THE DISC DAMAGE LIKELIHOOD SCALE: REPRODUCIBILITY OF A NEW METHOD OF ESTIMATING THE AMOUNT OF OPTIC NERVE DAMAGE CAUSED BY GLAUCOMA

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ABSTRACT

Purpose: The major objective of this study was to test the reproducibility of a new method of estimating the amount of optic disc damage in patients with glaucoma.

Methods: The Disc Damage Likelihood Scale (DDLS) is based on the appearance of the neuroretinal rim of the optic disc corrected for disc diameter. The eight stages, extending from no damage to far advanced damage, are based on the width of the neuroretinal rim or the circumferential extent of absence of neuroretinal rim. Reproducibility was measured by two masked observers staging 48 optic nerve stereoscopic photographs by two different methods, the cup/disc ratio (c/d) and the DDLS. Also, reproducibility was assessed by three observers examining 34 eyes of 24 patients.

Results: With regard to the photographs, the intraobserver and interobserver reproducibility was better using the DDLS than the c/d ratio (98% versus 85% for intraobserver of reproducibility, and 85% versus 74% for interobserver reproducibility). The DDLS correlated better with the Humphrey Visual Field than did any Heidelberg Retina Tomograph parameter.

Conclusion: In a clinical setting, the DDLS is as reproducible as, or more reproducible than, the c/d ratio system of estimating the amount of disc damage in patients with glaucoma.

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INTRODUCTION

Glaucoma is a process in which the tissues of the eye, most importantly the optic nerve, become damaged in a characteristic fashion, at least partially related to intraocular pressure (IOP). As such, evaluation of the optic disc plays a highly important role in the diagnosis and management of patients with glaucoma. Several methods have been described to stage the amount of disc damage.[1-5]

The first four of these have been available for some years but have not been widely utilized. We have developed a new scale that we believe offers significant advantages over the previous four scales.[5] We believe that this new scale may be useful in all those areas where it is appropriate to know how much glaucomatous damage a patient has sustained. This new scale is called the Disc Damage Likelihood Scale (DDLS). In the present study we evaluated the DDLS in terms of reproducibility and reliability.

From William and Anna Goldberg Glaucoma Research Laboratories, Wills Eye Hospital, Jefferson Medical College, Philadelphia, Pennsylvania (Dr Spaeth, Dr Henderer, Dr Kesen, Dr Altangerel, Dr Bayer, Dr Katz, Dr Myers, and Dr Rhee); Temple University School of Medicine, Philadelphia (Ms Liu); and the Tulane Center for Clinical Effectiveness and Prevention, Tulane University Health Sciences Center, Tulane University, New Orleans, Louisiana (Dr Steinmann). Supported in part by a grant from the Glaucoma Service Foundation of the Wills Eye Hospital and an unrestricted grant from Pharmacia, Inc.

METHODS

Patient photographs were selected by reviewing records from the Glaucoma Service Diagnostic Laboratory of the Wills Eye Hospital. Patients were placed into one of four categories according to the amount of visual field damage: no damage (15 patients), mild damage (12 patients), moderate damage (10 patients), and severe damage (11 patients). Photographs were examined using a stereo viewer by two glaucoma specialists who staged the optic nerves according to the DDLS (Table I and Figure 1) and the cup-disc (c/d) ratio method. It was assumed that all optic nerves were of average size. Graders noted both the vertical and the horizontal c/d ratios using a ruler. Each photograph was examined by each grader in three different sessions. Interobserver and intraobserver agreement was determined by the test-retest method for the DDLS and for the c/d ratio.

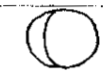
	Narrowest width of rim (rim/disc ratio)				Examples		
DDLS Stage	For Small Disc <1.50 mm	For Average Size Disc 1.50-2.00 mm	For Large Disc >2.00 mm	DDLS Stage	1.25 mm optic nerve	1.75 mm optic nerve	2.25 mm optic nerve
0a	.5 or more	.4 or more	.3 or more	0a			
0b	.4 to .49	.3 to .39	.2 to .29	0b			
1	.3 to .39	.2 to .29	.1 to .19	1			
2	.2 to .29	.1 to .19	less than .1	2			
3	.1 to .19	less than .1	0 for less than 45°	3			
4	less than .1	0 for less than 45°	0 for 46° to 90°	4			
5	0 for less than 45°	0 for 46° to 90°	0 for 91° to 180°	5			
6	0 for 46° to 90°	0 for 91° to 180°	0 for 181° to 270°	6			
7a	0 for 91° to 180°	0 for 181° to 270°	0 for more than 270°	7a			
7b	0 for more than 180°	0 for more than 270°		7b			

FIGURE 1

Disc Damage Likelihood Scale (DDLS) nomogram. DDLS is based on the radial width of the neuroretinal rim measured at its thinnest point. Unit of measurement is rim/disc ratio (ie, the radial width of the rim compared to the diameter of the disc in the same axis). When there is no rim remaining, the rim/disc ratio is 0. The circumferential extent of rim absence (0 rim/disc ratio) is measured in degrees. Caution must be taken to differentiate the actual absence of rim from sloping of the rim as, for example, can occur temporally in some patients with myopia. A sloping rim is not an absent rim. Because rim width is a function of disc size, disc size must be evaluated prior to attributing a DDLS stage. This is done with a 60D to 90D lens with appropriate corrective factors. The Volk 66D lens minimally underestimates the disc size. Corrective factors for other lenses are: Volk 60D × .88, 78D × 1.2, 90D × 1.33; Nikon 60D × 1.03, 90D × 1.63.

TABLE I: THE DISC DAMAGE LIKELIHOOD SCALE

STAGE	NARROWEST WIDTH OF RIM
0	0.3-0.5
1	0.2-0.29
2	0.1-0.19
3	0.01-0.1
4	No rim <45°
5	No rim 45°-90°
6	No rim 91°-180°
7	No rim >180°

Three observers examined 34 eyes of 24 consecutive glaucoma patients using a Haag-Strait slit lamp and a Volk 66 diopter lens,[6] making a single determination of the c/d ratio and the DDLS stage. The number of inter-observer agreements was tabulated using a cutoff of equal or less to 1 DDLS stage, and equal or less to 0.1 c/d ratio.

RESULTS

Results are summarized in Tables IIA, IIB, and III.

DISCUSSION

Diagnostic tests are valuable to the extent that they are (1) reliable, (2) "user-friendly," and (3) reproducible. *Reliable* means that the finding represents what it is supposed to represent. *User-friendly* is self-evident. *Reproducible* means on subsequent examinations the same observer or different observers will describe a particular finding the same way.

This report deals with the reproducibility of a measure to estimate the extent of any damage caused to the optic disc by glaucoma. The usual method now used to evaluate the state of the optic disc in patients with glaucoma is the c/d ratio.[7] This user-friendly system has resulted in better

TABLE IIA: INTEROBSERVER AND INTRAOBSERVER AGREEMENT (≤0.1 C/D OR <1 DDLS STAGE) FOR SELECTED DISC MEASUREMENTS

	ARMALY VERTICAL C/D RATIO			OVERALL DDLS STAGE		
Interobserver	Reading 1	Reading 2	Reading 3	Reading 1	Reading 2	Reading 3
Grader 1 + 2	32/48	34/48	32/48	40/48	41/48	42/48
Intraobserver	Reading 1 – Reading 2	Reading 2 Reading 3	Reading 1 – Reading 3	Reading 1 – Reading 2	Reading 2 – Reading 3	Reading 1 – Reading 3
Grader 1	43/48	43/48	42/48	48/48	47/48	47/48
Grader 2	43/48	47/48	47/48	48/48	47/48	47/48

c/d, cup-disc; DDLS, Disc Damage Likelihood Scale.

TABLE IIB: SUMMARY OF MEAN INTEROBSERVER AND INTRAOBSERVER AGREEMENT ≤1 DDLS STAGE OR <0.1 C/D RATIO/FOR REMAINING DISC CRITERIA (% AGREEMENT AND SD)

	INTEROBSERVER	INTRAOBSERVER	
		GRADER 1	GRADER 2
Horizontal c/d ratio	69 (0.02)	89 (0.07)	92 (0)
Vertical c/d ratio	68 (0.02)	89 (0.01)	95 (0.05)

c/d, cup-disc; DDLS, Disc Damage Likelihood Scale.

TABLE III: LEVEL OF IN VIVO INTEROBSERVER AGREEMENT (≤1 DDLS STAGE AND ≤0.1 C/D) FOR THE THREE OBSERVERS

	AGREEMENT OF ALL THREE OBSERVERS (%)	AGREEMENT BETWEEN 2 OF 3 OBSERVERS (%)
DDLS stage	24/34 (70.5)	34/34 (100)
Armaly c/d ratio	23/34 (67.6)	33/34 (97.1)

c/d, cup-disc; DDLS, Disc Damage Likelihood Scale.

TABLE IV: DISTRIBUTION OF THE DDLS IN A GLAUCOMA REFERRAL PRACTICE

DDLS SCALE	NO. OF CASES
0	271
1	500
2	447
3	330
4	176
5	105
6	136
7	186

DDLS, Disc Damage Likelihood Scale.

TABLE V: POSITIVE PREDICTIVE VALUE OF DISC FINDINGS

Acquired pit of optic nerve	High
Absent rim	High
Progressive narrowing of rim greater than that seen with normal aging	High
Breaks ISNT rule	Moderately high
Disc hemorrhage	Moderate
Large c/d ratio	Low
Significance of Disc Finding As Sign of Worsening	
Narrowing of rim	High
Disc hemorrhage	Moderate

c/d,cup-disc; ISNT, inferior, superior, nasal and temporal.

communication between observers and better care for patients. The reproducibility of the system, however, is only moderate.[8-12] Further, the reliability is not high.[13-15] That is, some patients have small c/d ratios but significant visual field loss, whereas some have large c/d ratios with little visual field loss. Finally, while the c/d ratio is of some value in patients with concentric cupping,[16] it may be seriously misleading when the loss of rim is limited to a single sector, as with a focal notch. In this latter situation, the c/d ratio may be recorded as small, and yet the disc and visual field may be badly damaged.

The DDLS was designed to be reliable, user-friendly, and reproducible. Reliability of the DDLS has been assessed by Bayer and colleagues,[5] who concluded that the DDLS correlated strongly with the amount of visual field damage.

Regarding user-friendliness, the DDLS is readily learned, and once the vertical diameter projected on the retina by the direct ophthalmoscope has been determined by using a strong plus lens such as the Volk 66, the only instrumentation required is the direct ophthalmoscope.

The DDLS system is now utilized as part of the routine examination in the office practice of the senior

author. Each time the disc is examined, the DDLS is recorded. This permits quantification, a characteristic considered important by Klein and associates.[17] The DDLS can be recorded in computer-compatible codes, so as to allow easy recovery of data. Such a code can include both the stage and the eye. For example, in our office we code all examinations with a DG (for the disc grade), followed by the eye (RT for right, and LT for left), and then the grade. Thus, DGRT 0 represents a disc grade of 0 in the right eye, and DGLT 2 represents a disc grade of 2 in the left eye.

Easy retrieval of information regarding the stage of patients with glaucoma facilitates a variety of projects related to clinical practice and research. For example, at present it is difficult to generalize results from one clinical study to another clinical study because of uncertainty regarding the similarity or dissimilarity of the populations involved. Knowing this information will allow better characterization of populations and better research. For example, Table IV lists the distribution of disc stages in the population of private patients followed by the senior author. This probably differs considerably from other practices, but whether this is indeed the case and to what extent there is a difference are at present difficult or impossible to ascertain.

Tests must also be reproducible to be valuable. The present study indicates that the DDLS is adequately reproducible. Indeed, it appears to be more so than the c/d ratio.

Diagnosis of glaucoma depends primarily on recognizing the pattern of characteristic damage (Table V). Just what is characteristic, however, is controversial. For example, hemorrhages crossing the rim of the optic disc are considered by some to be highly characteristic, and it has been shown that there is an association between the presence of hemorrhage and a worse prognosis in patients with glaucoma. However, such hemorrhages are seen in patients who do not have glaucoma and who never develop visual field loss or any other change believed to be characteristic of glaucoma. Lichter and Henderson[18] described a disc hemorrhage as a part of what they believed to be a stable condition different from glaucoma. Management of glaucoma depends largely on recognizing a change. Recognition of change requires reproducible quantification. The previous systems that have been suggested in this regard usually utilize the c/d ratio system and are limited to five stages, most of which describe the later stages of damage.[1-4] As such, detection of change becomes difficult. Additionally, these previously described systems have not been validated. Perhaps for these reasons, none of these existing systems has been widely utilized.

The DDLS was designed primarily for use in patients with glaucoma. Its value as a measure of estimating damage associated with other diseases of the optic nerve has not been studied.

CONCLUSION

The DDLS is a reproducible method of estimating the amount of optic nerve damage caused by glaucoma. It may provide a useful method of diagnosing and managing patients with glaucoma.

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DISCUSSION

DR JAMES C. BOBROW. Each time George Spaeth reports his observations, he challenges our intellects. Whether he is assessing the anterior chamber angle or observing the optic disc, he forces us to reconsider our presumptions. As long ago as 1985 and 1989, he argued that the methods used to estimate the extent of change of the cup/disc ratio as a measurement of damage from glaucoma need revision.[1,2] In addition, Dr Spaeth has been in the forefront of the comparison of clinically derived measurements of optic nerve parameters with scanning laser tomography.[3]

Now we are being asked to reconsider the damage to the optic nerve in glaucoma from the rim in instead of from the cup out, and we are being told that the quadrants that are most vulnerable—the superior and inferior poles of the disc—are the ones on which we should focus the majority of our attention and expand the range of quantification of our observations.

Some of these data are already used in the measurements of vertical and horizontal disc size and in the emphasis on contour and depth instead of color. However, in spite of our level of confidence in our own observations, we have been confronted by several investigators with the fact that we simply don't agree about our measurements.[4-6] Intraobserver differences appear to be fairly consistent, but interobserver agreement is often faulty using the Armaly-derived criteria. In Dr Spaeth's presentation, interobserver agreement has been demonstrated to be improved from previous studies.

I responded to Dr Spaeth's challenge by conducting a brief reconsideration of the visual fields and three-dimensional photographs of 30 eyes of 15 patients with glaucoma in my own practice to see whether I could confirm some of his observations and whether, by applying his method of evaluation, I would gain additional insight into the relationship between the appearance of the optic disc and visual fields obtained at approximately the same time.

The results confirm Dr Spaeth's study and show that these measurements are relatively easy to learn. The DDLS scores for each three-dimensional disc photograph were plotted against a scale of field loss. Scores ranged from 1 = normal, to 10 = extensive field loss. The graph is shown in Figure 1. The *r* value of the curve was 0.45.

The DDLS scores were then compared to the mean deviation score from the Humphrey Visual Field Analyzer (Zeiss Instruments San Leandro, California). Figure 2 shows the plot of DDLS versus mean deviation. Here *r* = 0.68.

We are fortunate in ophthalmology to be able to visualize much of our patients' pathology. In conclusion, I want to congratulate Dr Spaeth and his coworkers for again raising our clinical awareness that careful observation of our patients will yield accurate information to assist us in caring for them.

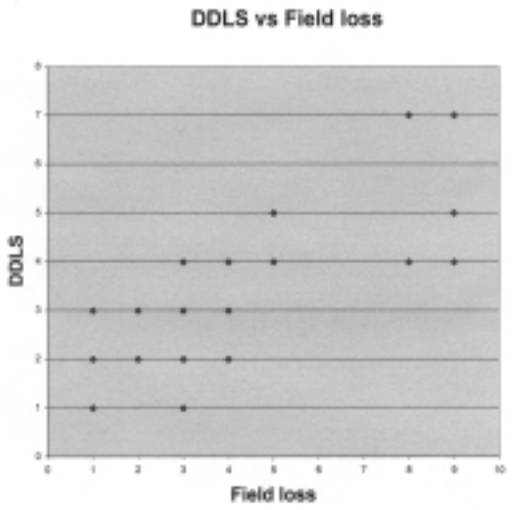

FIGURE 1
The DDLS scores for each three-dimensional disc photograph plotted against a scale of field loss. Scores ranged from 1 = normal to 10 = extensive field loss. *r* value of the curve was 0.45.

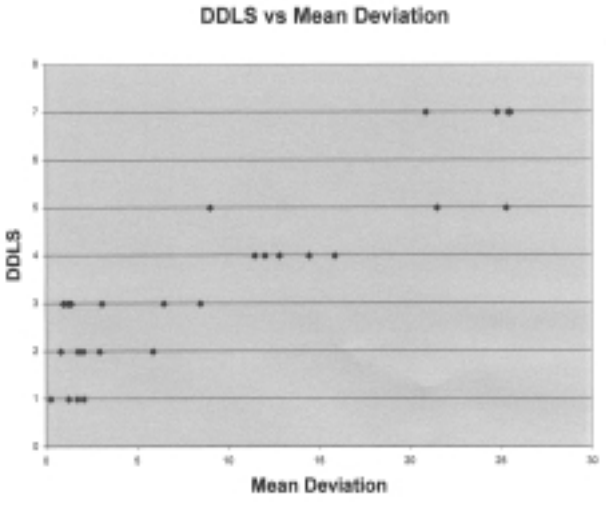

FIGURE 2
The DDLS scores compared to the mean deviation score from the Humphrey Visual Field Analyzer. *r* value of the curve was 0.68

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DR ROBERT RITCH. You stated that 30% of patients with hypotony get blebitis each year. There is probably more hypotony per se than bleb leaks leading to hypotony or bleb leaks leading to blebitis. You need to be careful in doing a Seidel test, since some ophthalmologists use dry strips and actually cause bleb leaks. Use a wet strip and just touch it to the bleb.

(Editors note: Dr Spaeth's comment was in the presentation but not in the paper)

DR GEORGE SPAETH. I want to thank Dr Bobrow for his discussion. Every presenter probably wants the people who discuss their presentations to understand the substance of their talks. What better way is there to do that than to test out the presenter's hypothesis? I am delighted that Dr Bobrow actually did that. I am pleased that he found the Disc Damage Likelihood Scale to be workable and apparently useful. I thank him for taking the time to test out the new system. I hope he continues to use it and finds it useful.

I agree with Dr Ritch that one needs to be careful in performing a Seidel test. However, I believe the significance of blebs which are sufficiently thin to allow aqueous to exit through the conjunctiva is becoming increasingly clear. When aqueous can exit through those blebs, then bacteria can enter through those blebs. A telling study presented at ARVO followed patients over a period of 10 years and noted that about 3.5% of patients developed endophthalmitis each 5 years. That is a deeply disturbing finding. My prediction is that few will be using mitomycin in association with the performance of primary guarded filtration procedures within 5 years.