

The Early Treatment in Diabetic Retinopathy Study Chart Compared with the Tumbling-E and Landolt-C



Visual acuity (VA) is a measure of the visual system's ability to resolve fine detail and is expressed using the logarithm of the minimal angle of resolution (logMAR), which depends on the angular size of critical detail in optotypes. Charts originally developed for the Early Treatment in Diabetic Retinopathy Study (ETDRS) and subsequently refined have become the gold standard in ophthalmology research and are based on the design principles of Bailey and Lovie; they have logarithmic scales, 5 optotypes per line, and geometric progression in letter size and spacing.^{1,2} The letter size on each line is 1.2589, or 0.1 log units, times bigger than those on the next line and optotypes are the 10 Sloan letters (C, D, H, K, N, O, R, S, V, and Z).

Because not all patients are familiar with the Roman alphabet, from which Sloan letters originate, other optotypes are used in charts modelled on the ETDRS layout. The Landolt-C and Tumbling-E are such optotypes consisting of a single shape (C or E) presented in 1 of 4 orientations: upright or up-side-down and facing left or right. The Landolt-C is internationally regarded as the reference optotype and the Tumbling-E is commonly used in clinical practice.³ Interestingly, of ETDRS optotypes, C has been shown to be the most difficult to resolve, whereas E is not utilized.² This study aimed to compare VA measured by Tumbling-E and Landolt-C charts with the gold standard ETDRS charts, thus helping to standardize clinical data across populations not using the Roman alphabet, such as many of those native to eastern Europe, the Middle East, Indian subcontinent, and Asia, as well as people using Latin languages who may be illiterate, particularly in the developing world.

Patients presenting at a community ophthalmology practice were invited to participate; 112 patients with an average age of 63 years (range 18–87) were recruited. The analysis included 221 eyes, almost one-half (48.9%) were healthy and various pathologic conditions affected remaining eyes (Table 1, available at www.aaojournal.org). Three low-vision eyes were excluded because no ETDRS optotypes could be determined at 1 meter. Patients were refracted according to the Age-related Eye Disease Study (AREDS) Manual of Procedures.⁴ Vision was tested using ETDRS, Landolt-C, and Tumbling-E charts, with separate versions of each for right and left eyes (Precision Vision, La Salle, IL; CAT Nos: 2122, 2123, 2210, 2210A, 2305, and 2305A). Charts were mounted in a retro-illuminated cabinet with luminance of 85 cd/m² (Precision Vision; CAT No: 2425). The order of chart presentation was randomized and instructions to patients and VA scoring were in accordance with the AREDS manual, with minor modifications allowing for the Landolt-C and Tumbling-E charts. Institutional ethics committee approval was granted by Trinity College Dublin Research Ethics Committee.

Descriptive statistics, with computation of mean, standard deviation, and 95% confidence interval (CI) and the Shapiro–Wilk test for normality of distributions were applied. A specific procedure for

generalized linear mixed models (GLIMMIX) for data with skewed distribution, correlations, or nonconstant variability was used. The procedure was applied with repeated effect for comparison between methods to obtain solutions with compound symmetry of covariance structures for all eyes with adjustment for possible correlation between the right and left eyes of an individual. Least-square means with 95% CIs were obtained and, if necessary, post hoc Tukey–Kramer adjustment for multiple comparisons of *P* values was calculated. Additional subgroup analysis was undertaken on eyes with poor VA (≥ 0.5 logMAR ETDRS). Differences between charts were graphically presented using Bland–Altman and frequency–distribution plots. Statistical significance was set at *P* < 0.05. Analyses were performed using statistical software packages IBM SPSS Statistics Ver.22 (IBM, Armonk, NY), Stata Ver.12.1 (StataCorp, College Station, TX), and SAS Ver.9.3 (SAS Inc, Cary, NC).

Using the GLIMMIX approach, the estimated mean VA measured with the ETDRS chart was 0.15 logMAR (95% CI, 0.11–0.20), the Tumbling-E chart was 0.17 logMAR (95% CI, 0.13–0.21) and the Landolt-C chart was 0.25 logMAR (95% CI, 0.21–0.30). The adjusted 0.02 logMAR difference between ETDRS and Tumbling-E charts was not significant (*P* = 0.116). However, the adjusted 0.10 logMAR difference between ETDRS and Landolt-C charts was significant (*P* < 0.0001). This shows that, although the average difference in VA measured with the Tumbling-E and ETDRS charts is negligible, there is a 1-line difference between the Landolt-C and ETDRS charts that may be clinically important. Bland–Altman plots, constructed with data from all 221 eyes, further demonstrate greater discrepancy between Landolt-C and ETDRS than that between Tumbling-E and ETDRS charts (Fig 1). Furthermore, the frequency of identical VA measurements was greater when comparing ETDRS to Tumbling-E charts than in the ETDRS versus Landolt-C comparison (Fig 2, available at www.aaojournal.org). Thus, the Tumbling-E chart provides VA measurements more closely matching the ETDRS chart. For low-vision eyes (ETDRS ≥ 0.5 logMAR), the mean difference between ETDRS and Tumbling-E charts was –0.07 (median, –0.04; interquartile range, –0.10 to 0.00) and between the ETDRS and Landolt-C was 0.13 logMAR (median, 0.10; interquartile range, 0.05–0.17). Possibly owing to the limited sample size (*n* = 21), the differences were not significant but do suggest that low-vision patients may score better with Tumbling-E than ETDRS charts; they may find the Landolt-C even more difficult to read.

Our findings are supported by a comparison performed amongst the Landolt-C, Tumbling-E, and the University of Crete letter charts, showing that the Tumbling-E was more comparable with the letter chart.⁵ The University of Crete chart is based on the ETDRS chart but uses different letters common to the Roman, Greek, and Cyrillic alphabets, so that it is readable in Greece and other parts of Eastern Europe. Our study is the first to compare the Landolt-C and Tumbling-E charts with the gold standard ETDRS chart. Limitations of our study are that test–retest variability was not measured and relatively few subjects with poor VA were included.

The Tumbling-E chart measured VA broadly in line with the gold standard ETDRS chart, particularly in patients with

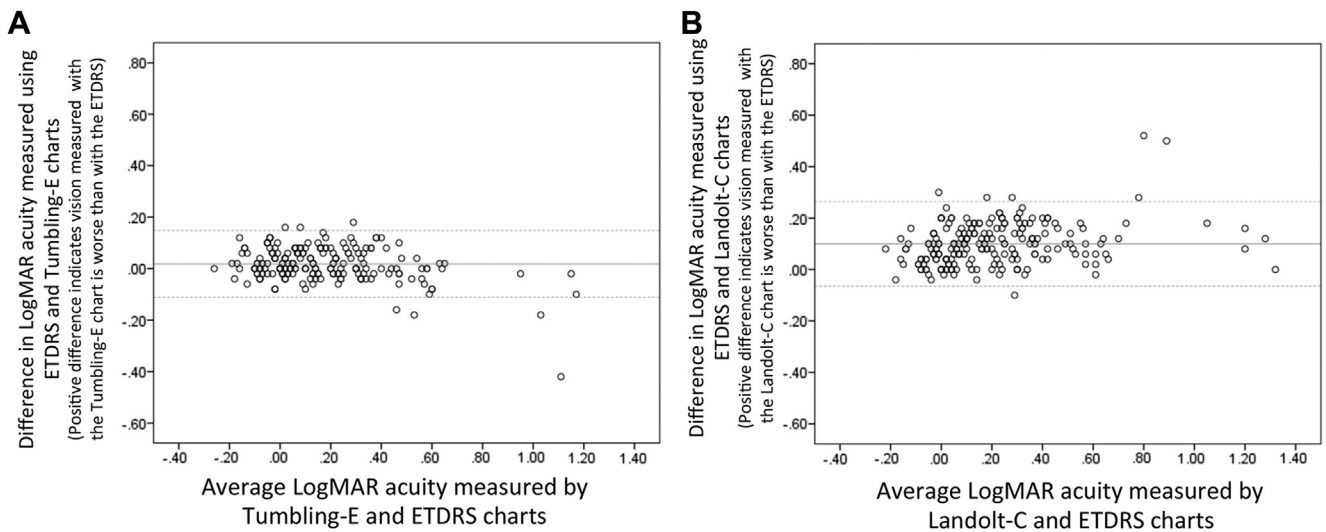


Figure 1. A, Bland–Altman plots comparing the Early Treatment in Diabetic Retinopathy Study (ETDRS) chart with (B) the Tumbling-E chart and the ETDRS chart with the Landolt-C chart. LogMAR = logarithm of the minimum angle of resolution.

reasonably good VA. This helps to validate the Tumbling-E chart for use in clinical and research settings among populations unfamiliar with the Roman alphabet. Caution should be exercised when extrapolating these results for patients with poor VA.

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Financial Disclosure(s): The authors have no proprietary or commercial interest in any materials discussed in this article.

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Table 1. Characteristics of the Diagnoses of Individual Eyes

Diagnosis	n	%
Ocular surface disease		
Dry eye	3	1.4
Tear film instability	2	0.9
Conjunctivitis	2	0.9
Media opacity		
Cataract	41	18.6
Corneal scar	1	0.5
PCO	3	1.4
Glaucomatous pathology		
Glaucoma	18	8.1
OHT	8	3.6
Macular pathology		
ARMD	18	8.1
CMO	1	0.5
Vitreoretinal pathology		
PVD	5	2.3
BRVO	2	0.9
NPDR	3	1.4
Neurologic pathology		
Amblyopia	1	0.5
Migraine	1	0.5
Total	221	100
Excluded eyes owing to severely reduced visual acuity*		
Toxoplasmosis	1	
Disciform scar	1	
Chronic RD	1	
Total	3	

ARMD = age-related macular degeneration; BRVO = branch retinal vein occlusion; CMO = cystoid macular edema; NPDR = Non-proliferative diabetic retinopathy; OHT = ocular hypertension; PCO = posterior capsule opacification; PVD = posterior vitreous detachment.

*Severely reduced VA is an inability to read any Early Treatment in Diabetic Retinopathy Study letters at 1 meter.