity but 87% specificity, yet the 2 image formats correlated poorly ($\kappa_w = 0.01$). The identification of geographic atrophy was 100% sensitive and 98% specific and had excellent correlation with the gold standard ($\kappa_w = 0.86$).

The ability to identify eyes with features of neovascular AMD such as subretinal or sub-RPE hemorrhage, subretinal fibrosis, evidence of previous laser photoabulation, serous or hemorrhagic retinal detachment and fibrovascular or serous PED is of particular importance for any AMD screening tool. If features of wet AMD can be identified, the patient can be referred for fluorescein angiography, clinical examination or both. Stereoscopic digital photography was fairly sensitive in identifying most features of neovascular AMD, sensitivities ranging from 75% for subretinal fibrosis to 100% for evidence of previous laser photocoagulation. However, the new image format was relatively insensitive (56%) for identifying fibrovascular or serous PED (AREDS level 4b1). Specificity was high for all features of neovascular AMD, ranging from 91% for fibrovascular or serous PED to 100% for evidence of previous laser photocoagulation. There was good to excellent correlation for all abnormalities except fibrovascular or serous PED, which demonstrated marginal reproducibility ($\kappa = 0.37$).

Because the overall goal of an AMD teleophthal-

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**Table 2—Concordance of stereoscopic digital and slide film imaging when identifying features of AMD in 200 eyes**

<table>
<thead>
<tr>
<th>AMD feature</th>
<th>PPV</th>
<th>NPV</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>$\kappa_w$</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum drusen size (µm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 63</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>63–125</td>
<td>0.31</td>
<td>0.31</td>
<td>0.31</td>
<td>0.31</td>
<td>0.31</td>
<td>0.31</td>
</tr>
<tr>
<td>&gt; 125</td>
<td>0.83</td>
<td>0.85</td>
<td>0.84</td>
<td>0.84</td>
<td>0.84</td>
<td>0.84</td>
</tr>
<tr>
<td>Maximum drusen area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; C-1</td>
<td>0.00</td>
<td>0.33</td>
<td>0.17</td>
<td>0.95</td>
<td>0.96</td>
<td>0.95</td>
</tr>
<tr>
<td>≥ C-1 &lt; I-2</td>
<td>0.43</td>
<td>0.55</td>
<td>0.49</td>
<td>0.93</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>≥ I-2 &lt; O-2</td>
<td>0.07</td>
<td>0.18</td>
<td>0.12</td>
<td>0.88</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>≥ O-2</td>
<td>0.92</td>
<td>0.85</td>
<td>0.89</td>
<td>0.74</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>RPE depigmentation</td>
<td>0.67</td>
<td>0.38</td>
<td>0.52</td>
<td>0.96</td>
<td>0.98</td>
<td>0.98</td>
</tr>
<tr>
<td>RPE hyperpigmentation</td>
<td>0.76</td>
<td>0.90</td>
<td>0.83</td>
<td>0.89</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>Geographic atrophy</td>
<td>0.71</td>
<td>0.80</td>
<td>0.76</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Subretinal or sub-RPE hemorrhage</td>
<td>1.00</td>
<td>0.75</td>
<td>0.88</td>
<td>0.98</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Subretinal fibrosis</td>
<td>1.00</td>
<td>0.75</td>
<td>0.86</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Previous laser photoabulation</td>
<td>1.00</td>
<td>*</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Serous or hemorrhagic retinal detachment</td>
<td>0.93</td>
<td>0.80</td>
<td>0.85</td>
<td>0.95</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>Fibrovascular or serous PED</td>
<td>0.50</td>
<td>0.25</td>
<td>0.35</td>
<td>0.97</td>
<td>0.95</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Note: PPP = positive predictive value; NPV = negative predictive value; OD = right eye; OS = left eye; $\kappa_w$ = weighted kappa; SE = standard error.

*Unable to calculate owing to division by zero.
mology system is to delineate an overall AREDS level rather than to identify isolated features of AMD, we were particularly interested in how stereoscopic digital photography would correlate with slide film photography in sorting eyes by AREDS levels (Table 3). Digital imaging had difficulty identifying early features of AMD, and it therefore was also not as sensitive (79%) in assigning a diagnosis of AREDS levels 0 to 2c3, diagnoses that would not result in any intervention. In comparison, it was very sensitive in identifying patients who would benefit from oral vitamin supplementation (AREDS level $\geq 3a$) and those who should be evaluated clinically (AREDS level $\geq 4b$), with sensitivities of 93% and 94%, respectively; specificity was more variable, ranging from 74% (level $\geq 3a$) to 94% (level $\geq 4b$).

Stereoscopic digital photography had good to excellent correlation, respectively, with slide film photography for AREDS level 3a or greater and AREDS level 4b or greater. Correlation of the 2 image formats was substantial in identifying AREDS level 3a or greater ($\kappa_w = 0.64$, SE = 0.08, PPV = 0.95, NPV = 0.66, sensitivity = 0.93, specificity = 0.74) and excellent in identifying level 4b or greater ($\kappa_w = 0.83$, SE = 0.05, PPV = 0.81, NPV = 0.98, sensitivity = 0.94, specificity = 0.94).

For the subset of 40 eyes regraded to assess intrareader variability with digital images, the correlation between gradings (Table 4) was low when identifying AREDS level 2c3 or less ($\kappa_w = 0.46$) and level 4a or less ($\kappa_w = 0.46$) but high when identifying AREDS level 4b or greater ($\kappa_w = 0.89$) and level 3a or greater ($\kappa_w = 0.88$).

Discrepancies between gradings were reviewed. Thirteen eyes were found to have a diagnosis of wet macular degeneration with one imaging modality and dry macular degeneration with the other (Table 5). The charts of the 12 patients were reviewed to identify a “true” diagnosis, which was made if the results of fluorescein angiography were known or the patient had been followed clinically for a minimum of 6 months. In 2 eyes wet macular degeneration had been identified by slide film photography but missed by digital imaging. The reverse was true for another 2 eyes. Seven eyes had been identified incorrectly by digital imaging as having features consistent with wet AMD, when in fact they had dry macular degeneration.

The probability of detecting AREDS level 4b was calculated with a positive and negative likelihood ratio. This calculation enables one to quantify the effect that a particular test result has on the probability of an outcome independent of the prevalence of the disease (i.e., diagnosis of the disease). For AREDS level 4b, the positive likelihood ratio was 14.44 (95% CI 8.08–26.40) and the negative likelihood ratio 0.07 (95% CI 0.02–0.18).

McNemar’s test found no statistically significant difference between digital and film photography for detecting CNV ($p = 1.0$) but a significant difference in the ability to detect the absence of CNV ($p = 0.04$).

**Interpretation**

In the past, most AMD studies have used stereoscopic 30° slide film photography of the retina to identify AMD. For this reason, stereoscopic slide film photography of the retina is the standard with which other imaging modalities have been compared when identifying AMD. More recent studies have shown that digital imaging of the retina can identify AMD.$^{22,23}$

Lim and colleagues$^{23}$ compared 35-mm slide images and low-resolution (640 x 480 pixels) non-stereoscopic 45° digital images captured with a non-mydriatic camera through an undilated pupil. They found a low sensitivity for digital imaging in identifying many features associated with AMD. In partic-
ular, sensitivity was poor in identifying drusen (64%), CNV (50%) and PED (50%). As a result, they felt that screening with nonstereoscopic digital imaging through an undilated pupil was unreliable. The addition of stereopsis, pupil dilation and increased digital image resolution are the most probable reasons behind the improved correlation between digital and slide film photography that were found in our study.

Van Leeuwen and associates compared stereoscopic 30° TIFF images with stereoscopic 30° slide film images in the identification of AMD. They concluded that the 2 imaging modalities were comparable. Similar to our results, they found the lowest $\kappa_w$ scores to be for early AMD and the highest for advanced AMD. However, for individual features of AMD their $\kappa_w$ values differed substantially from ours (in parenthesis), at 0.68 (0.49) for maximum drusen size and 0.79 (0.65) for maximum drusen area. The signs of advanced AMD were more comparable: subretinal fibrosis and geographic atrophy had $\kappa_w$ values of 0.88 (0.79) and 0.87 (0.86), respectively.

Our study was designed not to assess the ability of stereoscopic digital imaging to screen for early AMD but, rather, to see whether treatable AMD (AREDS levels 3 and 4) could be identified. All study participants had already been referred for possible treatment for AMD. Although most eyes had some degree of macular degeneration, many (49 by slide film imaging) had advanced AMD (AREDS level 4b or greater). The study results reflect this enrolment bias. All eyes included in the final analysis were found to have some level of macular degeneration by slide film photography. Digital imaging found no macular degeneration in 6 eyes. This suggests that compressed digital imaging may not be as sensitive as slide film photography when identifying small drusen associated with early AMD. However, other features of early AMD, such as smaller drusen sizes (< 125 µm) and areas (< C-1), may have shown poor correlation between the 2 formats because of the different measuring techniques. The digital software allows users to very accurately trace the drusen outline, at high magnification if desired, potentially allowing more accurate measurements.

We believe that the goal of an AMD teleophthalmology screening program should be to sort patients into 3 groups according to AREDS level of AMD: group 1, patients at level 2c3 or lower, would receive no intervention, but repeat photography would be recommended; group 2, patients between levels 3a and less than 4b, would be advised to take vitamin therapy and have repeat photography; and group 3, patients at level 4b or greater, would be advised to take vitamin therapy and would be referred for clinical examination and fluorescein angiography. The $\kappa_w$ statistics from this study demonstrated substantial correlation between our compressed stereoscopic digital images and stereoscopic slide film images for AREDS level 3a or greater and level 4b or greater. Furthermore, although digital imaging occasionally misidentified CNV as being present ($p = 0.04$), there was no statistically significant difference between the 2 imaging modalities in detecting CNV when truly present ($p = 1.0$). These results are consistent with the results from other studies assessing the utility of a

<p>| Table 4—Intrareader correlation in identifying treatable AMD from digital images of 40 eyes |</p>
<table>
<thead>
<tr>
<th>AREDS level</th>
<th>$\kappa_w$</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; 0 \leq 2c3$</td>
<td>0.46</td>
<td>0.31</td>
</tr>
<tr>
<td>$\geq 3a$</td>
<td>0.88</td>
<td>0.09</td>
</tr>
<tr>
<td>$&gt; 0 \leq 4a$</td>
<td>0.46</td>
<td>0.31</td>
</tr>
<tr>
<td>$\geq 4b$</td>
<td>0.89</td>
<td>0.08</td>
</tr>
</tbody>
</table>

<p>| Table 5—Discrepancy between digital and film imaging in identification of wet vs. dry AMD, as confirmed by fluorescein angiography or clinical follow-up, in 13 eyes |</p>
<table>
<thead>
<tr>
<th>AREDS level (digital)</th>
<th>AREDS level (slide)</th>
<th>Fluorescein angiography</th>
<th>Clinical follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>4b2</td>
<td>3c</td>
<td>No CNV</td>
<td></td>
</tr>
<tr>
<td>4b1</td>
<td>3c</td>
<td>ND</td>
<td>Dry AMD</td>
</tr>
<tr>
<td>3a</td>
<td>4b2</td>
<td>CNV</td>
<td></td>
</tr>
<tr>
<td>3c</td>
<td>4b1</td>
<td>ND</td>
<td>Dry AMD</td>
</tr>
<tr>
<td>4b1</td>
<td>3c</td>
<td>No CNV</td>
<td></td>
</tr>
<tr>
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<td>3c</td>
<td>No CNV</td>
<td></td>
</tr>
<tr>
<td>4b4</td>
<td>4a</td>
<td>No CNV</td>
<td></td>
</tr>
<tr>
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<td>3c</td>
<td>No CNV</td>
<td></td>
</tr>
<tr>
<td>4b2</td>
<td>4a</td>
<td>CNV</td>
<td></td>
</tr>
<tr>
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<td>4a</td>
<td>No CNV</td>
<td></td>
</tr>
<tr>
<td>4b3</td>
<td>4a</td>
<td>CNV</td>
<td></td>
</tr>
<tr>
<td>3c</td>
<td>4b2</td>
<td>CNV</td>
<td></td>
</tr>
</tbody>
</table>

Note: CNV = choroidal neovascularization; ND = not done.
novel teleophthalmology screening tool\textsuperscript{19,20} and suggest that such a system would be of benefit as a screening tool for patients with macular degeneration.

We offer our gratitude to Bernd Schwanke, Ken Dalton and Bruce Winship for their time and effort spent in capturing the film photographs. We also thank the office staff at Alberta Retina Consultants for their support in this project.

REFERENCES


**Key words:** age factor, diagnostic imaging, macular degeneration, photography, teleophthalmology