CORRELATION OF DISC DAMAGE LIKELIHOOD SCALE WITH FIELD DEFECTS IN ESTABLISHED GLAUCOMAS- AN ANATOMICAL VERSUS FUNCTIONAL CORRELATION

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ABSTRACT

BACKGROUND

Glaucoma is a chronic progressive optic neuropathy characterised by optic nerve head changes and field defects due to apoptosis of ganglion cells, with raised intraocular pressure being the most important risk factor. Traditionally Armaly’s cup/disc (C/D) ratio was considered as a standard method of evaluation of optic nerve head. The Disc Damage Likelihood Scale DDLS relies on the optic nerve as a direct indicator of disease. Because the scale divides glaucomatous progression into 10 stages, it can also aid to monitor the disease progression. DDLS helps in quantification of the amount of damage that the optic nerve has sustained. This study correlates the DDLS score with the visual field indices establishing a structural and functional correlation. We wanted to analyse Disc Damage Likelihood Ratio in patients with established open angle glaucoma and to correlate it with field defects and to thereby obtain an anatomical versus functional correlation. This study also evaluates the diagnostic ability of disc damage likelihood scale in glaucoma.

METHODS

50 cases of established open angle glaucoma were included in this study. For all cases visual fields were recorded by Octopus 301 using G1 program and TOP strategy. After field testing, DDLS scores were calculated after dilatation. The DDLS score and field parameters of the patients were analysed.

RESULTS

Of the 50 patients included in this study, 70% were on topical antiglaucoma medications and 30% had undergone trabeculectomy. DDLS score and average loss variance showed a strong positive correlation as the r value was 0.95.

CONCLUSIONS

Disc diameter evaluation is an important part of optic nerve head evaluation. In cases with asymmetry of the cup disc ratio between two eyes, asymmetry of the disc size should also be considered if the neuroretinal rim is healthy. Disc Damage Likelihood Scale (DDLS) is a better indicator of optic nerve head status and has strong positive correlation with visual field indices.

KEYWORDS

Disc Damage Likelihood Scale, Automated Perimetry, Field Defects in Glaucoma.

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Disc can be classified as follows:
- Small, with disc diameter less than 1.5 mm.
- Medium, with disc diameter between 1.5 - 2 mm.
- Large, with disc diameter more than 2 mm.

**Step 2: NRR Assessment**

The unit of measurement of DDLS scale is the rim/disc ratio, that is, 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 is measured in degrees. Actual absence of rim should be differentiated from sloping rim. Sloping rim can occur temporally in myopes. Because rim width is a function of disc size, disc size must be evaluated prior to attributing a DDLS stage.

**Stages of DDLS**

The DDLS relies on the optic nerve as a direct indicator of disease. Because the scale divides glaucomatous progression into 10 stages, it can also aid to monitor the disease progression. The DDLS helps in quantification of the amount of damage that the optic nerve has sustained.

For small discs (disc diameter less than 1.5 mm), the DDLS scale is increased by one. For large discs (disc diameter more than 2 mm), the DDLS scale is decreased by one.

| DDLS Stage | Narrowest Rim Width (Rim Disc Ratio) |
|------------|--------------------------------------|
| At risk    | 0.4 or more                          |
| 2          | 0.3-0.39                             |
| 3          | 0.2-0.29                             |
| 4          | 0.1-0.19                             |
| Glaucoma   | Less than 0.1                         |
| Damage     | 0 (extension less than 45°)          |
| 7          | 0 (extension: 46° to 90°)            |
| Glaucoma   | 8 (extension: 91°-180°)              |
| Disability | 9 (extension: 181°-270°)             |
| 10         | 0 (extension: more than 270°)        |

**Armaly's Cup Disc Ratio vs. Disc Damage Likelihood Scale**

Armaly's cup/disc (C/D) ratio describes the disc using cup diameter as a percentage of overall disc diameter.

**Advantages**
- Ease of use.
- Lack of magnification artefacts.

**Limitations**
- **Disc size not taken into consideration**

The size of the nerve is widely variable among individuals, while the neuroretinal rim area is similar. If the rim area is roughly constant, the cup area is directly proportional to disc area. If cup/disc ratio alone is used as a criterion for damage then it is possible that large optic nerves will incorrectly be called glaucomatous, and small optic nerves incorrectly will be called normal.

- **Focal narrowing of neuroretinal rim which is characteristic of glaucoma is missed.**

In both the figures, the vertical CD ratio is the same. But figure 2 has focal neuroretinal rim narrowing.

**Disc Damage Likelihood Scale**

**Advantages:** This scale classifies the disc based on its size.

The asymmetry between figures 3 and 4 is due to asymmetry in disc size. Studies by Henderer JD et al. found that the DDLS helps in quantification of the amount of damage that the optic nerve has sustained.

**METHODS**

50 patients with open angle glaucoma attending glaucoma services of Regional Institute of Ophthalmology And Government Ophthalmic Hospital, Chennai between April 2016 and August 2016, who satisfied the following inclusion criteria were included in the study.

- All patients underwent the following examinations
  1. Best corrected visual acuity.
  2. Detailed anterior segment examination by slit lamp biomicroscopy.
  3. Intraocular pressure by Goldmann tonometry.
  4. Gonioscopic examination of angle by Goldman single mirror gonioscopy.
  5. Automated perimetry by octopus 301 using G1 program, TOP strategy.
  6. Disc damage likelihood scale calculation.
Inclusion Criteria
- **Age:** Patients aged 45 yrs., or more were included.
- **Best Corrected Visual Acuity:** Patients with best corrected visual acuity of more than 6/24 were included. This is because the visual fields by automated perimetry are not very reliable in patients with low visual acuity. There is generalised decrease in retinal sensitivity in patients with low visual acuity.
- **Gonioscopy:** Patients with open angles by gonioscopy (Shaffer’s grading more than or equal 3) were included
- **Fields:** Patients with established field defects, at least 2 consecutive and reliable fields by Octopus 301 automated perimetry done over a period of 6 months showing glaucomatous fields, were included in this study.
- Post-operative patients (Post cataract, post trabeculectomy) of more than a year of surgery were included.

Exclusion Criteria
- Other causes of optic neuropathy like traumatic optic neuropathy were excluded.
- Gonioscopy: patients with narrow and occludable angles (Shaffer's grade less than 2) were excluded
- Best Corrected Visual Acuity: Patients with best corrected visual acuity of less than 6/24 were excluded.
- Patients with secondary glaucomas like lens induced glaucomas, traumatic angle recession glaucomas, post inflammatory glaucomas, neovascular glaucomas were excluded.
- Patients operated less than a year were excluded.

Disc Damage Likelihood Scale Calculation
- Disc damage likelihood scale was calculated after pupillary dilatation with 0.5% tropicamide.
- Using a volk 90 D lens and a slit lamp, the width of the disc and the rim width were calculated.
- A correction factor of 1.3 was used.
- The disc was classified as small, medium and large and the scale was calculated accordingly.

Clinical diagram was made for the discs. The recordings were done by a single ophthalmologist which was further verified by two other doctors.

Example:

**Figure 5. Right Eye Disc Diagram of a 50-Year-Old Male**

**Step 1:**
- Measured disc diameter= 1.2
- Disc diameter= 1.2 x 1.33=1.66
  Medium Disc.

**Step 2:**
- Rim width= 0 between 180°-270°

**DDLS Stage 9.**

**Figure 6. Left Eye of The Same Patient**

**Step 1:**
- Measured disc diameter=1.2
- Disc diameter=1.2 x 1.33=1.66
  Medium Disc

**Step 2:**
- Rim width=0.2 x 1.33=0.26
- Rim /Disc ratio=0.26/1.66=0.16

**DDLS Stage 4.**

**Figure 7. Field Defects- Right Eye**
Impression: tubular fields

**Figure 8. Field Defects- Left Eye**
Impression: relative defects in superior arcuate region.
RESULTS

Demography

| Age Group (in years) | No. of Patients |
|----------------------|-----------------|
| 45-50                | 15              |
| 51-55                | 10              |
| 56-60                | 5               |
| 60-65                | 8               |
| More than 66         | 12              |

Table 1. Age Distribution

Sex Distribution

Of the 50 patients included in this study, 31 were males and 19 were females.

| Sex          | No. of Patients |
|--------------|-----------------|
| Male         | 31 (62%)        |
| Female       | 19 (38%)        |

Table 2. Sex Distribution

Modality of Treatment

Of the 50 patients included in this study,
- 35 patients were on medical management. They were on topical medications (which included topical beta blockers, prostaglandins, brimonidine or combination of drugs).
- 15 patients had antiglaucoma surgery done (trabeculectomy done).
- Of these 15 patients, 2 patients were on additional medical management. Topical antiglaucoma medication for IOP control.

Chart 1. Showing Age Distribution

Chart 2. Sex Distribution

Chart 3. Distribution According the Treatment Modality

| Treatment Modality          | No. of Patients |
|----------------------------|-----------------|
| Medical (topical antiglaucoma medication) | 35 (70%) |
| Surgical trabeculectomy     | 13 (26%)        |
| Both medical and surgical   | 2 (4%)          |

Table 3. Showing Distribution According the Treatment Modality

Chart 4. Classification According to Disc Diameter

| Disc Size         | No. of Eyes |
|-------------------|-------------|
| Small discs       | 0           |
| Medium discs      | 86 (86%)    |
| Large discs       | 14 (14%)    |

Table 4. Classification According to Disc Diameter

Disc Size

Of the 100 eyes of 50 patients examined,
- None of the patients had small discs (disc diameter of less than 1.5 mm).
- 86 eyes had medium size discs (diameter between 1.5-2 mm).
- 14 eyes had large discs (diameter more than 2 mm).

Chart 5. No. of Patients with Symmetrical and Asymmetrical Discs

Asymmetry of Disc Diameter

Of the 50 patients examined, 4 patients had asymmetry of disc diameter.

| Disc Diameter of Two Eyes | No. of Patients |
|---------------------------|-----------------|
| Symmetry of disc diameter | 46              |
| Asymmetry of disc diameter| 4               |

Table 5. No. of Patients with Symmetrical and Asymmetrical Discs
DDLS Score
The following were the DDLS score of 100 eyes.

| DDLS Score | No. of Eyes |
|------------|-------------|
| 1          | 0           |
| 2          | 4           |
| 3          | 11          |
| 4          | 19          |
| 5          | 18          |
| 6          | 15          |
| 7          | 9           |
| 8          | 11          |
| 9          | 13          |
| 10         | 0           |

Table 6. DDLS Score of 100 Eyes

Classification Based on DDLS Score
Of the 100 eyes included in the study
- 34 eyes came under classification of “At risk of glaucoma”
- 42 eyes came under classification of “Glaucoma damage”
- 24 eyes came under classification of “Glaucoma disability”

| Classification     | No. of Eyes |
|--------------------|-------------|
| At risk            | 34 (34%)    |
| Glaucoma damage    | 42 (42%)    |
| Glaucoma disability| 24 (24%)    |

Table 7. Classification According to DDLS Score

Classification of Field Defects:
Based on field defects, glaucoma can be classified as
- **Mild**
  Disc changes without field defects on white on white perimetry (defects may be present on swap blue on yellow perimetry. In this study, preperimetric glaucoma patients were excluded.
- **Moderate**
  Disc changes with field defects, involving one hemifield and not involving the central 5° of fixation. In this study, the following field defects come under this classification.
  - Areas of depressed sensitivity in paracentral region
  - Paracentral scotoma
  - Relative defects in superior arcuate region
  - Relative defects in the inferior arcuate region
  - Superior arcuate scotoma
  - Inferior arcuate scotoma
  - Biarcuate scotoma with nasal step defects
  - Tubular fields

Table 8. The Field Defects in 100 Eyes
• **Severe**
  Field defects in both hemifields and/or loss involving the central 5° of fixation. This includes biarcuate scotoma with step defects and tubular fields.

| Grading According to Fields | No. of Eyes |
|-----------------------------|-------------|
| Mild                        | 0           |
| Moderate                    | 72          |
| Severe                      | 28          |

*Table 9. Classification Based on Severity of Field Defects*

**Chart 9. Pie Chart Showing Classification Based on Severity of Field Defects**

### Field Indices

| Field Defects                          | Average Mean Sensitivity (db) |
|----------------------------------------|-------------------------------|
| Defects in paracentral region and paracentral scotoma | 28.89                         |
| Relative defects in superior and inferior arcuate region | 25.91                         |
| Arcuate scotoma (superior and inferior) | 23.30                         |
| Biarcuate scotoma with step defects    | 18.95                         |
| Tubular fields                         | 17.07                         |

*Table 10. Average Mean Sensitivity in Different Field Defects*

**Chart 10. Bar Graph Showing Average Mean Sensitivity in Different Field Defects**

### AVG MD (db)

| Field Defects                          | AVG MD (db) |
|----------------------------------------|-------------|
| Defects in paracentral region and paracentral scotoma | 30.15        |
| Relative defects in superior and inferior arcuate region | 28.58        |
| Arcuate scotoma (superior and inferior) | 27.35        |
| Biarcuate scotoma with step defects    | 26.42        |
| Tubular fields                         | 23.26        |

*Table 11. Average Mean Sensitivity in Various DDLS Scores*

**Chart 11. Bar Graph Showing Average Mean Defects in Different Field Defects**

### AVG LV (db)

| Field Defects                          | AVG LV (db) |
|----------------------------------------|-------------|
| Defects in paracentral region and paracentral scotoma | 8.66         |
| Relative defects in superior and inferior arcuate region | 14.62        |
| Arcuate scotoma (superior and inferior) | 39.30        |
| Biarcuate scotoma with step defects    | 101.54       |
| Tubular fields                         | 106.94       |

*Table 12. Showing Average Loss Variance in Different Field Defects*

**Chart 12. Graph Showing Average Mean Defects in Different Field Defects**

### AVG MS (db)

| Field Defects                          | Average Mean Defect (db) |
|----------------------------------------|--------------------------|
| Defects in paracentral region and paracentral scotoma | 9.79                     |
| Relative defects in superior and inferior arcuate region | 14.62                    |
| Arcuate scotoma (superior and inferior) | 18.77                    |
| Biarcuate scotoma with step defects    | 26.83                    |
| Tubular fields                         | 24.93                    |

*Table 11. Average Mean Sensitivity in Different Field Defects*

**Chart 13. Average Mean Sensitivity in Various DDLS Scores**
As the DDLS score increases, the mean sensitivity decreases.  

**DISCUSSION**

50 cases of Primary open angle glaucoma with established field defects with visual acuity more than 6/24 were included in this study to analyse the Disc Damage Likelihood Scale and correlate with field defects.  

Of the 50 patients included in this study, 30% were in the age group of 45-50 yrs. and 24% were aged more than 66 years. 62% were male patients and 38% were female patients.  

Of the included established primary open angle glaucoma patients, 70% were on topical antiglaucoma medications and 30% had undergone trabeculectomy. Of the patients who had undergone trabeculectomy, 6% (2) of patients were on further antiglaucoma medications.  

According to this study, the average vertical disc diameter was 1.86 mm. Studies by Quigley et al have also shown that the average vertical disc diameter to be 1.88 and horizontal disc diameter to be 1.77 mm. Disc diameter in 50 patients ranged from 1.56 mm - 2.21 mm.  

In this study, the discs were classified as small, medium and large discs based on the disc diameter. Of the 100 eyes examined, none of the patients had small discs (disc diameter of less than 1.5 mm), 86 eyes had medium size discs (diameter between 1.5 – 2 mm) and 14 eyes had large discs (diameter more than 2 mm).  

Among the 50 patients, 4 patients had asymmetry of disc diameter between the right and left eye.

This table shows that the asymmetry of the cupping is due to asymmetry of the disc diameter. The cup disc ratio in all four patients showed significant asymmetry, of more than 0.2. But the DDLS score in these patients of both the eyes...
in all four patients were the same. This highlights the importance of estimation of disc diameter in the evaluation of optic nerve head.\textsuperscript{10}

DDLS score was calculated and of the 100 eyes included in the study. 34 eyes came under classification of “At risk of glaucoma” having a score of 1-4, 42 eyes came under classification of “Glaucoma damage” having a score of 5-7 and 24 eyes came under classification of “Glaucoma disability” having a score of 8-10. The field defects which were seen in these patients include areas of depressed sensitivity in the paracentral region (11%), paracentral scotoma (10%), Relative scotomas in superior and inferior arcuate regions (27%), superior and inferior arcuate scotomas (24%), biarcuate scotoma with step defects (13%) and tubular fields (15%).

Based on field defects, 72 eyes were classified to have moderate glaucoma and 28 eyes were classified to have severe glaucoma. Since this study did not include preperimetric glaucoma, none of the eyes could be classified to have mild glaucoma.

**Field Indices**

Mean sensitivity is the average of the threshold sensitivity values in a visual field test. Patients with defects in paracentral region and paracentral scotoma had a average mean sensitivity of 28.89 db. Patients with arcuate scotoma had a mean sensitivity of 23.30 db and patients with tubular fields had a mean sensitivity of 17.07 db. This shows that the average mean sensitivity decreases as the field defect progresses.

Mean defect is the weighted average of the total deviation values in a visual field test; the more important and less variable deviations near the centre of the field are weighted more than those at the edge. In this study, patients with defects in paracentral region and paracentral scotoma had a mean defect of 9.79 db. Patients with arcuate scotoma had a mean defect of 18.77 db and patients with tubular fields had a mean defect of 24.93 db. This study shows that the mean defect values are higher in patients with advanced field defects.

Loss variance is the local heterogeneity of a visual field defect. Loss variance is small in visual fields with generalized damage and loss variance increases with the number and depth of localized scotomas.\textsuperscript{11} Patients with defects in paracentral region and paracentral scotoma had an average loss variance of 8.66 db. Patients with arcuate scotoma had a loss variance of 39.30 db and patients with tubular fields had a loss variance of 106.94 db. In this study, the loss variance values are higher in patients with advanced field defects.

**Field Indices in Various DDLS Scores**

The average mean sensitivity among the different DDLS score showed a linear relationship, that is, higher the DDLS score, lower is the sensitivity value.

Pearson product –moment correlation coefficient (r value) is a measure of linear dependence between two variables, giving a value between +1 and -1. +1 indicates total positive correlation, 0 indicates no correlation and -11 indicates total negative correlation. In this study, the variables compared were DDLS score and average loss variance. The variables showed a strong positive correlation as the r value was 0.95 (approximately equal to one).

Studies by James C Borrow et al also showed a similar observation with a r value of 0.68 between the DDLS score and mean deviation (field testing done by Humphrey field analyser)\textsuperscript{12}

**Limitations of The Study**

The disc diameter measurement and DDLS calculation by 90 D lens is a subjective measurement. Objective evidence for the same by imaging is needed to overcome inter observer variability.

**CONCLUSIONS**

Disc diameter evaluation is an important part of optic nerve head evaluation. In cases with asymmetry of the cup disc ratio between the two eyes, asymmetry of the disc size should also be considered if the neuroretinal rim is healthy.

Disc Damage Likelihood Scale (DDLS) is a better indicator of optic nerve head status and has strong positive correlation with visual field indices.

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