LEARNING OBJECTIVES

1. Know visual signs and symptoms in TBI.
2. Explain the impairments and disabilities caused by hemianopia.
3. Determine what kind of rehabilitation program is indicated for a patient with TBI related visual deficits.

CME QUESTIONS

Patients with TBI – hemianopia:

1. Have reading problems because of low visual acuity – true or false?
2. Can improve orientation by:
   a) shifting their head to the blind side
   b) saccadic eye movements towards the blind side
   c) prisms and mirrors mounted in the spectacles
3. Normally have no additional impairments – true or false?

KEYWORDS

1. homonymous hemianopia
2. reading
3. orientation
4. rehabilitation
5. training

INTRODUCTION

Epidemiology

Traumatic brain injury (TBI) is an important cause of disability in the Western world. In the United States, the annual incidence of TBI is 1.4 million people, with estimated costs of $56 billion \(^{67}\) (for an overview see \(^{12}\)). Injury is the leading cause of mortality for under-45-year olds, with TBI being the major factor \(^{44}\). In TBI, 50,000 do not survive the acute stage, 235,000 are hospitalized and the remaining 1.1 million patients are treated and released from the emergency department. Mild TBI or concussion is often not accounted for because most of these patients are not admitted to a hospital, even though they also need rehabilitation \(^{51}\). Centers for Disease and Control Prevention estimate that more than 300,000 sports related concussions occur annually \(^{6,44}\). TBI is also the most important injury in the Middle East military conflicts, about 50% of them with mild TBI \(^{12}\). However, in mild TBI, even with normal conventional CT or MRI scans, cellular damage is observed in magnetic spectroscopy \(^{17}\). Many countries have been making great efforts to improve rehabilitation in TBI \(^{13,14,15,32,36,37,46,55}\).

CAUSES

The most significant accidents for TBI are traffic accidents (50%) \(^{66,67}\), involving cars, bicycles, motorcycles and pedestrians. These accidents are the major cause of TBI in people under age of 75 \(^{45}\). The second most frequent cause of TBI is falls (20–30%), especially in the very young and in the elderly. For persons 75 and older, falls cause the majority of TBIs. In many countries assault is becoming one of the leading causes of TBI, especially in war-torn areas and in low socio-economic groups. In the US approximately 20% of TBIs are due to violence, such as firearm assaults and child abuse and about 3% are due to sports injuries. Fully 50% of TBI incidents involve alcohol use.

A GENERAL CLASSIFICATION OF IMPAIRMENT, DISABILITY AND HANDICAP

The World Health Organization has elaborated a general classification of impairments, disabilities and handicaps (ICIDH) \(^{77}\), later modified to International Classification of functioning, disability and health (ICF) \(^{78}\). This classification can be well adapted to the visual system (see Figure 1 on page 68):

It considers the three fields:

1) Impairment, which assesses the pathology and the function on the basis of the organs.
2) Disability or activity limitation, which indicates the difficulties for the person caused by the impairment.
3) Handicap or participation restriction, which stands for the resulting problems in the patient’s environment.
Main impairments and disabilities in TBI

The disabilities after TBI depend upon the severity of the injury, its location, and the age and general health of the patient. Common impairments include physical impairments (paresis, spastics, epilepsy), problems with cognition (especially memory loss, thinking and reasoning), behavioural and mental health (depression, anxiety, personality changes, aggressive behaviour and social inappropriateness). Further problems are communication (expression and understanding) and sensory processing (visual, auditory, tactile, taste and smell) 45. Special aspects of brain damaged children are considered in several studies 27, 28, 33, 38, 80. A widely used instrument to classify 29, 79 and to predict 15, 18, 65 the outcome is the Glasgow Outcome Scale.

Visual impairments and disabilities after TBI

Little is known about the visual deficits associated with TBI. Visual impairments are often overlooked and not examined in patients with TBI, because other problems seem to be dominant and have to be addressed primarily addressed primarily.

Common visual impairments are 19:

- Accommodation dysfunctions
- Convergence problems
- Light sensitivity
- Diplopia – often not identified as such, but described as blur. Diplopia can be caused by decompensated phoria, fusional deficits and from cranial nerve palsy.

Eye movement disorders – can be caused by injury to brain stem nuclei and to conjugate gaze centers.

Visual field defects, especially homonymous hemianopia (see below).

Impaired eye–hand coordination., with either diplopia (reduced depth perception) or eye movement disorders (reduced visual feedback with reduced pursuit ability during the hand movement).

Higher visual disorders can cause agnosias, reduced motion detection, disturbed spatial orientation, visual neglect and attentional deficits.

The disabilities resulting from these visual impairments are:

1) Problems with near work; reading, manual activities, sewing, household etc. caused by accommodation disorders, diplopia, visual field defects and disturbed eye–hand coordination.

2) Problems with orientation and mobility; bumping into objects and persons, dropping objects, inability to perform sports, problems with wayfinding or navigating.

3) Problems with correct interpretation of the visual input leading to disturbed integration of visual perception into the activities of daily living.

The resulting handicaps:

1. Decreased or no participation in society.
2. Missing important information.
3. Decreased activities of daily living.
4. This causes a lack of independence and communication for recreation, restricts their ability to improve their self–esteem through hobbies or free–time activities, and altogether this means a severe reduction of their quality of life.

Visual rehabilitation in TBI (general)

In TBI patients, visual deficits are often overlooked because the physical and cognitive impairments are often so dominant that they are the focus of the rehabilitation programs. Patients often cannot clearly describe their deficits, often they complain about “blurred vision” or “impaired vision”– very non–specific symptoms. However, many other treatments and rehabilitation programs can be severely impaired if visual deficits are not optimally corrected/compensated. For example physical therapy can be much less effective if the patient does not properly see the required tasks.

Therefore, it is of great importance that the ophthalmologist, optometrist and/or orthoptist takes a very exact history either from the patient and/or from relatives in order to find out in which situations the deficits are recognized.

Specific and systematic examination should include the following main steps.
1) Exact determination of refraction and presbyopia and provision of optimal glasses for far and near distance are essential. Without the proper glasses the visual rehabilitation will be less than effective and possibly not accomplished! Also for other rehabilitation activities particularly, good near vision is required.

2) Examination of binocular status. If there is diplopia, prisms have to be provided as soon as possible, if appropriate. They have to be put in front of the non-paretic eye. An eye-patch should not be used, in order to maintain binocular vision, if possible. Optimal glasses and prisms (in case of diplopia) are a prerequisite for visual rehabilitation and should be provided as early as possible. The motivation of the patient for further rehabilitation can be improved substantially by these measures.

3) Contrast sensitivity is an important parameter and a reduced ability can be improved by optimal illumination.

4) Visual field defects. An exact perimetric examination under continuous fixation control is important for determining the deficit as well as the remaining seeing area. For reading ability it is important (in right more than left visual field loss) to determine whether patients have macular sparing or splitting, in order to maintain a sufficient size of a reading visual field (perceptual span) and in order to decide about proper rehabilitation programs (see below).

Before rehabilitation programs start, the patient and the relatives have to be informed in detail about the visual deficit. There are three points that have to be considered (C. Paul, personal communication):

1. To inform about the nature of the visual deficit (what does it mean to have a hemianopia, what are the consequences, what does it mean to have diplopia? why are prisms necessary?).
2. To sensitize: If the patient is sensitized to his/her visual deficit, it is easier to stimulate his will for change.
3. To motivate: For motivation and cooperation.

Additionally, the examiner has to look for neuro-psychological findings.

Specific Abnormalities:

- In 80% of patient, there are attentional deficits.
- Consider motor-based deficits.
- Additionally, there are often memory and language problems.
- Anosognosia can impair rehabilitation measures.

Important: the rehabilitation training has to be adapted to the individual deficits and to the individual personality of the patient!

Neuro-psychological rehabilitation in a multi-professional team

TBI patients usually have multidimensional deficits that have to be considered, assessed and treated by a multi-disciplinary team 74, 75, 76. Cognitive rehabilitation has been shown to be beneficial in many studies (for an overview see 8). Assessment and training of attentional processes can be helpful 2, 5, 8, 9, 50, 57, especially in neglect 56: It is of critical importance that the different professions involved in the rehabilitation of the patients fulfil the following conditions:

1. Competence in their own professional field.
2. Communication with the other professionals.
3. Focus on the benefit of the patient.

TBI AND HEMIANOPIA

In retrochiasmal lesions the visual field defect is homonymous, mostly an upper or lower quadrant, or a complete hemianopia with macular splitting. In cases of macular sparing of the occipital pole, there is sparing of 2° – 5° in the blind hemifield along the horizontal meridian at the fovea 26, 42. Although postulated for many years, the existence and significance of macular sparing was finally proven by a special fundus-controlled perimetry with the Scanning Laser Ophthalmoscope (SLO) 70. An additional type of foveal sparing, as described in non-human primates, is a morphological phenomenon caused by the distribution of the retinal ganglion cells, but is not a functional sparing 53. In cases showing an isolated lesion of the occipital pole, a small paracentral homonymous defect can result.

In a large sample of hemianopic patients 4, TBI was the cause in approximately 12%. The lesion was occipital in 12.5%, in the optic radiation in 23.2%, in the optic tract in 10.7% and multiple locations in 53.6%. Complete hemianopia (no seeing area within the affected hemifield, e.g., also without macular sparing) was present in 39% and incomplete in 61%. Remarkably, a median delay of 5 months was observed before documentation of the homonymous field defect 4.

**THE HEMIANOPIEIC READING DISORDER**

The term “hemianopic reading disorder” refers to those reading difficulties which are caused by the hemianopic field defect. Typically they are not caused by primary eye movement disorders, as assumed by some authors 10. Other reading disorders, which are due to lesions in higher cortical areas as V1, e.g. neglect or alexia, are not considered in this outline. Reading difficulty is one of the main complaints of patients with hemianopic field defects.

Normal reading:

Reading requires not only sufficient resolution (20/50 in 25cm), but also a sufficient size of retinal area used for reading. This minimum reading visual field has to cover 2°
right and left of fixation \(^1, 35, 52\); however, for fluent reading, \(^5\) (or 15 letters) in reading direction are necessary, as was shown in normal subjects \(^40\) and in patients with hemianopia \(^69\). This total perceptual span is asymmetric in favour of the reading direction \(^41\), thus providing a preview benefit based on parafoveal information processing and is therefore useful for guiding the next saccade to the appropriate landing position. The retinal area used for reading comprises only a few square millimeters but is highly magnified in the visual cortex \(^61\). The central 10° of the visual field, accounting for approximately 2 % of the total visual field, occupy more than 50 % of the primary visual cortex \(^26, 42\).

**Reading in hemianopia**

Homonymous hemianopia causes severe reading disability, since half the reading visual field is obscured in complete hemianopia (Fig.2A). In the presence of macular sparing, the reading visual field can be preserved and reading can be normal, despite the fact that there is a large field defect in the remaining hemianopic side (Fig.2B). On the other hand, a small paracentral homonymous scotoma occurring in isolated lesions of the occipital pole, causes severe problems with reading, because it covers half of the reading visual field (Fig.2C). These small paracentral scotomata are easily overlooked in automated perimetry, if the grid of the test program is not dense enough and/or the fixation is not monitored carefully. Hence, a special dense grid should be chosen with accurate fixation monitoring, while manual perimetry allows specifically searching for small scotomata.

The severity of the reading problems is not only influenced by the distance of the visual field defect from the centre, i.e. the size of the reading visual field, but depends also on the side of the defect, i.e. if the visual field defect is in the reading direction. Therefore, right hemianopia is extremely impairing in left to right readers. These patients show an increased number of saccades per line and make a lot of regressions to get through the line of text. A patient with left hemianopia quite easily gets through the line, but has difficulties finding the beginning of the next line of text reflected by additional steps during the return sweep \(^69, 71\).

Patients with hemianopia can learn compensating strategies: they perform frequent eye movements towards the blind hemifield, i.e. explorative saccades to increase the field of gaze, which shifts the field defect towards the blind side \(^70\). In early stages they often show a staircase pattern; later, an overshoot or predictive strategy \(^43\).

**THE HEMIANOPIC ORIENTATION DISORDER**

Patients with hemianopia are severely impaired in spatial orientation. They often bump into obstacles on the hemianopic side and can veer from a straight line path. This forces them to learn to perform explorative saccades towards the hemianopic side, which many patients start doing spontaneously \(^54, 70\). In conventional perimetry, this behaviour shifts the field defect to the blind side and this is often misinterpreted as an improvement of the visual field.

**Diagnostic procedures to examine reading ability**

- Specific diagnostics in regard to the existing and the potential reading ability is the basis for rehabilitation programs.
- Exact determination of the refractive error is necessary.
- Visual acuity for distance.
- Near visual acuity and range of accommodation.
- Examination of foveal (and parafoveal) contrast sensitivity \(^22\).

**FIGURE 2**

The impact of a homonymous field defect on reading performance:

A In macular splitting half of the reading visual field is covered by the field defect, which leaves no ability to read.
B If there is a macular sparing, reading ability is preserved, even though there is a large field defect, which causes spatial orientation problems.
C A small paracentral homonymous defect causes severe reading problems.
D Eccentric fixation creates a small perceptual area along the midline, which widens the reading visual field.

---

**THE HEMIANOPIC ORIENTATION DISORDER**

Patients with hemianopia are severely impaired in spatial orientation. They often bump into obstacles on the hemianopic side and can veer from a straight line path. This forces them to learn to perform explorative saccades towards the hemianopic side, which many patients start doing spontaneously \(^54, 70\). In conventional perimetry, this behaviour shifts the field defect to the blind side and this is often misinterpreted as an improvement of the visual field.

**Diagnostic procedures to examine reading ability**

- Specific diagnostics in regard to the existing and the potential reading ability is the basis for rehabilitation programs.
- Exact determination of the refractive error is necessary.
- Visual acuity for distance.
- Near visual acuity and range of accommodation.
- Examination of foveal (and parafoveal) contrast sensitivity \(^22\).
- Reading speed should be determined by having the patient read a text passage aloud. A whole text passage is preferable to a single sentence for more accurate speed measurement and judgement of fluency and mistakes. For this test, a newly developed set of equivalent texts in different languages is available, which can also be used for repeated testing. The texts are comparable not only within one language, but also between different languages. Therefore, they are optimally suited to be used in international studies (see www.amd-read.net).

- Determination of fixation behaviour can be helpful.

- Recording of the eye movements during reading is a valuable method for scientific studies showing the oculomotor reading strategy in detail.

Rehabilitation in TBI - Hemianopia
The aim of rehabilitation is to optimize the use of residual vision, especially with the goal of improving reading and spatial orientation, so that independence and quality of life of the patients can be regained or maintained.

Optical devices
Most people are confused by the double images and disturbances in spatial orientation caused by optical devices.

Binocular sector prisms cause a relocation of the field or a shift of the position of the field loss. They are not effective in hemianopia, but have been shown beneficial in patients with hemi-neglect. Most people are confused by the double images and disturbances in spatial orientation caused by optical devices.

Monocular prisms and mirrors have been used to shift the image of the blind hemifield into the normal one to expand the field. Monocular sector prisms cause diplopia and confusion. In this case, confusion is intended, because it indicates the presence of an object, which would not be visible without the prism and induces an eye or head movement towards the blind side. However, the diplopia in the centre was reported to be very unpleasant to the patients. Hedges et al. reported a benefit in 20% of his patients. Monocular sector prisms placed across the whole width of the lens, but only in the peripheral field have been reported beneficial in a small group of patients by expanding the field without central diplopia.

Altogether, while optical aids may be helpful in some selected individual cases, these interventions can not be recommended in general.

TRAINING IN HEMIANOPIA
For any training studies three main issues should be considered (see also).

1) Specificity: Spontaneous recovery has to be ruled out. Spontaneous recovery is observed mainly in the first weeks, and normally not after six months. Further, a control group is needed to verify specific improvement.

2) Reliability: Appropriate methods to assess a potential training effect are required.

3) Aim: How is improvement defined, and what degree of change is a clinically relevant improvement?

There are two main approaches for training: restitution and compensation. In studies using restitution training, the stimulation was performed at the border of the hemianopic field defect. The aim of restitution training was to reactivate incompletely damaged neurons in the blind field and to enlarge the visual fields by stimulation at the border of the field defect. Perimetric targets were presented along the visual field border at threshold or above threshold. In such a setting, there is a certain risk of stray light and high risk of eye movements towards the stimulus. The reported enlargement of the visual fields could not be confirmed by later control studies. Using a scanning laser ophthalmoscope with a special fundus perimetry under simultaneous fixation control, no improvement of the visual field could be found after "Visual Restitution Training VRT" (see also). Also in a study with conventional perimetry, no relevant effect after VRT was described.

Compensating training aims to enlarge the field of gaze by developing frequent eye movements into the blind hemifield and by shifting attention to the blind side. This kind of training was reported effective at improving the utilization of the blind hemifield. However, these studies did not use a control group. Therefore, we recently performed a randomized controlled trial with an explorative saccade training based on a search task, which clearly showed a beneficial effect compared to a control group.

Therefore, based not only on the studies with compensation training, but also especially based on the recent randomized control trial, an explorative saccadic training is recommended for patients with hemianopia to enlarge their field of gaze, to improve their orientation and mobility, their independence and their quality of life.

RECOMMENDED REHABILITATION OPTIONS
1) Approaches to improve the hemianopic reading disorder are:
   - Optimal illumination for best contrast - without glare and free of UV and IR light (should contain a cold light source).
   - Training to improve orientation on the page using visual and tactile tools (bar magnifier with underlining, ruler or forefinger are helpful).
   - Training predictive saccades, especially in left-sided hemianopia, to improve ability to find the beginning of the next line.
   - Special reading training with scrolled text.
- Moving the text into a vertical or diagonal position may be beneficial, but has not been tested in a larger patient group.
- Eccentric fixation to enlarge the perceptual span.

2) Approaches to improve the hemianopic orientation disorder are:
- Training of explorative saccades in daily life.
- Frequent saccades towards the hemianopic side for enlargement of the field of gaze.
- Specific visual search to systematize search strategies.
- Training to shift visual attention towards the blind side.
- Utilization of information from the blind hemifield, which can be seen on the seeing side (stray light, reflections, parts of objects).
- Training in the real life environment of the patient. Training with an orientation and mobility trainer.
- Specific explorative training with search tasks.

3) Counselling regarding public or other practical support:
Consideration must be given to how the visual impairment will affect the patient’s education, profession, leisure time and, in elderly patients, the ability to maintain an independent life style. Self help organizations, neighbours’ help and other social services can be very valuable. In addition, it is important to find out whether, and to what degree, the patient can expect to receive support from public agencies and institutions, which may vary among different countries.

4) Communicate with other disciplines involved in the patient’s rehabilitation.

5) General recommendations/conclusions:
- Explain to the patient and family the particular nature of the visual impairment, in detail. Ensure they are aware of the disabilities.
- Inform them that the patient is not allowed to drive (this law is valid in Europe and some of the States in the USA, although exceptions exist for getting a restricted licence).
- Training is important for optimizing the use of residual vision.
- Training has to be tailored to the individual patient.
- The value of training should be related to its relevance for everyday life.

CME ANSWERS
1. false, the reason is the limited reading visual field
2. c
3. false

REFERENCES