

The Value of Stereoscopic Optic Disc Photography

An update on imaging techniques and reliability.

BY STUART J. MCKINNON, MD, PhD

Why should clinicians image the optic nerves of their glaucoma patients? Is it because the AAO's *Preferred Practice Patterns* for primary open-angle glaucoma¹ states that "the preferred technique for optic nerve head evaluation involves magnified stereoscopic visualization (as with the slit-lamp biomicroscope) through a dilated pupil whenever feasible" and that "color stereophotography of the optic nerve head provides documentation and is the best routine approach to establish a baseline for future comparisons"? The answer is yes, but there are historical reasons for this approach as well.

IMAGING TECHNIQUES

The first stereoscopic fundus examination with a plano-convex lens and the slit-lamp biomicroscope was performed by El Bayadi² in 1953, and the technique gained widespread acceptance in the 1980s with the use of double aspheric lenses. During that decade, digital imaging was an emerging technology, so the most convenient method by which to document changes over time in the optic nerve's appearance was conventional, silver halide-based film photography.

Photographic films are coated with small crystals of light-sensitive, silver halide salts suspended in a transparent gelatin (an emulsion), which is coated on plastic film. When exposed to light, some of the silver halide crystals transform into metallic silver particles. During development and fixation, the metallic particles remain in the gelatin, and the unexposed crystals are removed. Black-and-white photographic film usually has one layer of silver salts. Color films use several emulsion formulations, and more chemical processing steps are needed to leave dyes that

represent the color content of the exposed image.

Clinicians routinely image patients' optic nerve heads with 35-mm film in fundus cameras, which create a single monoscopic image or two stereoscopic images, either in black and white or in color. The physician obtains the two stereoscopic fundus images simultaneously with prism-based optics³ (Figure 1) or sequentially in the following manner. The photographer customarily takes the first image as far to the left of the dilated pupil as possible. He obtains the second image with an Allen stereo separator or by moving the camera a minimum of 2 mm to the right to achieve between 15° and 30° of separation between the two images. For the second image, it is permissible to reduce the focus and clarity in order to maintain the stereoscopic effect.⁴

ASSESSING OBSERVERS' RELIABILITY

Methods

Reliability is defined as the degree to which errors in measurement are absent from the data. To assess

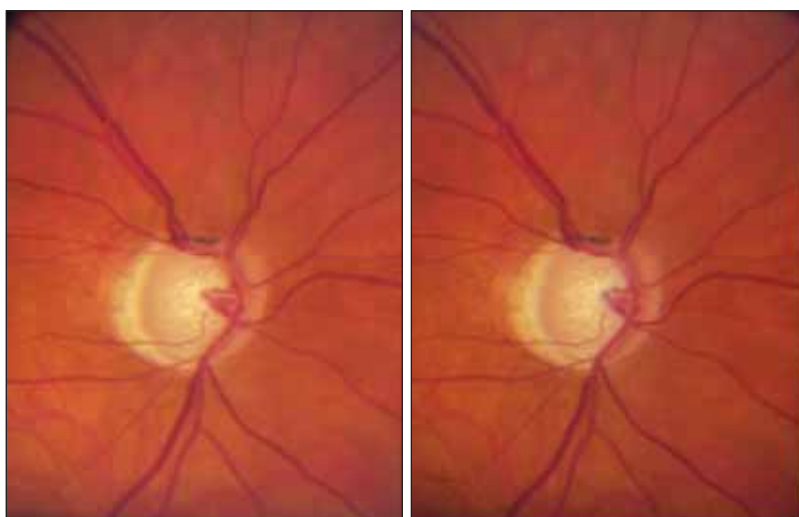


Figure 1. The practitioner obtains stereophotographs of a glaucomatous optic nerve simultaneously using a prism-based optical system.

observers as sources of error, one quantifies the data's consistency primarily through two approaches. Within-observer reliability, or intraobserver agreement, relates to how consistent the observer's repeated measurements were and the degree of measuring error in the observational data. Between-observer reliability, or interobserver agreement, refers to the degree to which observers are interchangeable.

The metrics commonly used to assess observational reliability include the Kappa statistic and the intraclass correlation coefficient (ICC). Kappa is directly related to the proportion of agreement achieved by raters beyond chance agreement, and it can be weighted to correct for chance agreement. Kappa values may range from -1.00 to 1.00. Kappa values greater than zero indicate that raters agree more frequently than predicted by chance, whereas values below zero indicate agreement less frequently than predicted by chance. Kappa values of less than 0.60 represent unacceptable reliability, and values greater than 0.80 represent excellent reliability.

Researchers use the ICC less commonly than Kappa. The ICC is related to the proportion of total variance in observations that is attributable to true variation. ICC values range from 0 to 1.00, with 1.00 indicating perfect observer agreement when there is some degree of variation.

Research Findings

Evaluating photographs of the optic nerve typically involves rating the horizontal and vertical cup-to-disc ratios and the neuroretinal rim. A number of studies have compared different imaging techniques and measured the intra- and interobserver agreement among raters of optic disc photographs. Lichter⁵ asked 16 glaucoma experts to assess 20 eyes of 10 patients. The results showed that the stereoscopic evaluation of cup-to-disc ratios yielded better intra- and interobserver agreement than monoscopic evaluation. A somewhat disquieting finding of the study, however, was the significant interobserver variability among the glaucoma specialists in their evaluation of cup-to-disc ratios.

Caprioli et al⁶ showed that the detection of structural changes through the qualitative evaluation of sequential stereoscopic optic disc photographs was more accurate than the qualitative evaluation of the nerve fiber layer and manual stereoplanimetry of the disc rim's area. In a study of three eyes, Rosenthal et al⁷ showed that simultaneous fixed-angle stereophotography was more reproducible than sequential stereophotography.

Tielsch et al⁸ reported strong intraobserver agreement ($K = 0.71$) and poor interobserver agreement ($K = 0.58$) between two expert examiners who evaluated the neuroretinal rims of 200 eyes. Similarly, studies by Abrams et



Figure 2. The physician uses a handheld stereoviewer to assess digital stereophotographs of the optic disc on a computer monitor.

al⁹ and Varma et al¹⁰ as well as one involving the European Glaucoma Prevention Study Group¹¹ verified that, when assessing a disc for glaucomatous damage, intraobserver agreement is generally much stronger than interobserver agreement.

THE FUTURE OF DIGITAL IMAGING

Digital images can be presented in various ways to provide greater sensitivity in detecting glaucomatous progression. By using systems that “flicker” serial disc images on a computer screen, one method improves the detection of changes in the neuroretinal rim compared with ophthalmoscopic and stereophotographic methods of assessment.¹² The Disc Photography Reading Center used in the Early Manifest Glaucoma Trial used flicker chronoscopy, which had previously been shown to sensitively detect small changes in optic disc topography.¹³

Parkin et al¹⁴ compared stereoscopic and monoscopic evaluations of optic disc pairs using flicker chronoscopy and a handheld stereoviewer (Figure 2). The investigators noted similar intraobserver agreement between stereoscopic and monoscopic evaluations of the vertical cup-to-disc ratios. Interobserver agreements showed better agreement for stereoscopic ($ICC = 0.84$) than for monoscopic evaluations ($ICC = 0.71$). Morgan et al¹⁵ also found an improvement in interobserver agreement when using digital images to estimate the cup-to-disc ratio for stereoscopic assessment ($ICC = 0.80$) when compared with monoscopic assessment ($ICC = 0.74$).

The advent of charge-coupled display (CCD) cameras allows clinicians to obtain digital images of the optic disc directly instead of relying on scanned 35-mm color slides. When comparing analog and digital imaging methods, it is useful to know that, given the density of silver halide crystals, the theoretical resolution of 35-mm film is approximately 6,000 dots per inch (dpi).¹⁶ Scanning a 35-mm slide (0.94 X 1.42 inches) at this resolution would generate an image that is over 144 megapixels in size. Due to interpolation routines in scanning software, such high resolution is rarely necessary.

Scanning at 3,000 dpi will produce a 36-megapixel color image with quality comparable to that of 35-mm film.¹⁷ With a digital camera—where each red, green, and blue CCD sensor registers as a separate pixel—the resolution of a 6.1-megapixel digital camera would be equivalent to scanning a 35-mm slide at 1,200 dpi. Khouri et al¹⁸ compared simultaneous optic disc stereophotographs obtained from 35-mm film to digital images obtained using a 6.1-megapixel camera. The investigators found no significant differences in agreement regarding the evaluation of cup-to-disc ratio.

STILL THE GOLD STANDARD

Several studies have documented that structural injury of the optic nerve head is one of the earliest indicators of progressive glaucomatous damage and can precede detectable visual field loss.¹⁹⁻²¹ It is therefore imperative that the imaging techniques practitioners employ permit them to discern subtle changes in the optic disc's appearance over time. The high resolution of 35-mm film stereophotographs has allowed physicians to detect these changes, but the method's shortcomings suggest that serial evaluations are most reliable when performed by the same person.

Digital stereophotography has the advantage of providing instant feedback on the image's quality, and it allows computerized analysis of the image, its electronic storage, and its use in telemedicine.¹⁸ Standard CCD cameras, however, provide less-than-optimal resolution compared with 35-mm film. These cameras may require a resolution higher than 6 megapixels in order to detect subtle changes in serial disc images.

One hopes that newly refined measures of quantifying changes in the optic disc and nerve fiber layer by means of confocal scanning laser ophthalmoscopy, ocular coherence tomography, or scanning laser polarimetry will allow the earlier detection of glaucomatous progression. Until longitudinal data validate these devices, stereophotography of the optic disc will remain the gold standard against which these exciting new technologies are measured. □

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