Published in final edited form as:

Ophthalmology. 2007 December ; 114(12): 2316–2322. doi:10.1016/j.ophtha.2007.01.033.

Comparing methods to quantify diplopia

Sarah R. Hatt, D.B.O., David A. Leske, M.S., and Jonathan M. Holmes, B.M., B.Ch.

Department of Ophthalmology, Mayo Clinic College of Medicine, Rochester, MN

Abstract

Purpose—Quantification of diplopia is important for describing severity of strabismus, measuring change over time and reporting surgical outcomes. The Cervical Range of Motion (CROM) method has been proposed as a simple, inexpensive alternative to the Goldmann perimeter for quantifying diplopia. The purpose of this study was to compare these two techniques and describe advantages and disadvantages.

Design—Cohort study.

Participants—Seventy six consecutive patients with binocular diplopia associated with any type of strabismus.

Methods—Patients underwent diplopia assessment with the CROM and the Goldmann perimeter; diplopia was scored between 0 and 100 based on previously published scoring systems. Where CROM and Goldmann results were disparate by more than 20 points the medical record was reviewed independently by two clinicians to determine the most likely reason for the discrepancy.

Main Outcome Measures—The two main outcomes were a measure of agreement between diplopia scores using the CROM and Goldmann using the Kappa test and the reasons for any disagreement between tests of greater than 20 points.

Results—Overall agreement between the two tests was good (Intra-class correlation co-efficient= 0.65; 95% Confidence interval 0.50 to 0.77). In 49 out of 76 (64%) results using the CROM and Goldmann were within 20 points. Of the 27 (36%) showing a greater than 20 point discrepancy, 17 were worse using the Goldmann and 10 using the CROM. The most frequent reason for worse diplopia using the Goldmann was poorer ability to fuse or suppress in the Goldmann apparatus compared to the real world targets used in free space for the CROM. Worse diplopia using the CROM was most often due to the deviation being present for distance only. In some cases differences were due to the greater weighting of primary position using the current scoring system for the CROM.

Conclusions—In the majority of cases the CROM and Goldmann provide equivalent measures of diplopia severity. However the Goldmann appears to overestimate diplopia in patients with fragile fusion or tenuous suppression, and underestimate diplopia in deviations present for distance only. The CROM method may be more representative of diplopia severity as experienced in everyday life.

Quantifying diplopia is an important aspect of describing the severity of strabismus. Numerical quantification provides a means of assessing recovery, deterioration or change in response to treatment and is particularly useful when reporting treatment outcomes. Plotting a field of single binocular vision using the Goldmann perimeter^{1–4} is currently considered the standard for quantifying diplopia, however Goldmann perimeters are expensive and are being replaced

Correspondence and reprint requests to: Dr. Jonathan M. Holmes, Ophthalmology W7, Mayo Clinic, Rochester, MN 55905. Phone: (507) 284-3760. Fax: (507) 284-8566. Email: holmes.jonathan@mayo.edu.

Presented in part at the British Isles Strabismus Association 9th annual meeting, Newcastle, UK, October 13, 2006

No conflicting relationships exist

in many Ophthalmology practices by automated perimeters for assessment of patients with glaucoma and neuro-ophthalmic conditions. The Cervical Range of Motion (CROM) method was recently proposed^{5, 6} in response to a need for a reliable but simple and inexpensive alternative to the Goldmann that permits diplopia to be evaluated at distance and near fixation.

The application of the CROM device as a measure of diplopia was originally described by Kushner⁵ who recorded the head position at which diplopia occurred in horizontal and vertical meridians. This method was modified by our research group⁶ to quantify diplopia using the CROM to position the patient's head for fixation in specified positions of gaze (see Table 1). The CROM method we describe uses real world targets in free space at 2 testing distances with the scoring weighted toward primary position and reading.⁶ The CROM method⁶ was designed to provide a more real world representation of a patient's diplopia.

The purpose of this study was to describe the relative advantages and disadvantages of the CROM and Goldmann techniques and to report the frequency and causes of discrepancies between the two methods.

Patients and Methods

Institutional Review Board approval was obtained and each patient gave informed consent before participating. All procedures and data collection were conducted in a manner compliant with the Health Insurance Portability and Accountability Act.

Patients

Consecutive patients aged 10 years or older, with binocular diplopia associated with any type of strabismus and better than 20/200 best corrected visual acuity in each eye were recruited. Diplopia was quantified first using the CROM and then with the Goldmann perimeter; patients were tested in their habitual refractive correction. The CROM method was performed and scored as described by Holmes et al.⁶ The examiner set the patient's head straight for the distance 20/200 'E' fixation target which was then used for 10 gaze positions (primary position, 10 and 30 degrees of right, left, up and down gaze, and "any position"). A near 20/200 'E' fixation target was used in a normal reading position. Diplopia was recorded as either present or absent for each position and scored as shown in Table 1. The initial score (from 0 to 25) was multiplied by 4 in order to convert it to a 0 to 100 scale. The Goldmann perimeter was performed using a III 4e light target as described by Woodruff et al¹ but scored using the weighting suggested by Sullivan et al³ (Figure 1) to yield a score from 0 to 100. Excursions were tested to 60 degrees in all directions. Diplopia scores, rather than single vision scores, were recorded for each test. For general acceptability of testing we did not use a method that involved a bite bar or head restraint.

For the purposes of the current study a discrepancy between CROM and Goldmann scores was defined as a difference of more than 20 points on the 0 to 100 scales. The choice of a 20-point difference was somewhat arbitrary but was based on an evaluation of the proportion of discrepancies occurring at specific thresholds i.e. 50, 40, 30, 20 and 10 points difference. Where there was more than 20 points difference the medical record (recorded history and entire orthoptic exam at that visit) was reviewed independently by 2 clinicians (SRH and JMH) to determine the primary reason for the discrepancy. Any disagreements as to the reason for discrepancy were resolved by discussion.

Results

Seventy-six patients aged 10 to 85 years with a range of ocular motility disorders were recruited (Table 2). Overall agreement was good (Intra-class correlation co-efficient (ICC) = 0.65 95%

Confidence interval (CI) 0.50 to 0.77). 49 of 76 (64%) had comparable scores (within 20 points) using the CROM and Goldmann (Figure 2). Of the 27 (36%) showing a discrepancy of more than 20 points, 17 (63%) scored higher (worse diplopia) using the Goldmann and 10 (37%) using the CROM.

There were no apparent differences in the diagnoses of those with a discrepancy between scores and those without (Table 2). Mean age was similar between those with and without discrepancies (52 ± 19 years (range 10–85) vs. 48 ± 18 years (range 15–77); t-test, $p=0.4$)

The reasons for discrepancies in scores are shown in Table 2. The most frequent reason for worse diplopia using the Goldmann (10/17; 59%) was poor ability to fuse the white light on the white background (without any peripheral fusion cues) in contrast to better ability to fuse the real world 'E' target in free space using the CROM method. This is illustrated by case #1 shown in Figures 3A and B: historically the patient reported diplopia only on lateral gazes following Foster augmented total transposition⁷ for a total right 6th nerve palsy. The Goldmann diplopia score was 91 (Figure 3A) whereas ability to fuse the more real world target in free space reduced the CROM diplopia score to 52 (Figure 3B).

The second reason for worse diplopia using the Goldmann, affecting 4/17 (24%) patients, (Table 2) was a difference in weighting. Primary position constitutes 24% of the total using the CROM scoring system but only 12% using the Goldmann, therefore a small area of single in primary position would result in a relatively worse diplopia score using the Goldmann. For example, case #2 (Figures 3C and D) had a comparable central field of single vision on both Goldmann and CROM following surgery for a right 6th nerve palsy and right INO, but diplopia measured 73 points using the Goldmann (Figure 3C) and 52 using the CROM (Figure 3D).

The third cause of higher Goldmann diplopia scores (3/17; 18%) was inability to suppress the light target in contrast to apparent suppression in the free space testing environment of the CROM. This is illustrated by case #3 (Figures 3E and F) a patient with recurrent right sixth nerve paresis due to neurofibromatosis and constant esotropia in primary position, greater on right gaze. The patient reported only intermittent diplopia but scored 100 using the Goldmann (Figure 3E) and 60 using the CROM (Figure 3F).

Higher diplopia scores using the CROM were most often due to a deviation being present for distance only (6/10; 60%). Case #4 with mild bilateral sixth nerve palsy and symptoms of diplopia for distance fixation only, showed this type of discrepancy. Diplopia using the Goldmann was 19 points (Figure 4A) whereas using the CROM it was 84 (Figure 4B). This would be predicted based on the distances at which the two tests were performed in this study.

For 3 of the 10 cases (30%) with worse diplopia using the CROM it appeared that the 20/200 'E' target was better able to detect torsional diplopia than the circular light of the Goldmann. As shown by case #5, a patient diagnosed with decompensating left fourth nerve palsy and 10 degrees of excyclotorsion; diplopia scored 53 using the Goldmann (Figure 4C) and 92 using the CROM (Figure 4D).

There was one case with severely restricted motility due to a right third nerve palsy and bilateral vertical gaze palsy (Table 2). Inability to fix beyond 30 degrees resulted in areas of apparently single vision using the Goldmann but the patient reported constant diplopia in everyday life and scored 100 using the CROM.

Discussion

In the majority of patients with diplopia, the CROM method provides a measure of severity that is equivalent to the Goldmann perimeter. Quantification of diplopia using the CROM is

an appealing alternative to the Goldmann because of its simplicity, portability and the ease with which it can be administered. Nevertheless, in approximately one third of patients there were discrepancies between the diplopia scores obtained from each method. In the majority of cases where there was a discrepancy, the CROM method appeared to more closely represent the patient's experience.

Some of the discrepancies between the CROM and Goldmann methods would be predicted based on the mechanics of the tests. Since the current scoring system for the CROM method includes 3 meter and 1/3 meter test distances,⁶ whereas the Goldmann scoring system only includes testing at 30 cm, differences would be expected where there is a near-distance disparity in the deviation. This difference was the most common reason for the Goldmann score under-representing a patient's diplopia in conditions where the deviation was only present at distance fixation e.g. mild partial sixth nerve palsy. We did not find any cases where diplopia was worse using the Goldmann because of deviation greater for near. In cases where diplopia is experienced only beyond the 30cm testing distance of the Goldmann bowl, the patient's experience will not be completely reflected.

The differences in fixation targets and the environment in which they are presented appeared to contribute to differences in scores. The Goldmann method uses a white light fixation target in the white bowl, and the CROM method uses a 20/200 'E' target in the clinic room. Inability to fuse the circular white light on the white background of the Goldmann bowl has been previously recognized^{3, 6} leading to possible overestimation of diplopia, especially in cases where fusion may be fragile. Using a circular white light target in an environment devoid of peripheral fusion cues does not represent the real life experience of the patient. As shown in case #1, there was a useful area of single vision both in everyday life and using the CROM method, but this could not be demonstrated using the Goldmann. As suggested in our previous report⁶ using a more real world target in free space i.e. in an examination room, seems to provide peripheral fusion cues, that in some patients are recruited in order to maintain or regain central fusion (particularly those with fragile fusion or at the limits of their fusional reserves). Using a 20/200 'E' target in an examination room may better represent the patient's everyday experience of diplopia but there is also a possibility that the patient is able to fuse the 20/200 'E' target momentarily during the test and that in real life diplopia is more frequent.

The light target of the Goldmann appeared to prevent some patients from suppressing despite the fact that the patient suppressed both in everyday life and in free space using the CROM method. It is possible that, as described by von Noorden⁸, the double image was merely ignored and not truly suppressed in some of the patients that we classified as suppressing. Viewing the isolated light target in the Goldmann might have therefore made the subject more readily aware of the second image. If true suppression was occurring it is possible that, in these cases, the suppression was shallow and that the light acted as an anti-suppressant.

Previous studies^{3, 9} have identified that torsion is not detected well with the circular III 4e light target and we confirmed this phenomenon in the present study. Some cases (e.g. case #5) had a higher diplopia score with the 20/200 'E' target used with the CROM, apparently due to inability of the circular III 4 e light to detect torsion. Summers et al⁹ suggested modifying the Goldmann technique by superimposing a horizontal light streak from a retinoscope over the circular III 4 e light, making any torsion more apparent. This approach might be difficult in some office settings since it requires two examiners to perform the test. Changing the circular light to a cross target was an alternative suggested by Sullivan et al³ to better detect torsion using the Goldmann. Nevertheless, modifying the Goldmann target does not negate the need for access to expensive equipment and may require permanent changes to the perimeter that would not suit its use for measuring monocular visual fields.

The relatively heavier weighting given to primary position using the CROM scoring system was another cause of differences between CROM and Goldmann diplopia scores. Using the current scoring systems,^{3, 6} achieving single vision in primary and downgaze reduces the potential diplopia score more using the CROM method than using the Goldmann. In addition, diplopia can be assessed in the Goldmann in up to 60 degrees of ocular excursion and in oblique planes whereas the current CROM method and scoring system only include up to 30 degrees and is limited to the horizontal and vertical planes. The current CROM testing method partly addresses this potential shortcoming by including an assessment of diplopia in 'any position' other than the positions already tested (Figure 1). Allocating 4% of the total score to 'any position' may be insufficient to adequately address diplopia outside 30 degrees and we plan to review weighting in future studies. In some cases in our study, weighting differences were also noted to be a possible secondary reason for discrepancies.

There are some limitations to the practical administration of the CROM: it requires a magnet to be worn and therefore is not suitable for patients fitted with a pacemaker. It also is not suitable for those with severely restricted head or neck mobility due to the need for head movement in the horizontal and vertical planes.

In the majority of cases, the CROM and Goldmann methods provide equivalent measures of diplopia severity. Our results suggest that the Goldmann may over-estimate diplopia in patients with fragile fusion or tenuous suppression and underestimate diplopia when the deviation is primarily at distance fixation. The CROM method has the advantage of being a more real world technique which we feel is more likely to represent a patient's everyday experience, however further studies of the patient's perception of severity are needed. The CROM method offers a good alternative to the Goldmann and currently may be the best method for quantifying diplopia in clinical practice and for clinical trials in strabismus.

Acknowledgments

Financial support: Supported by National Institutes of Health Grants EY015799 and EY011751 (JMH), Research to Prevent Blindness, Inc., New York, NY (JMH as Olga Keith Weiss Scholar and an unrestricted grant to the Department of Ophthalmology, Mayo Clinic), and Mayo Foundation, Rochester, MN.

References

1. Woodruff G, O'Reilly C, Kraft SP. Functional scoring of the field of binocular single vision in patients with diplopia. *Ophthalmology* 1987;94:1554–1561. [PubMed: 3431826]
2. Fitzsimons R, White J. Functional scoring of the field of binocular single vision. *Ophthalmology* 1990;97:33–35. [PubMed: 2314839]
3. Sullivan TJ, Kraft SP, Burack C, O'Reilly C. A functional scoring method for the field of binocular single vision. *Ophthalmology* 1992;99:575–581. [PubMed: 1584576]
4. Feibel RM, Roper-Hall G. Evaluation of the field of binocular single vision in incomitant strabismus. *Am J Ophthalmol* 1974;78:800–805. [PubMed: 4425006]
5. Kushner BJ. The usefulness of the cervical range of motion device in the ocular motility examination. *Arch Ophthalmol* 2000;118:946–950. [PubMed: 10900108]
6. Holmes JM, Leske DA, Kupersmith MJ. New methods for quantifying diplopia. *Ophthalmology* 2005;112:2035–2039. [PubMed: 16185766]
7. Foster RS. Vertical muscle transposition augmented with lateral fixation. *J AAPOS* 1997;1:20–30. [PubMed: 10530981]
8. Von Noorden, GK.; Campos, E. *Binocular Vision and Ocular Motility*. Vol. 6th ed.. 2002. p. 246-297.
9. Summers CG, Lavoie JD, Letson RD. Use of a modified binocular visual field to assess cyclodiplopia. *Ophthalmology* 1987;94:231–234. [PubMed: 3587898]

Figure 1.
Scoring system for diplopia as measured using the Goldmann perimeter adapted from Sullivan et al (ref ³).

Figure 2.

Distribution of Goldmann and Cervical Range of Motion diplopia scores, showing 64% within 20 points and 36% with a discrepancy of more than 20 points.

Figure 3.

Cases where the diplopia score was higher using the Goldmann (A, C, E, shaded area diplopia) than using the Cervical Range of Motion (CROM) method. B, D and F show CROM method superimposed on Goldmann chart for comparison: single vision represented by open circles and diplopia by closed circles. Circle below 30 degrees represents reading. Case #1: higher diplopia score on Goldmann due to poorer ability to fuse the light compared to real life CROM target. Goldmann diplopia score 91 (A). CROM diplopia score 52 (B). Case #2: greater diplopia on Goldmann due to relatively lower weighting of primary position. Goldmann diplopia score 73 (C) CROM diplopia score 52 (D). Case #3: greater diplopia using the Goldmann due to

inability to suppress the light target. Goldmann diplopia score 100 (E). CROM diplopia score 60 (F).

Figure 4.

Cases where the diplopia score was lower using the Goldmann (A, C, shaded area diplopic) than the Cervical Range of Motion (CROM) device (B, D). B and D show CROM method superimposed on Goldmann chart for comparison: single vision represented by open circles and diplopia by closed circles. Circle below 30 degrees represents reading. Case #4: greater diplopia using CROM due to distance deviation. Goldmann diplopia score 19 (A). CROM diplopia score 84 (B). Case #5: worse diplopia using CROM due to presence of torsion. Goldmann diplopia score 53 (C). CROM diplopia score 92 (D).

Table 1

Scoring system for diplopia as measured using the Cervical Range of Motion method

CROM	score if diplopic
Primary position	6
Reading	4
Up 10 deg	1
Up 30 deg	1
Down 10 deg	2
Down 30 deg	2
Right 10 deg	2
Right 30 deg	2
Left 10 deg	2
Left 30 deg	2
Any Position	1
Can you get rid of it? (all must be diplopic)	-1
Total* →	

* Total score (0 to 25) multiplied by 4 to give a value between 0 and 100

Table 2

Diagnoses for those with and without score discrepancies between Cervical Range of Motion and Goldmann methods, and reasons for the discrepancies.

Diagnosis	N (%)	Goldmann (n=17)		CROM > Goldmann (n=10)			No discrepancy (n=49)
		Fuses better on CROM	Suppresses more on CROM	Weighting	Distance deviation	Torsion detected on CROM	Unable to fix outside 30 degrees
6 th nerve palsy	13 (17%)	1	2	1	3		6
4 th nerve palsy	22 (29%)	3		1	1	3	14
3 rd nerve palsy	6 (8%)	2					4
3 rd nerve & bilateral vertical gaze palsy	1 (1%)						
CPEO *	1 (1%)	1					
Parinaud's syndrome	1 (1%)	1					
Duane's syndrome	3 (4%)		1	1			1
Brown's syndrome	2 (3%)						2
Graves eye disease	6 (8%)						6
Post scleral buckle	9 (12%)	1			2		6
Post scleral plaque	1 (1%)						1
Post cataract	1 (1%)						1
Orbital trauma	1 (1%)						1
Consecutive strabismus	5 (7%)	1		1			3
Decompensated Exophoria	1 (1%)						1
Divergence Insufficiency	3 (4%)						3
TOTAL	76	10	3	4	6	3	49

* Chronic progressive external ophthalmoplegia