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Comparison of Visual Acuity in Macular Degeneration Patients Measured with Snellen and Early Treatment Diabetic Retinopathy Study Charts

Iryna A. Falkenstein, MD[1], **Denine E. Cochran, COT**[1], **Stanley P. Azen, PhD**[2], **Laurie Dustin, MS**[2], **Ajay M. Tammewar, MD**[1], **Igor Kozak, MD**[1], and **William R. Freeman, MD**[1]

[1]Joan and Irwin Jacobs Retina Center, Department of Ophthalmology, Shiley Eye Center, University of California, La Jolla, California

[2]Statistical Consultation and Research Center, Department of Preventive Medicine, Keck Medical School of the University of Southern California, Los Angeles, California

Abstract

Purpose—To compare the measurements of visual acuity (VA) results measured with Snellen and Early Treatment Diabetic Retinopathy Study (ETDRS) charts in eyes with and without age-related macular degeneration (AMD).

Design—Cross-sectional study.

Participants—One hundred four participants (190 eyes) selected from a university retina practice; 80 participants (142 eyes) had some degree of AMD.

Methods—Visual acuity was measured in each patient using standard procedure with both snellen and ETDRS charts in random order. Statistical analysis of the results was performed.

Main Outcome Measures—Difference in VA measured by both charts in logarithm of minimal angle of resolution (logMAR) notations.

Results—Overall, the mean Snellen VA was 0.78 logMAR (= 20/120), and the mean ETDRS VA in the same eye was 0.54 logMAR (= 20/70; $P<0.001$). In the low vision group (<20/200), represented by patients with AMD, the average difference in number of lines was considerably larger than in the good vision range (>20/30). On average, 20/200 on Snellen was 20/95 on ETDRS (>3 lines difference), and 20/30 on Snellen was 20/25 on ETDRS (<1 line difference).

Conclusion—Our results show poor agreement between the Snellen and ETDRS charts, and it was more pronounced in the group with poor vision. The ETDRS measurements yielded better VA, particularly in participants with vision <20/200 (representing more advanced AMD patients). We suggest taking these findings into consideration when comparing outcomes in clinical practices (which typically measure VA using standard Snellen charts) with outcomes from clinical trials (which typically measure VA using ETDRS charts).

Visual acuity (VA) in clinical settings is an ability to discriminate two stimuli separated in space at high contrast compared with the background. This simple measure detects most of the

Correspondence to William R. Freeman, Joan and Irwin Jacobs Retina Center, Department of Ophthalmology, Shiley Eye Center, University of California, San Diego, 9415 Campus Point Drive, La Jolla, CA 92037. E-mail: E-mail: freeman@eyecenter.ucsd.edu..

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visual dysfunctions; therefore, determination and correction of VA is an important goal in ophthalmology practice.

The Snellen chart is the most widely adopted tool for VA assessment and currently remains the major type of VA measurement in clinical settings. The prototype of this chart was developed in 1862 by Dutch ophthalmologist Hermann Snellen. He defined “standard vision” as the ability to recognize one of his optotypes at a visual angle of 1 minute of arc. Later, the original chart was modified and became what is now known as a standard Snellen chart.

Although widely used, this chart has well-documented limitations owing to design flaws,[1-4] such as inconsistent progression in letter size from one line to another, unequal legibility of letters used, unequal and unrelated spacing between letters and rows, and large gaps between acuity levels at the lower end of the chart (20/80-20/400). Variability in background ambient illumination and contrast changes make these measurements even more inconsistent.[4] The poor reliability of the Snellen charts has been noted in many studies previously[1,5-7] and Snellen acuity test-retest variability (TRV) between visits is reported to be large, varying from ±0.1[8] to ±0.15[9] logarithm of minimal angle of resolution (logMAR) units to ±0.29 to ±0.33 logMAR units[10,11]

It has been known that Snellen measurements are in many cases inadequate, and it is virtually impossible to evaluate the acuity data properly from study to study, especially in the low-vision range.

To address these design flaws of the Snellen chart, newer alternative eye charts have been designed. The logMAR chart represents the result of a major effort to introduce a standardized chart based on the recommendation of National Academy of Sciences, National Research Council,[12] and is based on the design suggested by Bailey and Lovie in 1976.[13] Later, it was described in detail by Ferris et al in 1982,[14] and adopted for the Early Treatment Diabetic Retinopathy Study (ETDRS chart). The major advantages of this chart are regular geometric progression of the size and spacing of the letters, following a logarithmic scale in steps of 0.1 log units; equal number of letters in each row, 5 Sloan optotypes,[15] and comparable legibility of the sans serif letters used. This chart is currently used extensively in all clinical trials and research where the precision measurement of VA is crucial.

The ETDRS chart has been shown to be accurate and reliable[16] with similar precision for both high and low levels of acuity.[13,14] Even very low VA (in the count finger range) can be quantified reliably by the ETDRS chart, by changing the viewing distance from 4 meters to 1 or 2 meters.[17] Since 1993, the ETDRS chart has become the gold standard in vision research (Sheedy JE. Standards for VA measurement. In: Eye care technology forum proceedings. Bethesda, Maryland; NIH 1993).

The TRV of this chart varies from ±0.07 logMAR[16] to ±0.16 logMAR[3,7] in eyes with no ocular pathology and good vision, and from ±0.15 logMAR[18] to ±0.18 to ±0.2 logMAR units[11,19-21] in patients with reduced vision owing to ocular pathology including age-related macular degeneration (AMD). It is considerably better compared with Snellen chart TRV for both good and poor vision ranges.

Many investigators use Snellen acuity in clinical studies for retinal diseases treatment outcomes, particularly for AMD. The majority of studies of intravitreal Avastin (bevacizumab) treatment published to date used the standard Snellen chart to test VA, but the studies of Food and Drug Administration-approved drugs such as ranibizumab (Lucentis) and pegaptanib (Macugen) used the ETDRS chart for the visual outcome measurements.

Our study was designed to determine whether there was a discrepancy in VA results measured consecutively by two charts in the same patient with AMD or controls without retinal pathology. Our goal was to determine the magnitude of the variability when comparing VA outcomes in clinical trials with outcomes obtained in ophthalmologic offices.

Participants and Methods

One hundred four participants were chosen from a cohort of patients seen at a retina practice at the University of California, San Diego, Jacobs Retina Center, from January 2006 to June 2006. The Institutional Review Board at the University of California, San Diego, approved the study protocol and study procedures conformed to the Health Insurance Portability and Accountability Act regulations and the Declaration of Helsinki for research involving human subjects.

Of the 104 participants, both eyes were tested using both VA procedures in 86 (83%) participants; the remaining 18 (17%) participants had only one eye tested (at the patient's request), resulting in a total of 190 eyes tested. Of the 104 participants, 19 (18%) had no ocular pathology in either eye (controls), 5 (5%) had posterior vitreous detachment in 1 eye and 80 (77%) participants had some degree of AMD in ≥1 eye. Of the 80 participants with AMD, 62 had both eyes tested and 18 participants had only 1 eye tested (the worst eye with AMD). Choroidal neovascularization was found in 34% of the AMD patients. Twenty-four participants (23%) had vision ≥20/30 and 80 (77%) participants had some degree of visual impairment (<20/30).

Examination with both the Snellen and ETDRS charts was performed in the same room under the same light conditions. The order in which the charts were shown to each patient was randomized. Best-corrected VA was determined for 190 eyes, using a “line assignment” method for both charts.

Best-corrected VA was measured with a projected Snellen chart (LongLife TM Project-O-Chart, Reichert Inc, Depew, NY) adjusted for a 20-foot viewing distance (6.1 meters) for each patient according to a standard protocol. Refraction was performed using trial frames. Luminance of the chart was 65.0 cd/m^2 (measured with digital Gossen Starlite All-in-One light meter; Gossen Foto- und Lichtmesstechnik GmbH, Nürnberg, Germany). Contrast of the chart was calculated as 89% (contrast = [luminance of background]-[luminance of letters]/[luminance of the background]).[12]

Subjects were required to read the chart from the top to the bottom. Testing was terminated when >2 errors were made for the lines with ≥5 letters, more than one error for the lines with 4 or 3 letters. No errors were allowed for a line with ≤2 letters. The VA score was assigned as the smallest line with the majority of letters read correctly, according to a rule described above. For a VA <20/400 (unable to recognize letter “E” on the top of the chart) we used a single printed letter “E” (20/200) at different distances until the patient could identify correctly the direction of the letter.

Consecutive testing with the ETDRS chart (Lighthouse International, New York, NY) at viewing distance of 2 meters (6.3 feet) was also performed and the best-corrected VA was recorded. The printed panel charts were backlit in the standard Lighthouse box achieving a luminance of 121.0 cd/m^2 measured with digital light meter and contrast of 97%, calculated as described. A subject was required to read the chart from the top to the bottom until >2 letters were misread on the line. The visual score was assigned as the smallest line where 3 of 5 letters were identified correctly. For statistical analysis, 2-meter VA scores were converted to 4-meter acuity scores according to the standard ETDRS methodology by doubling the recorded vision fraction; for example, 10/200 at 2m = 20/400 at 4 m.

Visual acuity results were divided into 3 groups according to the VA range determined by the Snellen chart: ≤20/200 (severe), 20/100 to 20/40 (moderate), and ≥20/30 (mild). Eyes with ≥20/30 were non-AMD controls including posterior vitreous detachment and patients with no vitreoretinal pathology, for a total of 48 eyes (25%). Eyes with ≤20/30 vision were either eyes with dry AMD (77 eyes; 40%) or eyes with choroidal neovascularization owing to AMD before treatment or undergoing pharmacologic treatment (65 eyes; 34%). All VA results from both Snellen and ETDRS charts were converted into logMAR units for the statistical analysis (-$\log MAR_{10}$ [VA fraction]); for example, 20/200 is 1.0 logMAR and 20/25 is 0.10 logMAR.

Paired *t* tests were used to compare the average VA scores between the Snellen and ETDRS charts for all eyes by subject and within strata defined by VA severity. In addition, Bland-Altman charts were generated to contrast the variability of the Snellen and ETDRS results.[22] Repeated measures analyses were run to adjust for the correlation between eyes of the same participant and paired *t* tests were also used after first averaging the measures by subjects. Both tests gave similar *P* values. Paired *t* test *P* values were used to test for significance of absolute differences between the Snellen and ETDRS. All analyses utilized SAS programs, version 10.0 (Cary, NC).

Results

Table 1 contrasts the VA results as measured by the Snellen and ETDRS charts, overall and for different levels of visual impairment.

On average, VA measured by ETDRS was significantly better than VA measured by the Snellen chart. Overall, the mean Snellen VA was 0.78 (= 20/120), and the mean ETDRS VA in the same eye was 0.54 (= 20/70; Table 1). The average difference in VA (ETDRS-Snellen) for all tested eyes was 2.5 lines better if tested with ETDRS.

In eyes with 20/200 or worse vision, the mean VA was 1.34 (= 20/440) with the Snellen chart and 0.93 (= 20/175) with ETDRS. Visual acuity measurements were considerably better using ETDRS chart in this range of vision and the discrepancy between the Snellen and ETDRS charts was on average 4 lines (Table 1).

In the VA range of 20/100 to 20/40, which represents the majority of AMD patients who were improving on current antiangiogenic treatments for AMD, the average difference between the charts was approximately 2 lines. The average VA in this group was 0.48 (= 20/60) using Snellen and 0.30 (= 20/40) if tested by ETDRS. In participants with nearly normal vision (≥20/30), we found an average discrepancy only of less than one line between the 2 charts.

Table 2 contrasts samples of average VA levels tested with Snellen chart and corresponding average VA levels tested by ETDRS chart in the same eyes.

The Bland-Altman chart shows graphically that the VA measured by Snellen and ETDRS are less disparate for the eyes with near normal VA (as measured by Snellen), and more disparate for the eyes with visual impairment (Fig 1).

Discussion

To our knowledge, this study represents the first direct attempt to compare and quantify the difference in VA measurements between the two of the most widely used charts for VA assessment. Such a comparison is important because of the rapidly emerging clinical trial and clinical case series data on treatment options for exudative AMD as well as for other retinal diseases. The majority of the participants in our study were patients with variable degrees of AMD. Others previously suggested, using much smaller number of patients, that there is a 3-

to 4-line difference between the Snellen and ETDRS chart in AMD patients with decreased VA.[23]

Clinicians are presented with the clinical trials data showing VA results measured with the ETDRS chart, yet the majority of clinical case series published to date, as well as ophthalmologists' own VA outcomes, are measured with the standard Snellen chart. We emphasize that the ETDRS chart gives less variable results[3,16,18-21] and it usually records a better VA than the Snellen chart under the same conditions owing to the well-described Snellen chart design flaws.[1-4,14] The Snellen chart has large gaps between lines in the low VA levels (<20/80), where the ETDRS chart has equal smaller steps in line spacing at the same level of VA. This difference obviously will result in some degree of discrepancy between visual scores recorded with both charts. Our study was designed to explore the practical impact of the visual results difference and clinically quantify it at the separate levels of acuity (Table 2). It is important to estimate this difference to help clinicians judge and compare VA results using the 2 different methods.

A better luminance level and a higher contrast of the letters play an important role for the spatial resolution.[24] In cases of AMD, contrast sensitivity is an especially important issue because macular function of these patients is impaired[25,26] and they require higher luminance and contrast for letter recognition.[27] Others have shown that the reproducibility and sensitivity to small VA changes were poor with the Snellen chart and a luminance variation in different rooms further compromised the results.[3,6]

Low levels of contrast sensitivity in AMD patients may adversely influence VA measurements and further increase TRV[21] if measured under low and inconsistent luminance conditions, such as standard projected Snellen chart. A question regarding the delayed adoption of a more reliable ETDRS chart in everyday practice has been raised previously.[28]

The 2 important advantages of the Snellen chart are the time required for the test and the convenient design for the refraction. The testing time for the Snellen chart is half the testing time for the ETDRS chart.[10] These advantages, however, are not comparable for the problem in precision and accuracy, and therefore some guideline is necessary to interpret results of treatment studies, using the ETDRS versus Snellen charts. Although the ETDRS chart has incorporated Snellen equivalent numbers and Snellen acuity results can be converted to logMAR equivalent ([-logMAR_{10}[VA fraction]), it is important to realize that a simple mathematical conversion is misleading.

Our statistics show that the Snellen visual score was consistently lower (worse) than the ETDRS visual score in the same eye across all ranges of vision, particularly in patients with visually significant AMD. As mentioned, the unequal line spacing between the 2 charts at the lower VA level is expected to result in some level of discrepancy of visual scores. However at the better levels of VA (≥20/100) where the line spacing in both charts is similar, the difference in VA scores is reduced but not totally eliminated (Table 2). This should be taken into consideration when interpreting VA results in clinics.

It is of interest that approximately half of the studied eyes were AMD eyes treated with intravitreal injections of the anti-vascular endothelial growth factor agents such as pegaptanib or bevacizumab. Our experience suggests (Falk-enstein, unpublished data) that the Snellen chart was not as sensitive in detecting VA changes during or after treatment, as was the ETDRS chart. The magnitude of improvement was demonstrated better when VA was measured with ETDRS chart; therefore, ophthalmologists in clinical practice should adjust their expectations for the visual outcomes if they test VA in the office with the Snellen chart.

There are several scoring methods have been described for the Snellen chart and we used a combination of the 2 most commonly used methods[12,29] to estimate VA more rigorously and with a higher precision for both low and high VA levels. Although we do acknowledge that there may be some contribution to the score difference from the scoring methods we used, it would not account for the full magnitude of difference in the results we have shown. Also, given the large number of eyes used in our study and a high statistical significance of the results (<0.001), it is unlikely that our results are due to variance in TRV.

Clinical data on off-label drugs, such as bevacizumab, are accumulating quickly and to analyze such data using meta-analysis or other methods, it is still necessary to take into consideration the discrepancy between vision test methods. Our data do not allow a strict conversion between the 2 methods on a patient-to-patient basis; however, statistically the data we generated are very useful.

In this study, we focused on AMD because of the necessity to estimate visual outcomes properly during the course of treatment with currently available medications for exudative AMD. Our data could be applicable to other diseases as well, but further studies in eyes with different ocular pathology may be performed.

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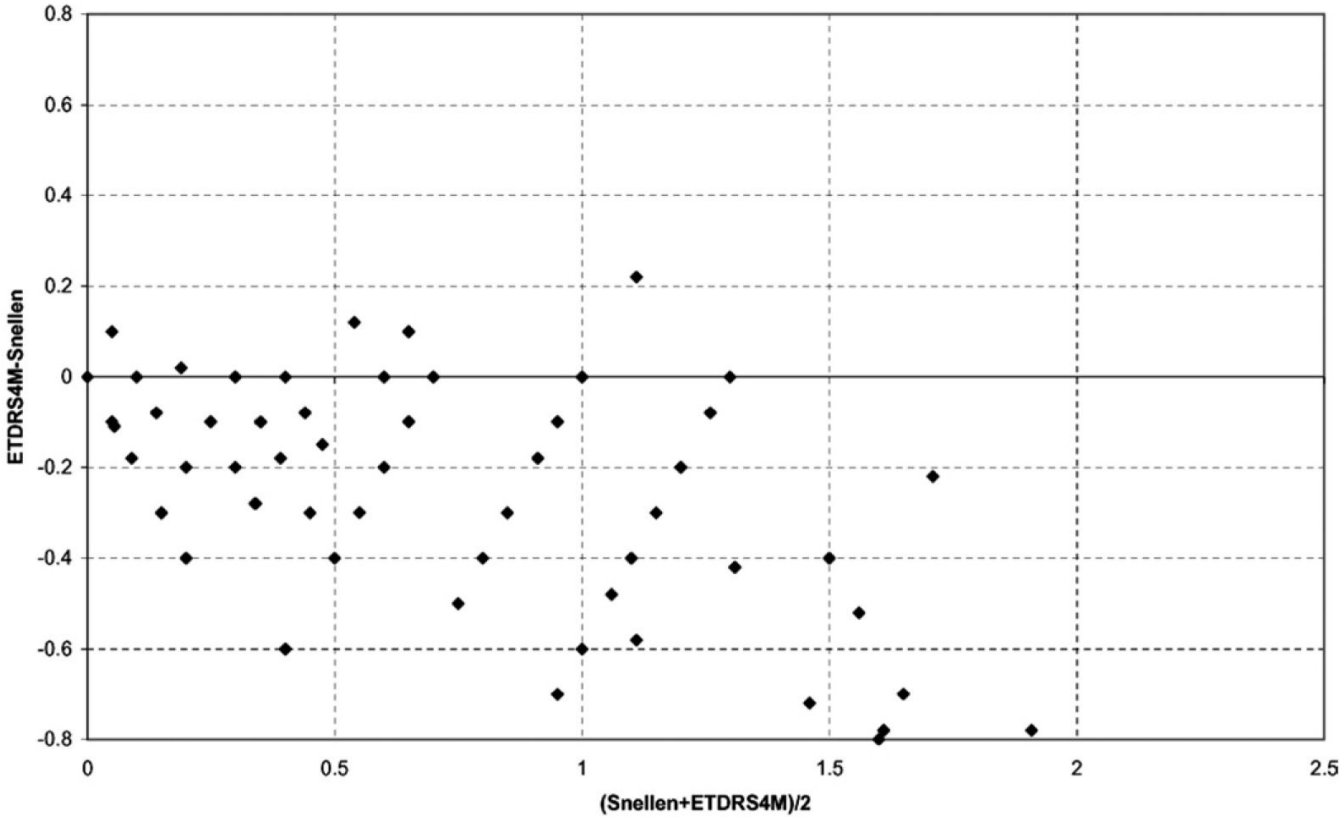

Figure 1.
Visual acuity (VA) measurement differences between Snellen and Early Treatment Diabetic Retinopathy Study (ETDRS) charts. This figure is a Bland-Altman chart, which graphically displays VA discrepancy between the 2 charts. The x-axis displays mean VA value between Snellen and ETDRS - (Snellen + ETDRS)/2; the y-axis displays the difference between measurements by both charts (ETDRS - Snellen). All numerical values on x-and y-axes are logarithm of the minimum angle of resolution (logMAR) units. All points below the solid line reflect Snellen score worse than ETDRS score in the same person and vice versa.

Table 1

Snellen and Early Treatment Diabetic Retinopathy Study (ETDRS) Visual Acuity (VA) Results Comparison

VA Category by Snellen	Snellen	ETDRS	Difference*	*P* Value
All VA (n = 104 subjects, 190 eyes)	0.78 (± 0.50)/0.74 (0-2.30)	0.54 (± 0.38)/0.50 (0-1.30)	-0.24 (± 0.22)/-0.20 (-1.11 to 0.12)	<0.001
Worse or = 20/200 (n = 62 subjects, 87 eyes)	1.34 (± 0.35)/1.30 (1.00-2.30)	0.93 (± 0.26)/0.96 (0.05-1.60)	-0.40 (± 0.28)/-0.40 (-1.11 to 0.22)	<0.001
20/100 - 20/40 (n = 45 subjects, 55 eyes)	0.48 (± 0.13)/0.48 (0.30-0.70)	0.30 (± 0.16)/0.30 (0-0.70)	-0.18 (± 0.13)/-0.15 (-0.60 to 0.01)	<0.001
20/30 or better (n = 33 subjects, 48 eyes)	0.11 (± 0.06)/0.10 (0-0.18)	0.05 (± 0.07)/0 (0-0.2)	-0.07 (± 0.06)/-0.08 (-0.18 to 0.05)	<0.001

All results are expressed in logarithm of the minimum angle of resolution notations as means (± standard deviation)/median (range). Means and medians reported are per subject.

*ETDRS - Snellen; each 0.1 = 1 line on ETDRS chart.

Table 2

Average Discrepancy between Visual Acuity (VA) Levels Measured by Snellen and Early Treatment Diabetic Retinopathy Treatment Study (ETDRS) Charts

No. of Eyes	Average Snellen VA	Average Corresponding ETDRS VA	Average Discrepancy in Lines*
39	1.3 (20/400)	0.95 (20/180)	0.35 (3.5)
30	1.0 (20/200)	0.68 (20/95)	0.32 (>3)
15	0.70 (20/100)	0.45 (20/57)	0.25 (2.5)
8	0.48 (20/60)	0.30 (20/40)	0.18 (2)
11	0.40 (20/50)	0.22 (20/33)	0.18 (2)
11	0.30 (20/40)	0.13 (20/27)	0.17 (2)
17	0.18 (20/30)	0.10 (20/25)	0.08 (<1)
20	0.10 (20/25)	0.02 (20/21)	0.08 (<1)

All results are expressed in logarithm of the minimum angle of resolution (logMAR) notations (20-foot Snellen VA fraction). This table should not he applied to predict directly VA in an individual patient, but rather to guide the expectations for a cohort of patients.

* Expressed in logMAR notations (corresponding no. of lines on ETDRS chart).