Differences between Recognition and Resolution Acuity in Patients Undergoing Macular Hole Surgery

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PURPOSE. The present investigation compared recognition acuities (ETDRS chart) with resolution acuities (Landolt-C chart) in a sample of patients with idiopathic macular holes (MH). Traditionally, visual acuity in a clinical setting is measured with a letter chart. Yet, the ability to recognize a letter differs from a resolution task, such as detecting the direction of a gap in a ring. It was hypothesized that resolution acuity would be more impaired than recognition acuity in patients with MH, because component cues in letter optotypes are not available in Landolt-Cs.

METHOD. Visual acuities of 23 patients with MH (age range, 52–82) were tested, using standard ETDRS and Landolt-C charts. Optical coherence tomography was used to confirm the diagnosis of MH.

RESULTS. Acuities correlated strongly, before and after surgery (r = 0.92 and r = 0.95, respectively). However, paired t-tests determined that resolution acuity was significantly more impaired at both time points than was recognition acuity (P < 0.001). Using Bland-Altman plots, the limits of agreement between the two acuity types indicated that resolution acuity differed from recognition acuity by up to five lines before surgery and up to 3 lines after surgery.

CONCLUSIONS. ETDRS and Landolt-C acuities differ in a clinically significant way in patients before and after MH surgery. Measuring recognition acuity by reading letters may lead to an overestimate of visual ability at the retinal level in patients with MH by including compensatory top-down cognitive processes that are unavailable for resolution tasks. (Invest Ophthalmol Vis Sci. 2006;47:3690–3694) DOI:10.1167/iovs.05-1307

The assessment of visual acuity forms one of the cornerstones in the detection, evaluation, and treatment of vision impairment. However, its proper measurement and interpretation remain a challenge, especially within the constraints of a clinical setting. Various acuity tasks are in use, many of which reflect unique properties of visual function. Researchers and clinicians worldwide use different optotypes in their investigations, and it becomes difficult to compare acuity outcomes across studies. Specifically, the comparison of recognition acuity (i.e., reading individual letters) and resolution acuity (i.e., detecting a gap in a Landolt-C) poses the question of whether these two types of measures evaluate visual function equally.

The Snellen chart has become the most frequently used tool for recognition acuity in the applied setting. Detailed evaluation of this measure has revealed several flaws in its design, resulting in the constant development of improved eye charts, including the ETDRS chart, which has become the scientific measure of choice. Resolution tasks are used when examining children, patients who are unfamiliar with the Latin alphabet, or those who are unable to communicate verbally. Here, the optotypes generally consist of one repeating symbol, where only the orientation of the target varies. The most commonly used resolution acuity charts are the Landolt-C and the Tumbling-E. Generally, recognition and resolution acuities are considered equivalent in their ability to assess visual function in normal observers, as differences were small and deemed clinically insignificant (Raasch TW, et al. IOVS 1984; 25:ARVO Abstract 87). It has been pointed out that the letter C, which is also contained in the ETDRS chart and is the sole symbol of the Landolt-C chart, is more difficult to identify than other letter optotypes. Although the letters T and Z have been considered easier to recognize than a Landolt-C, the letter R has been found to be more difficult. Furthermore, letter confusion has been particularly problematic among letters that contain curved components, such as C, S, D, and O. A scaling factor of 0.95 for letter optotypes has been suggested to obtain the same acuity as with Landolt rings. Whether these two types of acuities are comparable in the presence of visual disease has only been investigated in patients with amblyopia and remains to be fully evaluated in other diseases.

One form of disease in which surgical intervention is evaluated with the use of eye charts is macular hole (MH), an age-related condition that affects the central area of the retina (macula). In addition to declining acuity, this condition creates distortions and/or blind spots (scotomas) in the central visual field. Because of the central scotoma created by the presence of an MH, patients are forced to fixate eccentrically. Therefore, a decrease in acuity is expected, as both recognition and resolution acuity have been demonstrated to decline as a function of retinal eccentricity. Previous work with a scanning laser ophthalmoscope (SLO) has indicated that patients fixate at or near the edge of the MH before surgery and that fixation returns toward the central area of the macula after successful surgical closure of the defect. Nakabayashi et al. used the amount of fixation shift and its associated improvement of visual acuity to define functionally successful MH closure, in addition to the established standards for successful MH surgery.

In the present study, we investigated whether differences exist between acuity-chart types in patients with a diagnosis of MH. It was hypothesized that, even though recognition (ETDRS) and resolution (Landolt-C) acuities would be highly correlated, resolution acuity would be more impaired, and this
difference would be clinically significant in the presence of MH as well as after MH surgery.

METHODS

The protocol was approved by the Institutional Ethics Review Board, in accordance with the Canadian Tri-council Policy Statement of ethical conduct for research involving humans and adhered to the tenets of the Declaration of Helsinki. Patients were recruited on the day that MH was diagnosed, and the purpose and procedure of the study were explained. Written informed consent was obtained, and the participants completed the two acuity tests.

Participants

The participants were 18 women and 5 men with a mean age of 71.0 ± 7.7 years (SD; range, 52–82), currently being treated by one retinal surgeon. The sample consisted of 23 eyes of these 23 patients with a 7.7 years (SD; range, 52–82), currently being treated by one retinal surgeon. The sample consisted of 23 eyes of these 23 patients with a diagnosis of idiopathic MH in only one eye, with no concomitant retinal disease and a healthy second eye. MH diameter was measured using the appearance of intraocular lens implants at the time of diagnosis whereas, of the remaining 15 eyes, 2 (patients 15 and 22) showed clinically significant signs of cataract formation during the surgery. All patients were scheduled to undergo 25-gauge transconjunctival sutureless vitrectomy with gas tamponade between June 2004 and July 2005. Postoperatively, MH status was evaluated by OCT scan.

Apparatus and Procedure

Participants underwent refraction with an autorefractor (Autorefractor ARK-760A; Nidek, Gamagori, Japan), and then wore appropriate trial lenses for acuity measurement. Acuities were determined in the eye that was scheduled to receive surgery, whereas the other eye was occluded. Standard, retroilluminated ETDRS (Early Treatment Diabetic Retinopathy Study) and Landolt-C charts (Lighthouse International, New York, NY) were presented in that order at a distance of 1 or 2 m, to accommodate the acuity range of the patients. The Landolt-C chart contained rings with four orientations (right, left, up, down). Black optotypes were displayed at full contrast on a white background (luminance 185 cd/m²). The luminances fell within an acceptable range of established optimal parameters for eye-chart illumination.7 Participants were encouraged to identify optotypes one by one in each line while the experimenter scored correct responses. Testing stopped whenever a participant was unable to identify five consecutive optotypes in a line correctly. The same procedure was repeated between 1 and 3 months after MH surgery. For statistical analysis, acuities were expressed in logMAR (logarithm of the minimum angle of resolution) units.

RESULTS

Descriptive statistics for pre- and postoperative recognition and resolution acuities, together with patient variables, are displayed in Table 1. Pre- and postoperative ETDRS and Landolt-C acuities correlated significantly (r = 0.92 before; r = 0.95 after surgery; P < 0.001 for each). Preoperative acuities correlated with MH diameter (r = 0.80 for ETDRS and r = 0.74 for Landolt-C; P < 0.001 for each). Paired t-tests indicated that, before surgery, resolution acuity was significantly lower than recognition acuity (Δ(22) = 6.94, P < 0.001, η² = 0.69, observed power = 1.0). Analysis of the postoperative data resulted in identical findings (Δ(22) = 6.66, P < 0.001, η² = 0.67, observed power = 1.0).

Figure 1 displays the data in Bland-Altman plots.18,19 This type of graph more clearly indicates the extent to which these measures differ. To determine the clinical relevance of the differences, the limits of agreement (mean differences ± 2 SD) were calculated. For preoperative data, the upper and lower limits were 0.44 and −0.07 logMAR units, respectively. After surgery, the limits were 0.29 and −0.05 logMAR units. As 0.1 of a logMAR unit translates into 1 line on a standardized chart, acuities varied by approximately 5 lines before and 3 lines after surgery.

Table 1. Descriptive Statistics and Patient Variables

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</table>

Acuities are expressed in logMAR. MH diameter is expressed in micrometers (and degree of visual angle).

* Patients with failed Macular Hole surgery.

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When subtracting one acuity score from another, the resulting residuals would be expected to be distributed evenly and independently of acuity. In the present data, the lack of evenly distributed acuity differences (heteroscedasticity of residuals) across acuities was examined using Pearson’s correlation coefficients. Regression lines are included in the Bland-Altman Plots. Before surgery, a significant relation existed between acuity and acuity difference scores \( (r = 0.60, P < 0.01) \). After surgery, this relation became nonsignificant for participants with successful MH closure \( (r = 0.24) \), whereas the coefficient remained high for patients with failed surgery \( (r = 0.87) \). The small sample size \( (n = 4) \) did not allow for statistical significance in this latter value.

**DISCUSSION**

Even though recognition and resolution acuities were highly correlated, differences between these two measures ranged as high as 5 lines before and 3 lines after MH surgery. Though previous work had demonstrated that these acuities do not differ in a clinically significant way in normal observers,\(^1,^6\) this did not seem to be the case in patients with a diagnosis of MH. The discrepancy in the present sample must be seen in the context of already-published findings by Rassow and Wang,\(^10\) who reported a difference between ETDRS and Landolt-C acuity of approximately 3 lines in patients with strabismus-amblyopia or deprivation-amblyopia. These authors also tested discrepancies caused by cataract simulation, ametropia, and over-refraction in normal observers. Inspired by Rassow and Wang’s graphical presentation, Figure 2 displays data on acuity differences in relation to Landolt-C acuities across previously published studies.\(^6,^7,^10,^20\) It becomes apparent that, as Landolt-C acuity decreases due to various visual deficits, not only does the discrepancy with letter acuity increase but so does the variability in this difference.

In part, the increase in variability could be explained by the increased age of research participants, as several visual difficulties, such as MH or cataract, are age-related. This increasing variability in acuity with age has been reported.\(^21\) However, the discrepancy in amblyopia is intriguing, as this visual impairment occurs at the cortical rather than the retinal level and is not age related. In amblyopia, the visual cortex is unable to process all the available visual information. Therefore, these individuals cannot use component cues of the optotypes to recognize letters or gap location in a ring.

The results regarding heteroscedasticity of residuals in the present sample further indicate that a relationship exists between mean acuity on both charts and acuity differences between the charts. As acuity declined, differences between recognition and resolution acuities increased, both before surgery and when surgery failed. This discrepancy was reduced in patients with successful closure of the MH.

Resolution acuity was significantly poorer than recognition acuity in the present sample. Theoretically, by simply guessing the orientation of a Landolt-C (chance of one in four or one in eight, depending on the chart), resolution acuity should be better than letter acuity (chance of 1 in 10 or 1 in 26, from the patient’s perspective). In fact, the opposite is the case. In an attempt to explain why letter and resolution acuities differ so drastically in a clinical population, the characteristics of the optotypes must be considered. It has been established that the type of letter used in a chart has great impact on the legibility and difficulty of the task.\(^1\) The use of letters cognitively facilitates the acuity assessment. In addition, the identification of a letter is a more complex task than identifying the orientation of a ring.\(^7\) Under conditions of impairment, it may be this complexity that helps an observer to reconstruct the target cognitively. Components of a letter, such as diagonals or curves, facilitate its accurate identification, even if the entire target is not resolved. Conversely, resolving the gap in a ring is not facilitated by such component cues and becomes more difficult, thereby explaining why resolution acuities were poorer.

The difference between the two acuity types, before as well as after surgery may, in part, be explained by a change in fixation. Before surgery, monocular fixation is most likely to occur at or near the MH edge.\(^14,^15\) As all participants in the present study had a healthy second eye, the affected eye never had to develop a new and stable preferred retinal locus. It has previously been reported that the better eye generally dominates tasks that require fixation,\(^22\) which explains part of the poor monocular performance. If surgery fails to close the retinal defect (patients 2, 6, 19, and 20) but flattens and reattaches the MH edges, acuity may still improve but fixation remains peripheral and nonoptimal. In patients in whom MH

![Figure 1](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/932940/)
closure is accomplished, monocular fixation returns toward the center of the fovea, and acuity improves as the scotoma becomes smaller or disappears. This improvement may lead to more stable monocular fixation\textsuperscript{23} and differences between acuity types may be reduced, approaching values of normal observers. It is possible, however, that acuity may simply improve as patients learn to use eccentric fixation effectively with time.\textsuperscript{24}

Of particular relevance to the present study, is an eye chart that was developed for patients with MH.\textsuperscript{25} This chart displays multiple identical Landolt-C targets and is similar to an approach previously applied to age-related macular degeneration.\textsuperscript{26} The rationale underlying this chart design is that, by looking anywhere on the chart, at least one of the targets will fall on the most sensitive area of the retina. We questioned whether this measure reflects normal rather than optimal visual acuity, as patients may not consciously be able to use the part of the retina that provides optimal resolution.\textsuperscript{16,26,27} Horiguchi et al.\textsuperscript{25} were able to obtain acuities that were significantly better than those obtained with the standardized Landolt-C chart.\textsuperscript{25} Their acuities differed by approximately four lines before and two lines after closure of the MH. These differences could not be explained by the optotype used, as both chart types only contained Landolt rings. Here, the differences occurred because patients were not required to fixate on one target at a time but a full field of identical targets was presented. Patients achieved better acuities when fixation was not crucial in the measurement process. This raised the question as to which type of acuity test would be the best indicator of retinal resolution, to predict functional and structural outcome after treatment.\textsuperscript{29–30}

Anstis\textsuperscript{11} reported that letter acuity declines by 0.4 logMAR units per degree of retinal eccentricity. Therefore, a patient with an MH 2° in diameter (1° of eccentric fixation) should exhibit visual acuity of 0.4 logMAR. ETDRS acuities in the present sample are generally poorer than these expected values. This additional decline in performance is consistent with work by Sjaarda et al.,\textsuperscript{31,32} who described reduced functional ability in the area surrounding an MH. Therefore, visual function in the presence of MH is characterized by the absolute scotoma at the center, surrounded by a relative scotoma in the area immediately surrounding the MH.

Additional factors influencing visual acuity measurement should be considered, such as test–retest variability and possible fatigue effects. A certain amount of error is to be expected in any acuity measurement. The ETDRS chart has been shown to have test–retest variability of approximately 0.18 logMAR units.\textsuperscript{33} Because the present data were collected in the context of clinical treatment, test–retest data were not available. Nevertheless, if it is assumed that this error is present in both acuity measures simultaneously, the differences of 3 to 5 lines of acuity in patients with MH remain noteworthy. It is possible that Landolt-C acuities may have been affected by fatigue in the present study design as resolution acuity was always measured second, after recognition acuity. Still, the protocol did not require participants to undergo a lengthy series of acuity tests, and this type of systematic error is assumed to be negligible.

Previous work using SLOs in the context of MH research has greatly contributed to the understanding of structure–function relationships.\textsuperscript{15,16,27,34,35} This type of technology may shed more light on the question of whether Landolt-C acuity may be an indicator of retinal resolution, whereas ETDRS acuity may

\begin{figure}[h]
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\includegraphics[width=\textwidth]{acuity_difference.png}
\caption{Mean acuity differences (letter subtracted from Landolt-C, in logMAR) in relation to Landolt-C acuity. Error bars represent 95\% CI. Data have been incorporated from previous reports in the literature.\textsuperscript{6,7,10,20} Please note that the Landolt-C value by Raasch et al.\textsuperscript{6} is an estimate based on the report of acuity better than 20/25. Values by Sheedy et al.\textsuperscript{7} as well as Raasch et al. are only mean values as no confidence intervals or standard deviations were reported.}
\end{figure}
additionally reflect the patient’s cognitive ability to use this resolution. In conclusion, recognition and resolution acuities differ in a clinically relevant way in patients with MH, before as well as after MH surgery. The choice of acuity chart should be carefully considered in the context of clinical research and ophthalmic practice for the comparison of research findings as well as the ability to predict functional outcomes.

References