Displacement Threshold Hyperacuity as a Predictor of Postsurgical Visual Performance in Patients With Cataract

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Purpose. To evaluate the ability of Displacement Threshold Hyperacuity (DTH) in predicting the postoperative visual outcome in patients awaiting cataract surgery and discriminating between the relative performance of the neural and optical components of the visual system. To establish eventually the cut-off DTH values to be used clinically in the preoperative evaluation of patients with cataract.

Methods. Forty-five subjects admitted for extracapsular cataract extraction with implant were examined preoperatively and postoperatively. In addition to DTH, logMAR visual acuity (VA), contrast sensitivity, and a cataract classification system were used to obtain a more comprehensive assessment of the patient's visual performance.

Results. DTH was found to be sensitive to decreased macular function but relatively unaffected by the severity of the cataract; higher thresholds were associated with denser opacities. A preoperative threshold of 50 seconds of arc was found to be the upper limit under which normal macular function is likely. DTH sensitivity and specificity for decreased macular function was 1.00 and 0.8, respectively.

Conclusions. If preoperative DTH is 50 seconds of arc or lower, the subject will achieve a postoperative logMAR VA better than 0.3 (Snellen equivalent 20/40). On the contrary, higher DTH seems to give no reliable information about the patient's visual function. Invest Ophthalmol Vis Sci. 1995;36:686-691.
Displacement Threshold Hyperacuity (DTH)—that is, the smallest amplitude of oscillation that gives rise to the sensation of movement—has been shown to be not only resistant to image degradation produced by cataract but also sensitive to neural dysfunction. DTH depends on the integrity of the photoreceptor mosaic and the extra sensitivity that the fovea possesses compared to more eccentric retinal areas. Thus, DTH would be expected to be markedly raised in macular disease. This technique has, therefore, been used to assess visual function in the presence of opaque media. At present, there has only been one published article relating to the efficacy of DTH in predicting the postoperative outcome of cataractous patients. In this study, the subjects were taken from a randomly selected sample with no concomitant diseases. No cut-off DTH values were established that could be used in clinical work. In addition, visual function of the subjects was evaluated only with Snellen VA and therefore parametric statistics could not be used.

The aim of the present study was threefold: first, to evaluate the ability of DTH in predicting the postoperative visual outcome; second, to assess the sensitivity of DTH to decreased macular function; and third, to establish the cut-off DTH values that could be used clinically in the preoperative evaluation of cataractous patients.

**METHODS**

Forty-five subjects (mean age, 75 ± 8 years) who were listed for extracapsular implant cataract surgery were examined preoperatively. Informed consent was obtained from the subjects, and approval from an institutional human experimentation committee was granted. In addition, the tenets of the Declarations of Helsinki were followed. The examination was repeated 6 to 9 weeks after surgery, and any possible complication of surgery was also assessed. Some subjects with ocular pathologies were included because unselected groups of subjects can give misleading results due to the high proportion of good vision obtained after surgery in developed societies. Seven cases from the sample were detected to have macular changes of various etiology and severity. Six subjects had previously been diagnosed with primary open-angle glaucoma with visual field loss, and one subject also had ocular hypertension. One subject had extensive myopic degeneration, and two had insulin-dependent diabetes. The other subjects had no apparent pathology.

Before any of the tests was employed, the subjects were fully refracted and the best corrected logMAR VA was measured using the Ferris–Bailey charts at 4 m at a mean luminance of 160 cd/m² according to international standards. Contrast sensitivity was then tested using the Pelli–Robson chart. The procedure has been described in previous articles. Displacement threshold hyperacuities were subsequently determined in a darkened room. The subjects had various degrees of opacity that were classified according to the Oxford Clinical Cataract Classification and Grading System. Pupils had already been dilated with tropicamide 1% and phenylephrine 10%. Finally, ophthalmoscopy and Goldmann applanation tonometry were performed.

The equipment used to measure DTH is described in another article, but basically it consisted of two slide projectors and a translucent screen. A target bar was projected by means of a 250 W quartz–halogen source through a 35-mm slide onto a large diffusing screen via an oscillating mirror. A sweep function generator was used to induce an oscillating movement of the mirror about its vertical axis and also to control the temporal frequency. The waveform of the oscillation was sinusoidal, and the temporal frequency of oscillation was fixed at a value of 4 Hz because DTH is unaffected by cataract at low oscillation frequencies. DTH at low temporal frequencies of oscillation is affected by image degradation when nearby references are not available. Hence, two stationary reference lines of identical size and luminance to the target bar were located on either side of it. The total separation between the outer bars was 60', although the distance between them can be increased up to at least 80' without affecting threshold. This means that, unlike in other hyperacuity tasks such as vernier acuity, patients with a wide range of visual acuities can be tested. The oscillating vertical target was observed from a distance of 6 m in a darkened room. At this distance, the target subtended 5' wide and 20' high. The luminance of the bar and the two reference lines were fixed at 500 cd/m². A psychophysical method of adjustment was used to achieve a threshold. The amplitude of oscillation was increased until the subject detected the movement of the target; then it was decreased until the target appeared to stop. An average of three ascending and three descending threshold estimates were taken to determine the final displacement threshold.

**RESULTS**

The Kolmogorov–Smirnov test showed that the data were normally distributed for preoperative (d = 0.17, NS) and (d = 0.16, NS) postoperative values and, therefore, parametric statistics were used. Figure 1 shows a scattergram of preoperative versus postoperative DTH. It can be seen from this figure that as preoperative thresholds become higher, the discrepancy between them and postoperative thresholds increases. Thresholds were increased, particularly in those sub-
FIGURE 1. Preoperative DTH is plotted against postoperative DTH. The diagonal line represents the line of "perfect agreement" between preoperative and postoperative thresholds. DTH tends to underestimate the postoperative results.

FIGURE 2. Preoperative visual acuity is plotted against preoperative displacement thresholds. Thresholds as low as 50 seconds of arc were found with VA less than 6/60. However, higher thresholds were associated with poorer presurgical visual acuity values. ° = normal cataractous eyes; □ = pathology cataractous eyes.

FIGURE 3. Scattergram of preoperative DTH against postoperative visual acuity. The horizontal line indicates a successful outcome criterion of 0.3 (Snellen equivalent 20/40). The vertical line through 50 seconds of arc marks the cut-off value that maximizes the test efficiency. □ = pathology group; ° = normal group. DTH = Displacement Threshold Hyperacuity.

FIGURE 4. ROC curve by plotting the percentage of true-positive decisions (sensitivity) against the percentage of false-positive decisions (1-specificity) for five different thresholds. The point closer to the left-hand corner of the plot represents the highest sensitivity and specificity and therefore can be considered the best criterion to discriminate between subjects with successful and unsuccessful outcomes. - = seconds of arc; ROC = receiver operating characteristic.
of subjects with postoperative logMAR VA worse than 0.3 were correctly identified and 80% of subjects with post logMAR VA better than 0.3 were also correctly identified. However, these results should be viewed with some caution because of the small number of subjects with decreased macular function.

The groups with glaucoma and maculopathy were compared with the rest of normal subjects from the sample. The preoperative and postoperative DTH from the group of subjects with glaucoma (including the subject with ocular hypertension) were not statistically different from the normal group (t = -0.64 NS, and t = 0.50 NS, respectively). The ages of the group with glaucoma and the normal group were not statistically different (t = -1.539 NS). On the other hand, a statistically significant difference in postoperative DTH values was found between the group with macular problems and normals (t = 5.02 P < 0.0001). Preoperative DTH shows also a significant discrepancy between the group with macular disease and the normal group (t = 2.65, P < 0.01).

Multiple comparison analysis of variance indicated that the ratio of preoperative and postoperative DTH was not significantly different for any cataract morphology. Thus, cataract morphology does not seem to affect the accuracy of DTH in predicting visual outcome.

DISCUSSION

Previous studies have shown that DTH increases only slightly with the severity of the opacity. Although we have shown that DTH is relatively unaffected by the presence of cataract, thresholds as low as 50 seconds of arc were found in subjects with presurgical VA worse than 20/200 (Fig 2). Our results indicate, then, a more marked influence on DTH (Fig 1). This may be due to a smaller reference bar separation and the higher temporal frequencies used in this study compared to the parameters used by other authors. This influence increases with cataract severity and, as a result, predictions of postoperative VA were less accurate for cataractous subjects with poor presurgical VA and CS values. These findings are in agreement with Watkins and Buckingham, who found DTH to be resistant to contrast reduction as low as 15%, but below this level threshold increased significantly.

In the present study, 50 seconds of arc was chosen as the clinical cut-off threshold. This agrees with previous studies in which no thresholds lower than 50 seconds of arc were found in patients with decreased macular function. It can also be inferred that if preoperative DTH are 50 seconds of arc or lower, there will be a high probability (100% in this study) that the subject will achieve a postoperative logMAR VA better than 0.3. On the other hand, if DTH are higher than 50 seconds of arc, the probability of having a postoperative logMAR VA worse than 0.3 is only 40%. This indicates that DTH higher than 50 seconds of arc seems to give no reliable information about patient visual function. Alternatively, it might be argued that a high DTH threshold associated with a contrast sensitivity or logMAR value near normal would indicate neural abnormality. This fact cannot be proven from the present study because of the small number of subjects with decreased macular function.

As far as cataract in the presence of other concurrent diseases is concerned, DTH was shown to be sensitive to the presence of maculopathies that affected VA in the presence or absence of cataract. These results are in agreement with the findings of previous studies in which a significant increase in DTH was reported in subjects with maculopathies without cataract. In theory, these findings confirm that DTH gives valuable information about the integrity of the macula through media opacities, but in clinical practice most of the maculopathies will not be detected preoperatively because the high thresholds obtained will be difficult to distinguish from those caused by dense opacities.

The presence of glaucoma did not appear to affect DTH values. These results disagree with previous work in which DTH was found to increase in glaucoma and ocular hypertension. It should be noted that the group with glaucoma and ocular hypertension was small (seven subjects) but, nonetheless, all the subjects achieved thresholds smaller than 50 seconds of arc. In any case, if the presence of glaucoma were to affect visual predictions, its effect on DTH values would have to be more marked, as it is with maculopathies.

Four subjects from the sample achieved poor postoperative VA scores despite the presence of normal (<50 seconds of arc) postoperative DTH values. Visual acuity improved in the following months without any apparent reason, until these subjects reached the expected normal values of VA. These puzzling findings may be explained by the presence of the macular edema, which has been said to occur as a physiological response to surgical trauma. Faulkner found the same phenomenon using the Rodenstock Retinometer in the presence of macular edema and in recently reattached retinas. He claimed that the tilted retinal receptor cells, found in both cases, respond better to an interference fringe pattern than to Snellen VA testing. This theory accounts neither for the similar findings of Guyton using the potential acuity meter (PAM) nor for the findings of this study. It may be that light rays are scattered by the edematous inner layers of the retina and, thus, if the stimulus is limited to a small light beam as it is with the Rodenstock Retinometer and PAM, there will be much less scattered light. This will tend to give a better Retinometer
or PAM result than the actual VA, providing that the photoreceptor layer is still healthy. The known resistance of DTH to image degradation, in this case caused by the edematous inner layers of the retina, might well explain this. It could also explain why this was not found in one subject with diabetic macular edema because, in such patients, the photoreceptor layer is usually affected by the nature of this chronic condition. Nonetheless, in an early stage of clinical development, DTH can be regarded as a quick clinical technique, and none of false-negative predictions have been reported elsewhere. However, it is thought that conditions such as vitreous and retinal hemorrhage and the presence of an epiretinal membrane could confuse any predictions. The presence of irregular corneal astigmatism, or a residual posterior capsule after extracapsular extraction, can lead to a false-positive result with the DTH technique because it is unaffected by optical abnormalities. Furthermore, DTH is elevated in optic neuritis but does not affect VA. It should be noted that in predicting postoperative VA, these conditions will produce predictions slightly poorer than those actually achieved. Fortunately, the greatest elevation of DTH scores occurs in macular disorders.

DTH can be regarded as a quick clinical technique in which no pupil dilation is required. It is, nonetheless, in an early stage of clinical development, and some problems have to be resolved before it can be considered a reliable technique. One of the greatest problems to overcome seems to be that a subject’s DTH can be markedly increased by severe opacities, and, therefore, high thresholds due to macular problems are difficult to distinguish from those due to the severity of the cataract.

Key Words

cataract, displacement threshold hyperacuity, retinal function, preoperative evaluation, retinal diseases

References

Hyperacuity as Predictor of Postsurgical Cataract Outcome


