An Overview of Recent Developments in Automated Perimetric Techniques Used in the Detection of Glaucoma

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Abstract

The use of automated perimeters in clinical ophthalmic practice forms a crucial element in the detection and management of glaucoma. Publication and advertising on the rapid changes in research and development of perimetric techniques can create an information overload to those in clinical practice. The following paper will attempt to provide an overview of recent research developments in automated perimetric techniques and their potential usefulness as a clinical tool in glaucoma.

Key Words:
Flicker, Blue-Yellow, Motion Detection

Glaucoma is a frequent cause of blindness in the elderly population. Recent population-based studies estimate the incidence of glaucoma at between 1.3 to 2.1 percent in the over forty age group.[1,2] In a recent Visual Impairment Study Project in Melbourne, Australia, a population-based sample of 3270 non-institutionalised people over the age of forty years, 1.6 percent were diagnosed with definite primary open angle glaucoma and a further 1.7 percent were suspected of having glaucoma.[3] With an increasing aged population, it has been estimated that by the year 2000, glaucoma will come second to cataract as the most prevalent cause of blindness in the world.[4] With increased demand on health care services to successfully manage people suffering from cataract and glaucoma, a need is created for further research into the processes which underlie these diseases.

Ultimately, the aim of research into glaucoma is to identify disease susceptibility in people before nerve fibre damage can occur. In such people, the development of preventative management techniques could lead to the ultimate control of glaucoma. At this stage in the development of knowledge on glaucoma, research has concentrated on the early detection of the disease and the careful follow-up of established cases. In the quest for therapeutic success, there is demand for the development of more sensitive testing techniques. The requirement is for reliable testing methods which are quick and easy to administer. These tests must be able to accurately indicate whether the disease is present, stable or progressive.

Histopathological investigations on glaucomatous eyes demonstrate that the extent of "silent loss" of ganglion cells, ie. the percentage lost prior to detection with standard perimetry, can vary according to the type of perimetric test performed, the region of retina tested, and the reliability of both the subject and the examiner. The range of variability in undetected ganglion cell loss has been estimated to lie between 15 to 50%.[5] Up to 40% of the optic nerve fibres may be damaged when a 10 dB (decibel) loss is found in the central 30 degree visual field as measured by standard light threshold perimetry.[6]

Based on these findings, various testing methods have been investigated for their sensitivity in detecting early ganglion cell damage. These have included retinal nerve fibre layer imaging, electrophysical and psychophysical investigations of people with, or suspected of having glaucoma. Electro-diagnostic investigations have include electroretinograms and visual evoked

potentials. Areas of psychophysical investigation include the assessment of deficits in temporal sensitivity, contrast resolution, low frequency colour perception and motion perception. These tests are often compared to standard light threshold perimetry as a gold standard.

The development of computer driven static perimetry (automated perimetry) allowed visual fields to be assessed with greater accuracy and reproducibility. Due to the psychophysical nature of the test, the compromises in accuracy from the patients' viewpoint still remain. Such factors include changing psychological states, fatigue and physical constraints.[7] However, automated perimetry minimises the influence of the test operator on the accuracy of the test results. Other advantages include a standardised test protocol, the mathematical analysis of results and the calculation of patient reliability indices. Consecutive automated visual field tests can be statistically compared and analysed in order to detect progressive decline in threshold values of the entire visual field as a whole, or for any region within the field, or for any individual stimulus location.

The study of visual fields in a patient with glaucoma has become an essential component of glaucoma management. Recent advances in the computing software, testing programs and perimetric hardware are aimed at achieving a greater sensitivity and specificity of visual field results. In the quest of developing a visual field test which is faster to perform clinically, hopefully with minimal compromise to test sensitivity, some manufacturers are producing software modifications to the traditional test strategy program. However, standard automated threshold perimetry may not be the test of choice in detecting early glaucomatous nerve fibre damage.

There is evidence of other techniques which may also reflect early glaucomatous selective nerve damage. Spatial contrast sensitivity involves the presentation of alternating (non-flickering) light and dark sinusoidal bars at different spatial frequencies. The minimum threshold contrast at which the bars can be seen at each frequency is then measured. The results of investigations into spatial contrast sensitivity deficits in glaucoma to date have been equivocal. It has been reported that in the absence of significant field loss in subjects suspected of having glaucoma, spatial frequency performance may be compromised within the central visual field region.[8] In another study of central contrast sensitivity, comparisons were made between people with glaucoma, ocular hypertension and normal eyes. It was found that no significant differences could be found between the groups for any of the spatial frequencies tested.[9]

The measurement of contrast sensitivity within the peripheral field as measured by resolution perimetry (or high-pass perimetry) has been extensively investigated.[10-12] The results of these studies reveal contrast sensitivity losses in the peripheral field of people with glaucoma.

Resolution perimetry has been compared to standard threshold perimetry in the presence of glaucoma in several studies.[13-15] The findings in these studies demonstrate that resolution perimetry results are slightly less, if not, equally sensitive to standard threshold perimetry. These results are confirmed when resolution perimetry results are compared to both standard and flicker threshold perimetry.

Sensitivity to short-wavelength light has been reported to be affected by glaucoma. Previous research has explored the use of blue and blue-yellow colour vision deficits as early indicators of glaucomatous damage. Through use of a FM 100-Hue colour vision test it was found that patients with ocular hypertension and such colour vision deficits stood a much higher risk of developing glaucomatous visual field loss over five years.[16] Such sensitivity to central colour deficits have not been confirmed in subsequent studies by Lachenmayr.[11, 17]

Recent studies on specific colour sensitivity losses peripherally across the visual field, have offered more promise. Much development in this area of research is based on the principle that early damage to ganglion cells near the fovea result in disruption to the blue/yellow colour wavelength detecting system.[18] Short wavelength light sources are used as target points in the peripheral visual field. Short wavelength automated perimetry (SWAP), otherwise known as blue-on-yellow perimetry, has been reported to be sensitive to early glaucomatous field.[19-22]

In a three year prospective study, Casson, Johnson, and Shapiro, (1993) compared the progression of standard threshold, to flicker threshold perimetry and blue-on-yellow perimetry in early glaucoma and ocular hypertension.[23] It was concluded that both blue-on-yellow and flicker perimetry show sensitivity to early glaucomatous damage and that both techniques were sensitive and specific testing procedures for the detection of early glaucomatous visual field loss.

Two major disadvantages of blue-on-yellow perimetry are the influence of age upon the optical media and the greater magnitude of long-term fluctuation as compared to standard threshold perimetry. Age-related yellowing of the human lens reduces the amount of short wave-

length light reaching the retina, especially blue light. The amount of light transmission loss produced by the lens must be evaluated prior to blue-on-yellow perimetry in order to establish the amount of sensitivity loss that can be attributed to optical factors. The procedures to evaluate this transmission loss can be complex and time consuming.[24]

Newer techniques have been developed to test motion sensitivity deficits in the presence of glaucoma.[25,26] These studies have demonstrated that glaucoma can affect the perception of motion; however, tests of motion sensitivity were not sensitive to early glaucomatous ganglion cell loss and therefore not effective as an early diagnostic tool.

The development and research of perimetric motion tests such as Motion Automated Perimetry (MAP) in glaucoma, have demonstrated a greater sensitivity to glaucomatous visual field loss than larger foveally centred motion tests. The results however demonstrated that MAP did not have an advantage over standard threshold perimetry in detecting localised visual field defects.[27]

Psychophysical investigations into temporal transfer deficits in the presence of glaucoma have been divided into two major areas; critical fusion frequency (CFF) and modulation (flicker) sensitivity measures. Critical fusion frequency measurement represents a point at which an intermittent (flickering) light stimulus characterised by an increasing frequency is first perceived as a continuous light.[22] This represents the highest resolvable frequency. Modulation (or flicker) sensitivity represents the minimum illumination at which a flickering stimulus at a set frequency is first perceived as flickering.[28] This represents the lowest resolvable illumination for a specific stimulus frequency.

Critical fusion frequency deficits in the presence of glaucoma or ocular hypertension have been studied in the past. The findings of these studies are equivocal. Two papers demonstrated definite critical fusion frequency deficits in the presence of glaucoma.[17,29] In 1992, Tyler, measured significant critical fusion frequency deficits at frequencies greater than 20 Hz in the presence of ocular hypertension.[30] However, in a study in which glaucoma was simulated by artificially increasing intraocular pressure, there were no significant measurable critical fusion deficits.[31] It appears that, although the measurement of critical fusion frequency may demonstrate early glaucomatous ganglion cell damage, there may be a more sensitive test strategy available.

In 1990, Toi, Grounauer and Burckhardt compared critical fusion sensitivity to modulated flicker sensitivity in simulated temporary hypertension. It was found that artificially increasing intraocular in normal human eyes produced loss of flicker sensitivity although central CFF was unaltered.[31] These findings have been confirmed in other studies, although there is some dispute as to the frequency at which significant flicker sensitivity loss occurred.[32] Such comparisons between the two strategies of temporal transfer measurement suggest that the measurement of flicker sensitivity may be preferable to critical fusion frequency techniques in detecting early pathological rises in intraocular pressure.

Another technique used to assess temporal (or flicker) resolving power is called multi-flash capimetry.[33] This technique involves the measurement of the minimum interval required for the detection of flicker in a central target. The stimulus is flickering at a constant 5Hz and the area of the stimulus is varied from a 0.625 degree to 20 degree visual field. This technique is reported to be as sensitive, if not more so than conventional standard threshold perimetry, however comparisons between this modality and that of flicker sensitivity have not been made.

Changes in central flicker sensitivity in the presence of glaucoma and ocular hypertension have been extensively investigated.[29,30,32,34-36] The authors of these papers are in general agreement that the presence of glaucoma is accompanied by flicker sensitivity losses, especially at the higher temporal frequencies of 25 to 50Hz . A small percentage of subjects with ocular hypertension also demonstrated mild sensitivity losses.[36] A study of full-field flicker sensitivity deficits in patients with glaucomatous perimetric defects found that sensitivity was significantly reduced in patients with both diffuse and localised field defects.[37]

The development of a flicker sensitivity measurement system in the peripheral retina has resulted in the creation of flicker threshold perimetry. Several investigators have studied influence of glaucoma and/or ocular hypertension on flicker threshold perimetry results as compared to subjects without glaucoma.[38-41] All studies demonstrated significantly greater flicker sensitivity losses in subjects with early glaucoma as compared to an age-matched normal population at all frequencies.

Longitudinal measurements of flicker threshold perimetry in the presence of glaucoma and ocular hypertension were compared to standard threshold perimetry by Casson and Johnson in 1992.[20] It was reported that the early glaucoma subjects demonstrated equally reduced sensitivity to all flicker frequencies. There were flicker threshold perimetry defects present in all subjects demonstrating defects to standard

threshold perimetry. Flicker perimetry provided consistent results which, in many cases, predicted the onset or progression of standard threshold perimetry deficits and successfully identified which subjects with ocular hypertension would go on to develop glaucoma in the near future.

After reviewing the literature, the use of a flickering stimulus in a psychophysical testing procedure appears to provide a sensitive technique for the early detection of ganglion cell loss due to primary open angle glaucoma. In the past, several different modalities have been investigated for their ability to detect early ganglion cell loss in glaucoma. The overall aim of these investigations is to develop a quick, easy and reliable test which was capable of detecting glaucomatous nerve cell damage earlier than current standard threshold perimetric techniques.

Flicker threshold perimetry remains as one of the more promising of these techniques due to its resistance to the confounding effects of media opacities, optical blur and refractive errors, its comparable levels of subject response variability to standard threshold perimetry and its practicality of use in the clinical setting.[42] Standard threshold perimetry is currently used as the clinical gold standard psychophysical technique by which glaucomatous ganglion nerve fibre damage can be documented. Flicker threshold perimetry can co-exist in this clinical environment, and in some cases co-inhabit the same testing equipment, to hopefully provide a more sensitive diagnostic test of choice for people with early or suspected primary open angle glaucoma.

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