A review of the current practice in diagnosis and management of visual complaints associated with concussion and postconcussion syndrome

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Purpose of review
Concussions and their related sequelae have received significant attention given the high-profile media coverage from professional sports and recreational leagues. A better understanding of the diagnosis and symptom management may limit the long-term impact these injuries have on the affected individual. The aim of this review is to provide updated information for both diagnosis and ongoing management for visual symptoms of concussions.

Recent findings
New testing including a brief vestibular/ocular motor screening assessment and the importance of near point of convergence measurements may prove beneficial to the diagnosis and identification of patients at greater risk for developing postconcussion syndrome. Additionally, the development of postconcussion syndrome is more likely when symptom burden is greater upon presentation.

Summary
Currently, there is not a single testing method that can universally identify all individuals with concussion. Current management of concussion focuses on targeted treatment based upon symptoms and signs present at onset to decrease disease burden and help restore baseline functioning as soon as possible.

Keywords
concussion, convergence insufficiency, oculomotor dysfunction, postconcussion syndrome

INTRODUCTION

The media coverage of professional athletes with long-term disability including chronic traumatic encephalopathy and the subsequent physical and mental health struggles has highlighted the potential severity of the long-term effects of concussions. As evidence mounts about the potential long-term morbidity of repetitive traumatic brain injury (TBI), including altered cognition, depression, and neurodegenerative diseases (Alzheimer's disease and chronic traumatic encephalopathy) [1,2], there has been an increase in the focus and attention on improved identification and treatment of athletes who experience head injuries. The Centers for Disease Control (CDC) states that in 2009, an estimated 248 418 children (age 19 or younger) were treated in United States emergency departments for sports and recreation-related injuries that included a diagnosis of concussion or TBI [3]. Additionally, the rate of emergency department visits for sports and recreation-related injuries with a diagnosis of concussion or TBI, alone or in combination with other injuries, rose 57% among children (age 19 or younger) from 2001 to 2009. As a result, tremendous progress has been made in both the diagnosis and management of TBI and concussions [3].

Concussions are a mild form of TBI resulting from a diffuse axonal injury with microstructural white matter changes that have been shown with diffusion tensor imaging (DTI) to have a high prevalence of injury in the frontal lobes, corpus callosum, corona radiata, and diffuse deep white matter [4,5]. With around half of the neural connections in the brain involved in vision and visual processing, visual complaints such as photophobia, double vision,

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KEY POINTS

- Multiple testing methods exist to diagnose concussion but no single test has been found to be all-inclusive.
- Recent research has shown promise in the use of a novel VOMS test, the CISS, and NPC measurements for both diagnosis and predicting which patients may develop PCS.
- Additional predictors for developing PCS include patients meeting criteria for VOD at presentation (four times increased odds) as well as patients with higher PCSS scores (indicating higher total symptom burden) at time of presentation.
- Concussion injuries reflect a multifaceted disease, including ocular and vestibular dysfunction, for which individual treatment plans focusing on specific disability should be developed and adjusted as needed.

blurred vision, and visual processing problems are seen throughout the spectrum of severity in TBI [6].

Sixty-nine per cent of adolescents with a concussion had an associated visual diagnosis in a recent cross-section study performed by Master *et al.* [7▪▪] in their comprehensive concussion program. The most common visual abnormalities included accommodative disorders, convergence insufficiency, and saccadic dysfunction (29%) [7▪▪]. Although this number may be inflated based upon their role as a subspecialty referral center, there is ample literature to support the frequency of vision problems in adults in the literature [4,8–16]. Given the significant number of concussions and frequency of associated visual complaints, it is essential that quick diagnosis and comprehensive postconcussion care be provided.

Along with visual dysfunction, significant morbidity from vestibular dysfunction following concussion can arise from central or peripheral structures within the vestibulospinal system resulting in disequilibrium and impaired balance. This can also be combined with dizziness, vertigo, nausea, and difficulty in active environments from disruption of the vestibulo-ocular system resulting in significant impact in function [17]. The most common vestibular issues following sports-related concussion are benign paroxysmal positional vertigo (BPPV), visual motion sensitivity (VMS), balance dysfunction, vestibule-ocular reflex (VOR) impairment, cervicogenic dizziness, and exercise-induced dizziness [18▪▪]. Corwin *et al.* [19▪] completed a retrospective cohort study at a tertiary pediatric hospital and found that 81% of their 247 patients had a vestibular abnormality (defined by abnormality in VOR testing or abnormal tandem gait) on initial clinical examination.

DIAGNOSIS

There are several different tests that have been used to identify patients with TBI. As these test evolve and more focus is placed on early detection and identification of individuals with TBI, the need for an easy to administer and straightforward test has blossomed. The King Devick (K-D), Balance Error Scoring System (BESS), Sports Concussion Assessment Tool 3rd Ed (SCAT3), and the Immediate Postconcussion Assessment Cognition Test (ImPACT) are currently employed to diagnose concussions. Table 1 includes a brief description of these common concussion tests as well as their advantages and disadvantages. Although the K-D, SCAT3, and BESS tests all have limitations when used individually, the addition of the K-D to the SCAT3 and BESS in one study of University of Florida athletes correctly identified the 10% of athletes not identified by the SCAT3 and BESS alone [2,20▪].

Postconcussion symptoms scale (PCSS) [6] is a standard 22-question form with patients rating symptoms on a 7-point Likert scale (0 – no symptoms through 6 – very severe symptoms). Symptoms are categorized as physical, emotional, cognitive, and sleep-related. The obvious limitation with this assessment is its subjectivity allowing for artificially low or high scores depending on the motive of the test taker.

It should be noted that, by definition, neuroimaging is often grossly normal in the setting of concussion but should be utilized, if clinically indicated, to rule out other pathologies that may produce concussion like signs and symptoms.

Master *et al.* [7▪▪] sought to see if the Convergence Insufficiency Symptom Scale (CISS) would be useful in helping identify adolescent patients with vision problems following TBI. The CISS is a 15-point validated questionnaire developed to monitor symptom recovery for patients performing convergence exercises for underlying convergence insufficiency. Master found a high CISS score of $\geq$16 was strongly associated with a visual problem ($P < .001$, PR = 1.85; CI = 1.25–2.75) showing promise as a possible screening tool when only 29% of their patients with concussions specifically reported vision symptoms on PCSS [7▪▪].

Mucha *et al.* [21▪▪] proposed a brief vestibular/ocular motor screening (VOMS) assessment as a possible tool for concussion detection. In this cross-sectional study, the VOMS assessment was administered with five domains tested: smooth pursuit, horizontal and vertical saccades, near point of

Table 1. Summary of common concussion tests and their advantages and disadvantages

Test	Description	Advantage	Disadvantage
King-Devick (K-D)	Patient reads numbers from three test cards as quickly as possible	Quick and easy to administer (1–2 min); portable; assesses eye movement/ saccades without formal training	Baseline testing required; performance can vary with effort; no assessment of memory, balance, accommodation, convergence
Balance Error Scoring System (BESS)	Patient stands in three different positions on two separate surfaces (firm ground and foam) with hands on hips and eyes closed – errors tallied over 20 s intervals	Specifically focused on balance; portable; cost effective	Poor inter-rater reliability (best to have same administrator); performance can vary with fatigue, injury
Sport Concussion Assessment Tool, Third Edition (SCAT3)	Includes Glasgow Coma Scale (GCS); 22-item symptom checklist; cognitive and physical examination; modified BESS; Maddox questions (set of five questions related to game orientation and recent memory); Standardized Assessment of Concussion (SAC) (series of questions assessing orientation, immediate memory, and concentration)	Includes symptom reporting, balance, clinical appearance	Baseline testing required; takes 15–20 min to complete; does not test vision; SAC scores can be inflated with memorization of questions; medical training required to administer components (GCS, physical examination)
Immediate Postconcussion Assessment Cognitive Test (ImPACT)	Computerized neuropsychological test	Software to detect purposeful poor performance	Baseline testing required; computer required; insufficient test-retest reliability and validity for return to field decisions; normal test scores possible despite ongoing metabolic abnormalities

convergence (NPC) distance, horizontal VOR, and VMS. Patients also complete PCSS testing. The VOR and VMS were most predictive of being in the concussed group with all domains positively correlating to the PCSS scale. Additionally, a NPC $\geq$5 cm increased the probability of correctly identifying a concussed patient by 38% [21▪▪].

Further support for the use of NPC in diagnosis of concussion was presented by Pearce *et al.* [22▪▪] who showed convergence insufficiency (NPC >5 cm) was found in 42% of athletes presenting within 1 month of injury. These patients performed worse on neurocognitive testing including verbal memory, visual motor speed, and reaction time in addition to having greater total symptoms scores (PCSS).

Along with the above assessment tools, newer technology is being developed and tested to better predict individuals at-risk for sustaining concussions. Head impact sensors in football helmets recording rotational and linear acceleration as well as location of impact are being utilized to try to identify players at-risk for concussion based upon collision data [23]. Complementary testing is still warranted as individuals with impacts below thresholds can still have a concussion [24].

When symptoms have been present for longer than 1 month, criteria is met for a diagnosis of postconcussion syndrome (PCS) as defined by the WHO *International Classification of Diseases, 10th Revision* (ICD-10). A review of the literature reveals a wide range (10–59%) of incidence of PCS [25–32]. This is an important statistic as several studies [33–35] have shown an increased risk for impaired school performance, migraine headaches, depression, and anxiety in this population.

ASSESSING RISK OF POSTCONCUSSION SYNDROME

Recent literature has focused on identifying signs and symptoms that may predict who may have a more difficult and prolonged recovery. Ellis *et al.* [36▪] found that in a retrospective chart review, patients meeting criteria for vestibulo-ocular dysfunction (VOD) at presentation had four times the odds of developing PCS even when controlling for confounding variables. VOD was defined as more

than one subjective vestibular and oculomotor complaint (dizziness, blurriness, etc.) and more than one objective physical examination finding (abnormal smooth pursuits, saccades, VOR, and near point of convergence). Incidence of VOD was found in 29% of patients with acute sports-related concussion (symptoms <30 days) and 63% of those with PCS [36▪]. They also found that patients who reported amnesia at time of concussion and those with a higher PCSS score had significantly higher odds of developing PCS [36▪].

Meehan *et al.* [37▪▪] recently reported on a prospective cohort study involving 531 patients. They evaluated possible predictive variables including age, sex, initial scores on symptom inventories, history of prior concussions, number of prior concussions, performance on computerized neurocognitive assessments (ImPACT), loss of consciousness at time of injury, amnesia at time of injury, history of medical treatment for headaches, self-reported history of migraine headaches, and family history of concussion. They found that the only predictor for prolonged symptom burden (>28 days) after sports-related concussion (SRC) is total symptom burden at time of presentation (based on PCSS score) [37▪▪]. Eighty-six per cent of patients with PCSS score of less than 13 had a resolution of symptoms by 28 days whereas 65% of patients with a PCSS score of ≥13 had prolonged symptoms compared with the 14% with a PCSS score less than 13 [37▪▪].

MANAGEMENT STRATEGIES

Serial monitoring of recovery with both subjective and objective methods is the mainstay of current guidelines as developed by the International Concussion in Sport Group [38,39]. Rest is felt to be beneficial as it prevents ATP, oxygen, and glycogen diversion from injured neurons to support nonessential activity. The problem lies in the interpretation of 'rest' which may be as strict as sequestering the patient in a dark room to allowing for moderate activity so long as symptoms are not worsened.

There have been no randomized controlled trials evaluating rest in athletes following concussion [40]. The evidence for physical rest centers on animal models exhibiting metabolic dysfunction with additional injury sustained during recovery further prolong recovery time and impair the ability to learn [41–44]. This should also be weighed against the significant negative psychological impact of withholding athletes from participation in academic, athletic, and social activities [45,46].

Tjarks *et al.* [47] found the K-D test to be effective for monitoring recovery of both visual processing and oculomotor speed. They also found that the ImPACT testing scores correlated significantly with the improvement noted in K-D scores and PCSS scores decreased over time indicating a progressive recovery from brain injury [47].

The recent advancements in handheld tablets and electronic interfaces highlight the need for identification of patients with visual sequelae after concussion. Appropriate accommodations in the office and school setting are essential for progressive recovery in the time following concussion [48,49]. These accommodations may include excused absences, starting later or ending the school day earlier, audio books, large-font print, oral teaching, preprinted notes, and frequent visual breaks. Additionally, the use of handheld tablets with ability to enlarge print and sync with classroom boards may be helpful. More long-term recovery measures may include developing an individualized education plan (IEP) or a 504 plan (a section of the Rehabilitation Act) that provides for medical need accommodations.

VISUAL COMPLAINTS

In patients with visual complaints, an evaluation for microstrabismus, convergence insufficiency, accommodative insufficiency, and perhaps visual field testing should be undertaken. Small microtropias should be treated with prismatic correction. Over 70% of patients with a vertical heterophoria reported relief with prismatic correction [11]. Accommodative symptoms may occur as a result of accommodative insufficiency (incidence of 10–33%), accommodative excess (4%), or varying accommodation [50]. Treatment for accommodative complaints may be addressed with spectacle correction for near. Oculomotor training may improve accommodative symptoms in patients with concussion [50], but the improvements may not be sustained after treatment termination [51▪]. Convergence insufficiency treatments include base in prism, near convergence exercises with in-office or home based programs and oculomotor training. The only study to date on convergence insufficiency treatment in patients with concussion utilized oculomotor training and reported encouraging results [50]. Convergence insufficiency therapies may be an effective tool in helping patients improve performance at work and in the classroom however, further research into effectiveness of convergence exercises in patients specifically following concussion are needed. In patients with blast-related brain injuries, approximately one-third had some type of abnormal global visual field defect ranging from hemianopia to milder visual field deficits [52▪]. Awareness of

visual deficits can lead to strategies to minimize the impact on activities of daily living.

VESTIBULAR COMPLAINTS

In their study on vestibular deficits following youth concussions, Corwin *et al.* [19▪] found that patients with abnormal VOR or tandem gait took significantly longer time to return to school (medial 59 vs. 6 days, $P = 0.001$) or to be fully cleared (median 106 vs. 29 days, $P = 0.001$).

Vestibular rehabilitation includes targeted intervention for specific symptoms and dysfunction and has significantly increased over the past decade. However, studies focusing on the pediatric population are sparse [19▪]. Improvement in vestibular deficits in adults with mild TBI center around exercises that promote habituation (for impaired motion sensitivity), adaptation (for impaired convergence), substitution (for severe impairments), and balance exercises [53,54]. A summary of common interventions for vestibular impairment following concussion can be found in the recent review article by Broglio *et al.* [18▪▪].

OTHER TREATMENTS

Cifu *et al.* [55▪] performed a single center, randomized, double-blinded, sham controlled, prospective study of hyperbaric oxygen treatments on patients with mild TBI to see if these treatments resulted in improvement in eye movements abnormalities (fixation, saccades, and smooth pursuit) utilizing a standardized computerized eye tracking protocol administered just prior to and immediately postintervention. No significant improvement in eye movement abnormalities were noted with hyperbaric oxygen treatment [55▪].

Pharmacological management of concussion-related symptoms including nonsteroidal anti-inflammatory medications, acetaminophen, neurostimulants, anxiety/mood altering medications, and agents to help with sleep-related issues should be considered off-label use as there is no US Food and Drug Administration-approved pharmacologic treatment for sports-related concussion. Current research shows that pharmacologic treatments usually begin about 10 days after injury [56] but further study of efficacy and best time for intervention to achieve maximal benefit is needed.

CONCLUSION

Although numerous testing methods exist to evaluate and diagnose patients with concussions and TBI, no single test has demonstrated the ability to universally identify all individuals. Concussion injuries reflect a multifaceted disease for which no 'one size fits all' treatment plan exists. Current management of concussion focuses on targeted treatment based upon symptoms and signs present in an effort to restore function as quickly as possible. Visual complaints are common in patients with concussion and need to be formally evaluated and treated if possible. Future areas of study include improved efficiency in diagnosing individuals with concussion and finding other treatment modalities, both pharmacologic and therapy based, to help patients at-risk for developing PCS.

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Conflicts of interest

There are no conflicts of interest.

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- ▪ of special interest
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