Optometry (2008) 79, 259-265

The frequency of occurrence, types, and characteristics of visual field defects in acquired brain injury: A retrospective analysis

Irwin B. Suchoff, O.D., D.O.S., Neera Kapoor, O.D., M.S., Kenneth J. Ciuffreda, O.D., Ph.D., Daniella Rutner, O.D., M.S., Esther Han, O.D., and Shoshana Craig, O.D.

State University of New York, State College of Optometry, Raymond J. Greenwald Rehabilitation Center, New York, New York.

KEYWORDS
Acquired brain injury;
Cerebral vascular accident;
Hemianopia;
Quadrantanopia;
Stroke;
Traumatic brain injury;
Visual field defects;
Visual neglect

Abstract

BACKGROUND: The purpose of this retrospective study was to determine the frequency of occurrence of visual field defects in a sample of visually symptomatic, ambulatory outpatients who have acquired brain injury (ABI), either traumatic brain injury (TBI) or cerebral vascular accident (CVA).

METHODS: The medical records of 220 individuals with TBI (n=160) or CVA (n=60) were reviewed retrospectively. This was determined by a computer-based query spanning the years 2000 through 2003. The individuals' records were reviewed to determine the frequency of targeted visual field defects that were classified as scattered, restricted, homonymous, nonhomonymous, and visual neglect. The altitudinal and lateral characteristics of these defects were also determined.

RESULTS: In the total ABI sample of 220, some 102 (46.36%) individuals had 1 of the targeted defects diagnosed. These defects were present in 62 (38.75%) of the TBI subgroup and in 40 (66.67%) of the CVA subgroup. The most frequent defects in the TBI group were scattered (58.06%) followed by homonymous (22.58%). In the CVA group, the most numerous were homonymous (47.5%), with scattered and nonhomonymous accounting for 20% each.

CONCLUSION: The uniqueness of the current study is that it reports the frequency of occurrence of specified visual field defects in the total ABI sample and in the TBI and CVA subgroups. This enabled comparisons with other studies that generally have reported on just 1 of these groupings. The current results are in accord with most of the other studies that are reviewed. The findings of this study should alert the reader to the high frequency of occurrence of visual field defects in the ABI population, and make the reader aware of the adverse effects they can have on quality of life and rehabilitation.
Optometry 2008;79:259-265

Acquired brain injury (ABI) encompasses 2 groups of individuals based on the nature of the insult to the brain: insult generated by a source external to the cranium or insult that occurs within the cranium. The former condition is termed *traumatic brain injury* (TBI), and it is divided into either closed head injury or open (penetrating) head injury. The group in which insults occur within the cranium primarily includes cerebral vascular accident (CVA), cerebral aneurysms, and arteriovenous malformations.[1,2] In the current study, these conditions will be termed *CVA*. It has been

Corresponding author: Irwin B. Suchoff, O.D., D.O.S., 3201 Chippewa Run, Kennesaw, Georgia 30152.
E-mail: idrga@aol.com

1529-1839/08/$ -see front matter
doi:10.1016/j.optm.2007.10.012

suggested that reasons to incorporate both TBI and CVA under the aegis of ABI is the suddenness with which the consequent neurologic sequelae occur and, further, that the medical care system for both is similar.[2]

Impaired ocular and visual functioning are examples of neurologic compromise resulting from ABI.[1,3-7] Among these conditions are visual field defects. Zihl[8] proposed that these disorders are probably the most frequent type of visual impairment after brain damage. Suchoff and Gianutsos[9] indicated that although visual field impairments are fairly common, they often are undiagnosed or underdiagnosed.

Previous studies of visual field defects in ABI

There have been several noteworthy investigations on the occurrence of visual field defects in individuals with ABI. The report by Zihl[8] was based on a group of 392 patients who were examined between 1978 and 1986. His subjects were predominately individuals with CVA (79%). Zihl[8] found that 370 (94%) of his subjects had unilateral defects, whereas the remaining 22 subjects had bilateral defects. Overall, hemianopias predominated, whereas quadrantanopias and paracentral scotomas were rare. He did not specify the protocol for visual field testing.[8] Sabates et al.[10] reviewed the records of 181 consecutive patients who had incurred closed head TBI. Some 35% of their sample manifested unspecified visual field defects. The visual field testing protocol was not provided.[10] Suchoff et al.[3] reported on 64 patients who had incurred insult to the brain. The sample was composed of 60% recovering from TBI and 24% recovering from CVA. Unspecified visual field defects were present in 32.5% of the 40 ABI patients who were able to be tested. The researchers did not break down the percentages into the TBI and CVA groups. They did specify their visual field testing protocol that included confrontation testing and automated perimetry.

It is generally accepted that homonymous hemianopia, often coupled with visual neglect[11,12] (also known as unilateral spatial inattention[13]), is the most common type of visual field defect in CVA. When homonymous hemianopia and visual neglect co-exist, the visual field defect is evident by conventional perimetry, but the patient is unaware of the loss of that area of visual space; when there is "pure" visual neglect, the visual field defect is not evident by conventional perimetry, but again, the patient is unaware of the loss of that area of visual space.[13-15]

Estimates have been given that vary with regard to the occurrence of visual neglect in CVA. For example, Robertson and Halligan[14] summarized 10 studies of the presence of visual neglect in CVA. Percentages ranged from a high of 95% in 1 study, to a low of 12% in another. It has been proposed that these variations in occurrence can be accounted for by different sample compositions, sizes, and diagnostic protocols.[13] Further, in the case of CVA, homonymous hemianopia can be present without accompanying visual neglect.[15] Thus, there appears to be no firm estimate of the overall occurrence of homonymous hemianopia in CVA, with the exception of the estimate of Beis et al.[16] of 20%.

The above findings indicate that visual field impairments are a common result of ABI; however, there are incomplete data regarding their frequency of occurrence and the types of defects that might be prevalent in the ABI subgroups. This is particularly important because of recent advances in the diagnosis and management of visual field defects.[17]

The goals of the current study were to (1) determine the frequency of occurrence, types, and lateral and altitudinal characteristics of visual field defects in a substantial sample of ABI patients, where the diagnostic protocol is specified and (2) determine the frequency of occurrence, types, and lateral and altitudinal characteristics of these visual field defects in the sample subgroups of TBI and CVA.

Methods

A computer-based query was obtained for patients examined at the Raymond J. Greenwald Rehabilitation Center (RJGRC) between October 1, 2000, and October 7, 2003. This unit is a clinic at the State University of New York, State College of Optometry. The query used the 99203 (new patient evaluation) and 99213 (established patient evaluation) Current Procedural Terminology (CPT) codes. The majority of these patients were referred from rehabilitation professionals at the following institutions: Rusk Institute of Rehabilitative Medicine at the New York University (NYU) Medical Center, Bellevue Hospital at NYU Medical Center, Department of Rehabilitative Medicine at Mount Sinai Medical Center, Lenox Hill Hospital, New York Hospital, and the International Center for the Disabled. Other referrals were from rehabilitation professionals in private practice in the greater New York City area. Referrals were also received from other units within the College's University Optometric Center including primary care, low vision, contact lens, ocular disease, and special testing. Referred patients were not limited to those with either TBI or CVA; individuals with other neurologic conditions that affect the visual system, such as vestibular dysfunctions, cranial postsurgical complications, and brain tumors comprise a sizeable patient base.

Staff optometrists at the RJGRC performed the eye health and vision examinations of these patients. These examinations assessed distance and near visual acuities and refraction, distance and near binocular and oculomotor status, accommodative status, color vision, ocular health (including dilated fundus examination if the procedure was not performed within the past year), and visual fields. In some instances, not all of these areas could be evaluated because of limitations in the patient's cognitive status, language ability, or physical state. However, all subjects who were included in the current study had visual field

Table 1 Age range, mean, and standard deviation of the total sample (ABI) and the TBI and CVA subgroups

Subgroup	Age range (y)	Mean (y)	Standard deviation (y)
TBI (n=160)	8 to 91	44.9	15.8
CVA (n=60)	24 to 90	61.2	14.7
ABI (n=220)	8 to 91	49.3	17.1

assessments for each eye by the confrontation method.[13,14] This comprised individual stimulation of each lateral visual field and then simultaneous stimulation of both lateral visual fields The simultaneous stimulation portion tests for the extinction phenomenon, i.e., the patient perceives the stimulus when each visual field half is tested individually. However, when there is simultaneous stimulation of both visual field halves, the patient is unaware of the stimulus on the 1 side, which is most frequently the left portion of visual space. Presence of the extinction phenomenon is a key finding for visual neglect.[13,14] All patients were also tested on either static or kinetic perimetry. The perimetric instruments chosen varied according to the examiner's determination of appropriateness for the particular patient. Amsler Grid evaluations were performed as the examiner deemed necessary by the patient's history and/or particular clinical findings.

The computer query yielded 486 records, of which, 300 were selected randomly. Each of 3 members of the RJGRC's clinical staff then randomly chose 100 of the records. Of these, only patients with a history of TBI (n=160) or CVA (n=60) were reviewed. Table 1 lists the age characteristics of the patients in each group at the initial evaluation at RJGRC. Table 2 presents the range of years after injury and the mean for each category upon initial presentation at RJGRC. All subjects were ambulatory and visually symptomatic.

The reviewers then examined each record and selected only those that specified some type of visual field defect. These defects were then targeted as *scattered* (more than 1 noncontiguous defect), *restricted* (intactness of only one quadrant), *homonymous, nonhomonymous,* and *visual neglect*.

The homonymous and nonhomonymous categories were further classified in terms of their spatial characteristics: Homonymous hemianopias were classified according to the lateralization of the affected fields; homonymous quadrantanopias were classified by lateralization and altitudinal position of the affected fields. Nonhomonymous defects were classified according to the lateral and altitudinal positions of the affected field.

All selected records were then separated into TBI and CVA groups and the types of visual field defects, and, where appropriate, the lateral and altitudinal characteristics of these defects were recorded for each group.

Table 2 Range and mean of the number of years (postinjury) upon initial presentation for the total sample (ABI) and the TBI and CVA subgroups

Subgroup	Range (y)	Mean (y)
TBI (n=160)	0.1 to 42.0	4.5
CVA (n=60)	0.1 to 18.0	2.7
ABI (n=220)	0.1 to 42.0	4.0

Table 3 Frequency of occurrence of visual field defects in the total sample (ABI) and the TBI and CVA subgroups

Subgroup	No. of subjects with VF defects	Percentage of subjects with VF defects
TBI (n=160)	62	38.75
CVA (n=60)	40	66.67
ABI (n=220)	102	46.36

VF = visual field.

Results

Frequency of occurrence of the targeted field defects in the total ABI sample and the TBI and CVA groups

Some type of visual field defect was specified in 102 records of the 220 in the sample of ABI patients (46.36%). The TBI group accounted for 62 of these defects, and the CVA group for 40. Table 3 presents these numbers and the percentages for the TBI and CVA groups and the total ABI sample (TBI+CVA).

The data for the types of the targeted visual field defects found in the total sample of 220 and the subgroups are presented in Table 4. It shows that, in the TBI group, the most frequent defect was the scattered variety (22.5%), whereas each of the other primary categories ranged from 8.75% to 1.25%. In the less numerous CVA group, the greatest frequency was homonymous defects (31.67%) followed by 13.33% in each of the scattered and nonhomonymous groups (*see* Table 4).

Frequency of occurrence of the targeted visual field defects in the ABI, TBI, and CVA groups for those subjects with visual field defects

The data regarding the numeric and percentage distribution of the targeted visual field defects for all subjects with defects are presented in Table 5. In this sample of 102, the scattered defects accounted for the largest number (n=44; 43.14%) followed by homonymous defects (n=33; 32.35%). Restricted visual field defects were present in 15

Table 4 Percentage of targeted visual field defects for all subjects (ABI) and for the TBI and CVA subgroups

Subgroup	Scattered defects, %(n/N)	Restricted VF defects, %(n/N)	Homonymous VF defects, %(n/N)	Nonhomonymous VF defects, %(n/N)
TBI (n=160)	22.5 (36/160)	6.25 (10/160)	8.75 (14/160)	1.25 (2/160)
CVA (n= 60)	13.33 (8/60)	8.33 (5/60)	31.67 (19/60)	13.33 (8/60)
ABI (n=220)	20 (44/220)	6.82 (15/220)	15 (33/220)	4.55 (10/220)

VF = visual field.

individuals (14.71%), and nonhomonymous defects were evident in 10 individuals (9.8%).

An examination of these results for the TBI and CVA groups is also presented in Table 5. It shows that the most frequent defect in the TBI group was the scattered (58.06%), followed by 22.58% with homonymous defects. In the CVA group, the most frequent defect was homonymous (n=19; 47.50%), with 20% in each of the scattered and nonhomonymous categories. None of the subjects in the current study was diagnosed with visual neglect.

Lateral and altitudinal characteristics of homonymous and nonhomonymous visual field defects

Table 6 summarizes the lateralized and altitudinal characteristics of homonymous and nonhomonymous visual field defects found in the current study. In the CVA group of 40, there were 16 individuals with homonymous hemianopia; in the TBI group of 62, only 7 individuals had this condition. The CVA group had 2 quadrantanopias, and this condition was found in 7 of the TBI group. Only 1 homonymous (complete) altitudinal defect was found; this was located in the inferior fields of a CVA subject.

One TBI subject had a nonhomonymous left field defect and another TBI subject had a nonhomonymous defect in the right field. Six CVA subjects had nonhomonymous left visual field defects. Nonhomonymous quadrantanopia and altitudinal defects were of little note in both groups. Only 1 CVA subject had an homonymous (complete) altitudinal defect.

Further analysis of the data summarized the lateral frequency of both homonymous and nonhomonymous field losses in the TBI and CVA groups. Right defects were more numerous in the former, and left defects were more numerous in the latter (*see* Table 7).

Discussion

Comparison of the current findings with those of other studies

The findings for our overall ABI sample and the breakdown into the CVA and TBI groups allow for focused comparisons with other studies. Thus, in our combined pool of 160 TBI and 60 CVA subjects, 102 (46.36%) had some type of visual field defect according to the targeted categories. In the more numerous TBI group, 38.75% had 1 of these defects (*see* Table 3). This percentage is quite close to the findings of Sabates et al.[10] of 35% in their sample of 188 TBI closed head patients. It is also close to the findings of Suchoff et al.[3] of 32.5% in their sample of primarily (60%) TBI patients. Thus, the findings of the current study give further indication that, in studies of an ABI sample in which TBI subjects predominate, the frequency of occurrence of visual field defects is approximately 35%.

Almost 67% of the CVA group had some type of visual field defect (*see* Table 3). This is close to the total sample of Zihl[8] of 392, where 75% were CVA patients. However, there is a difference between the 2 studies in the type of field defects. In the total CVA sample of the current study, homonymous defects were present in almost 32% of the subjects (*see* Table 4), whereas Zihl[8] reported that unilateral (nonhomonymous) field losses were present in 94% of his sample. This might be explained by the difference in CVA sample sizes in the 2 studies; CVA accounted for some 75% of Zihl's total sample, whereas the CVA group in the current study was just 27% (60 of 220).

A more recent report by Zihl[18] replicated his earlier findings. In this subsequent study, the sample was 714 subjects, who were mainly CVA patients (76%). His unilateral (nonhomonymous) grouping of hemianopia and qua-

Table 5 Percentage with subcategories of visual field defects for those with visual field defects

Subgroup	Scattered defects, %(n/N)	Restricted VF defects, %(n/N)	Homonymous VF defects, %(n/N)	Nonhomonymous VF defects, %(n/N)	Visual neglect (%)
TBI (n=62)	58.06 (36/62)	16.13 (10/62)	22.58 (14/62)	3.23 (2/62)	0
CVA (n=40)	20 (8/40)	12.5 (5/40)	47.5 (19/40)	20 (8/40)	0
ABI (n=102)	43.14 (44/102)	14.71 (15/102)	32.35 (33/102)	9.80 (10/102)	0

VF = visual field.

Table 6 Number of those with TBI and CVA presenting with specific lateral and altitudinal characteristics of homonymous and nonhomonymous visual field defects

TBI	Left hemi	SLQ	ILQ	Right hemi	SRQ	IRQ	CIAD	CSAD
Homonymous defects	2	2	1	5	2	2	0	0
Nonhomonymous defects	1	0	0	1	0	0	0	0
CVA								
Homonymous defects	11	1	0	5	0	1	1	0
Nonhomonymous defects	6	0.5*	1	0	0.5*	0	0	0

Hemi = hemianopia; SQL = superior left quadrant; ILQ = inferior left quadrant; SRQ = superior right quadrant; IRQ = inferior right quadrant; CIAD = complete inferior altitudinal defect; CSAD = complete superior altitudinal defect.

* One subject had both a superior left quadrantanopia and a superior right quadrantanopia.

drantanopia accounted for 81% of the visual field defects. He also reported that 11% of the sample showed bilateral (homonymous) defects: of these, 53.8% were hemianopias and 10% were quadrantanopias.[18] Because of his sample's heavy bias of CVA patients, a comparison of our data should be with the current study's percentage of the 40 CVA subjects (*see* Table 5) who had a targeted visual field defect. In this regard, 11 had a left homonymous hemianopia and 5 a right homonymous hemianopia (*see* Table 6). This comes to 40% (16 of 40) compared with Zihl's[18] 53.8%. Only 2 of our 40 CVA (5%) subjects had a quadrantanopia compared with Zihl's[18] 10%. The difference in CVA sample sizes in the 2 studies might account for these differences. Nevertheless, both show that in CVA, homonymous hemianopias are more frequent than homonymous quadrantanopias.

For those TBI subjects with visual field defects, the frequency of occurrence of the homonymous type was almost 23% as indicated in Table 5. These constituted 7 hemianopias and an equal number of quadrantanopias that were fairly evenly divided between the left and right side (*see* Table 6). The CVA analogous group's percentage of homonymous defects was almost 48% (*see* Table 5). Here, there were 16 of these defects, with 11 being left homonymous hemianopias (*see* Table 6). This finding adds evidence to the assertions of others as to the most common presence of this type of visual field defect in CVA.[11-21] None of the CVA subjects had a visual neglect diagnosed, a condition that has been most reported to occur in this group.[11-13] However, there is a caveat: visual neglect can occur in peripersonal space, which is considered to be within an individual's arm reach, and/or extrapersonal space, which is the "space beyond."[22] Determination of neglect in peripersonal space requires various paper and pencil testing, such as copying a figure and bisecting lines randomly but equally placed on both sides of a sheet of paper. In these tests, the product is biased toward the nonvisual neglect, or intact side.[12,13] We did not include such testing but rather confined the protocol to the determination of visual neglect in extrapersonal space.

Nonhomonymous hemianopias were rare in the TBI group, but there were 6 of these in the CVA group, again on the left side. There was only 1 complete inferior altitudinal defect (*see* Table 6).

Table 7 Percentage with subcategories of lateralized visual field defects

ABI subgroup	Left defects (homonymous and nonhomonymous), %(n/N)	Right defects (homonymous and nonhomonymous), %(n/N)
TBI (n=160)	3.8 (6/160)	6.3 (10/160)
CVA (n=60)	33.3 (20/60)	11.7 (7/60)

General comments

An indication of the increasing involvement of optometrists in the ocular and visual care of ABI patients is the number of their contributions to the general rehabilitation literature pertaining to these patients.[6,7,9,23] Further, recent articles that studied the same sample as the present study's have indicated that these patients are at significant risk for various types of ocular disease[24] and oculomotor dysfunctions.[25] The potential negative effects of both conditions on one's quality of life and rehabilitation are discussed in these recent articles.

The adverse effects of visual field impairment on quality of life and rehabilitation are well recognized. In the case of homonymous hemianopia they include an awareness that 1 side of the world is missing to a total unawareness of the loss as is the case in visual neglect,[13-14,16] inability to negotiate traffic as a driver or pedestrian, loss of place and decreased speed when reading because of inadequate left visual scan to the next line of print, and consistent collisions with people and objects on 1 side of space.[13,23,25,26] Homonymous hemianopias and homonymous superior quadrantanopias can cause additional head injury because of impaired awareness of tree branches, low doorways, or other obstacles. Homonymous hemianopias and inferior homonymous quadrantanopias can impede mobility and cause falls because of the impaired visual awareness of objects, children, or animals on the ground.[27]

The results of the current study should alert optometrists who treat ABI patients to the frequency of occurrence of visual field defects in this population. The finding that almost 50% of the 220 ABI subjects had some type of visual field defect suggests that the practitioner should suspect some type of defect until proven otherwise. This mandates that careful and complete confrontation testing be carried out, along with other appropriate more detailed perimetric testing. Once a visual field defect is found, it is equally important to know that there are various means to compensate for these defects.

One general area for compensation is the use of single or yoked prism. The optics and detailed explanations of the use of these devices is beyond the scope of this report and are described elsewhere.[13,27-29] A second area is the use of behavioral methods that instruct the patient to scan into the affected field. Again, these methods are more fully described elsewhere.[6,9,17,23,27-29] Appropriate application of one or both of these therapies should be considered for all patients with visual field impairments.

The current study was retrospective. As such, clinical testing was conducted according to the protocol of RJGRC. Although perimetric testing is required for all patients, the type, static or kinetic, and the precise instruments are not specified but are left to the examiner's discretion. In a prospective study it would be beneficial to standardize this area of clinical investigation.

Summary

1. The current study is unique in that the frequency of occurrence and the lateral and altitudinal characteristics of specific types of visual field defects are presented for a total group of ABI patients and additionally for the TBI and CVA subgroups.
2. In the total sample (ABI) of 220 subjects, 46.36% had a diagnosis of visual field defect (*see* Table 3).
3. In the TBI sample of 160 subjects, 38.75% had a diagnosis of visual field defect (*see* Table 3).
4. In the CVA sample of 60 subjects, 66.67% had a diagnosis of visual field defect (*see* Table 3).
5. For those subjects with visual field defects, the scattered variety was diagnosed in almost 60% of the TBI group and exactly 20% of the CVA group. Homonymous defects were present in almost 23% of this TBI sample and 47.5% of this CVA sample. It is noteworthy that the intactness of only 1 quadrant (restricted) was present in almost equal amounts in the 2 groups and almost 15% of this total group (ABI) with visual field defects (*see* Table 5).
6. In those patients with visual field defects, the total of homonymous hemianopias and quadrantanopias was far greater than the nonhomonymous types by a total of 28 to 7. In the TBI group of these patients, there were 7 hemianopias and an equal number of quadrantanopias, with a fairly even distribution between right and left locations. In the CVA group, there were 16 homonymous hemianopias and 7 homonymous quadrantanopias, with a strong a bias for the left side (12 to 5). Nonhomonymous defects were rare in both groups, and there was only 1 complete (homonymous) altitudinal defect (*see* Table 6).

References

1. Hibbard MR, Gordon WA, Kenner B. The neuropsychological evaluation: A pathway to understanding the sequelae of brain injury. In: Suchoff IB, Ciuffreda KJ, Kapoor N, eds. *Visual and vestibular consequences of acquired brain injury*. Santa Ana, CA: Optometric Extension Program Foundation, 2001:32-45.
2. Suchoff IB, Ciuffreda KJ, Kapoor N. An overview of acquired brain injury and optometric implications. In: Suchoff IB, Ciuffreda KJ, Kapoor N, eds. *Visual and vestibular consequences of acquired brain injury*. Santa Ana, CA: Optometric Extension Program Foundation 2001:1-9.
3. Suchoff IB, Kapoor N, Waxman R, et al. The occurrence of ocular and visual dysfunctions in an acquired brain-injured patient sample. *J Am Optom Assoc* 1999;70:301-9.
4. Scheiman M, Wick B. *Clinical management of binocular vision*, 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2002:573-95.
5. Morton RL. Visual dysfunction following traumatic brain injury. In: Ashley MJ, ed. *Traumatic brain injury rehabilitative treatment and case management*, 2nd ed. Boca Raton, FL: CRC Press, 2004:183-206.
6. Suter PS. Rehabilitation and management of visual dysfunction following traumatic brain injury. In: Ashley MJ, ed. *Traumatic brain injury rehabilitative treatment and case management*, 2nd ed. Boca Raton, FL. CRC Press, 2004:209-49.
7. Kapoor N, Ciuffreda KJ. Vision disturbances following traumatic brain injury. *Curr Treat Options Neurol* 2002;4:271-80.
8. Zihl J. Cerebral disturbances of elementary visual dysfunctions. In: Brown JW, ed. *Neuropsychology of visual perception*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1989:35-58.
9. Suchoff IB, Gianutsos R. Rehabilitative optometric interventions for the adult with acquired brain injury. In: Grabois M, Garrison SJ, Hart KA, et al., eds. *Physical medicine and rehabilitation*. Malden, MA: Blackwell Scientific Publications, 2000:606-21.
10. Sabates NR, Gonce MA, Farris BK. Neuro-ophtlalmological findings in closed head injury. *J Clin Neurol Ophthalmol* 1991;11:273-7.
11. Frieden RA. Early rehabilitation after stroke. In: Gordon WA, ed. *Advances in stroke rehabilitation*. Boston: Andover Medical Publishers, 1993:18-33.
12. Macintosh C. Stroke re-visited: visual problems following stroke and their effect on rehabilitation. *British Orthoptic Journal* 2003; 60:10-4.
13. Suchoff IB, Ciuffreda KJ. A primer for the optometric management of unilateral spatial inattention. *J Am Optom Assoc* 2004;75:305-19.
14. Robertson IH, Halligan PW. *Spatial neglect: a clinical handbook for diagnosis and treatment*. East Sussex, UK: Psychological Press, 1999.
15. Ferber S, Karnath HO. Parietal and occipital lobe contribution to perception of straight ahead orientation. *J Neurol Neurosurg Psychiat* 1999;67:572-8.
16. Beis J, Andre J, Sauguez A. Detection of visual field deficits and visual neglect with computerized light emitting diodes. *Arch Physical Med Rehab* 1994;75:711-4.
17. Suter PS, Margolis N. Managing visual field defects following acquired brain injury. *Brain Injury Professional* 2005;2:26-8.

18. Zihl J. *Rehabilitation of visual disorders after brain injury*. *Neuropsychological rehabilitation: A modular handbook*. East Sussex UK: Psychology Press, 2000.
19. Muller-Oehring EM, Kasten E, Poggel DA, et al. Neglect and hemianopia superimposed. *J Clin Exp Neuropsychol* 2003:1154-68.
20. Kapoor N, Ciuffreda KJ. Vision problems. In: Silver JM, McAllister TW, Yudofsky SC, eds. *Textbook of traumatic brain injury*. Washington, DC: American Psychiatric Publishing, Inc 2005:405-15.
21. Ciuffreda KJ, Suchoff IB, Kapoor MJ, et al. Normal vision function. In: Gonzalez EG, Myers SJ, Edelstein JE, et al., eds. *Downey & Darling's physiological basis of rehabilitation medicine*, 3rd ed. Boston: Butterworth Heineman, 2001:241-61.
22. Stein JF. Representation of egocentric space in the posterior parietal cortex. *Quar J Exp Physiol* 1989;74:583-606.
23. Suchoff IB, Gianutsos R, Ciuffreda KJ, et al. Vision impairment related to acquired brain injury. In: Silverstone B, Lang MA, Rosenthal BP, et al, eds. *The lighthouse handbook on vision impairment and vision rehabilitation,* Vol 1. New York: Oxford University Press, 2000:517-39.
24. Rutner D, Kapoor N, Ciuffreda KJ, et al. Occurrence of ocular disease in traumatic brain injury in a selected sample: a retrospective study. *Brain Inj* 2006;20:1079-86.
25. Ciuffreda KJ, Kapoor N, Rutner D, et al. Occurrence of oculomotor dysfunction in acquired brain injury: A retrospective analysis. *J Am Optom Assoc* 2007;78:155-61.
26. Seiler BI, Warren M. Assessment of visual impairment following adult brain injury. In: Grabois M, Garrison SJ, Hart KA, et al., eds. *Physical medicine and rehabilitation—the complete approach*. Malden, MA: Blackwell Scientific, 2000:342-50.
27. Margolis NW, Suter PS. Visual field defects & unilateral spatial inattention: Diagnosis and therapy. *J Behav Optom* 2006;17:31-7.
28. Cohen AH. Management of patients with hemianopic visual field loss. *J Optom Vis Dev* 2003;34:111-8.
29. Padula W, Wu L, Nelson C, et al. Evaluating and treating visual dysfunction. In: Zasler ND, Katz DI, Zafonte RD, eds: *Brain injury medicine: Principles and practice*. New York: Demos Publishers, 2007:511-28.