Head Injuries in Sports

237

Paul McCrory

Contents

Abstract

This chapter discusses the types of common head and brain injuries that may be seen in sports and outlines the clinical assessment and return to play issues that need to be considered. The approach is based on the most recent 2013 Zurich Concussion in Sport Guidelines, and the assessment tools derived from those guidelines are included in the chapter.

Introduction

Sports medicine physicians, trainers, and others involved in athletic care have to both recognize and manage a wide range of head injuries ranging from the mildest form of concussion to fatal brain injury. A key knowledge requirement for all healthcare providers is to have a thorough understanding of the early management of the head injuries and the potential sequelae of such injuries that may impact upon the athlete's ability to return to sports.

Definition

Head trauma is the description applied to injuries to the brain or its coverings, the skull, as well as the soft tissues and vascular structures of the head and neck. In this chapter, when considering such injuries, the term traumatic brain injury (TBI) will

P. McCrory (✉)
The Florey Institute of Neuroscience and Mental Health, University of Melbourne, Melbourne Brain Centre – Austin Campus, Heidelberg, VIC, Australia
e-mail: paulmccr@bigpond.net.au

M.N. Doral, J. Karlsson (eds.), *Sports Injuries*,
DOI 10.1007/978-3-642-36569-0_231

be applied to the injuries of the brain or central nervous system and head to incorporate injuries to other structures of the head including the skull and craniofacial bones. Orofacial and ocular injuries will not be discussed in this chapter.

Although a number of general classification schemes for TBI have been proposed, the most widely used system is the Glasgow Coma Scale (GCS) (Jennett and Bond 1975). The GCS is incorporated in the SCAT3 tool (Fig. 1). The GCS has two distinct and separate uses: (a) for serial measurement of brain injury status and (b) to separate TBI into a clinically and prognostically useful injury severity grading.

In the former role, an immediate GCS is performed at the time of the initial assessment of an injured patient and then serially to monitor progress. In the latter role, the separation of mild (GCS 12–15), moderate (GCS 9–11), and severe (GCS $\leq$8) TBI is based upon a scoring system that uses eye opening, verbal response, and motor response to standard stimuli and should be measured 6 h post-injury after resuscitation has been completed. It is important to note that the term *concussion* (or *commotio cerebri*) refers to a different injury construct and is not synonymous with the term "mild TBI," that is, a concussed athlete may have a normal GCS.

Epidemiology

The crude incidence for all traumatic brain injuries is estimated at approximately 300 per 100,000 population per year with the majority (80–90 %) of those suffering a mild TBI. The Center for Disease Control estimates that 1.6–3.8 million sports-related concussions occur each year in the United States (Langlois et al. 2006). Sporting injuries contribute approximately 10–15 % of all cases.

Diagnostic Thinking

The key objectives when assessing any athlete who has sustained an acute head or brain injury are to:

1. Institute an appropriate first aid sideline assessment of the injured athlete
2. Make an accurate diagnosis
3. Manage the injury appropriately, minimizing the risk of any "secondary" injury, such as might be seen with coexistent hypoxia or hypotension
4. Safely remove the athlete from the field of play to an appropriate medical facility for further investigation and assessment
5. Determine subsequently when it is safe for the athlete to return to play

Initial Assessment of Head and Brain Injury

Usually, the fact that an athlete has suffered a head injury is obvious to the team medical staff. Head injuries in collision sports are usually the result of direct trauma to the athlete's head and should also be considered when there has been a rapid acceleration and deceleration type of injury, but no direct head contact. Information about the event and about the immediate clinical findings should be conveyed to the medical staff looking after the patient.

The major priorities at this early stage are the basic principles of first aid, e.g., ensure a patent airway with adequate oxygenation, ventilation, and circulation. Once these basic aspects of first aid care have been achieved and the patient stabilized, then consideration of removing the patient from the field to an appropriate facility is necessary. It is essential that all team physicians who have an on-field injury management role in their sports have formal training and certification for both first aid and trauma management.

At this time, careful assessment for the presence of a cervical spine or other injury is necessary. If an alert patient complains of neck pain, has evidence of neck tenderness or deformity, or has neurological signs suggestive of a spinal injury, then cervical immobilization and transportation with suitable spinal frame is required. If the patient is unconscious, then a cervical injury should be assumed until proven otherwise.

SCAT3

Sport Concussion Assessment Tool – 3rd Edition

For use by medical professionals only

Name | Date/Time of Injury: Date of Assessment: | Examiner:

What is the SCAT3?[1]

The SCAT3 is a standardized tool for evaluating injured athletes for concussion and can be used in athletes aged from 13 years and older. It supersedes the original SCAT and the SCAT2 published in 2005 and 2009, respectively[2]. For younger persons, ages 12 and under, please use the Child SCAT3. The SCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concussion Recognition Tool[1]. Preseason baseline testing with the SCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the SCAT3 are provided on page 3. If you are not familiar with the SCAT3, please read through these instructions carefully. This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. Any revision or any reproduction in a digital form requires approval by the Concussion in Sport Group.

NOTE: The diagnosis of a concussion is a clinical judgment, ideally made by a medical professional. The SCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgement. An athlete may have a concussion even if their SCAT3 is "normal".

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific signs and/or symptoms (some examples listed below) and most often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour (e.g., change in personality).

SIDELINE ASSESSMENT

Indications for Emergency Management

NOTE: A hit to the head can sometimes be associated with a more serious brain injury. Any of the following warrants consideration of activating emergency procedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15
- Deteriorating mental status
- Potential spinal injury
- Progressive, worsening symptoms or new neurologic signs

Potential signs of concussion?

If any of the following signs are observed after a direct or indirect blow to the head, the athlete should stop participation, be evaluated by a medical professional and **should not be permitted to return to sport the same day** if a concussion is suspected.

Any loss of consciousness?	Y	N
"If so, how long?"		
Balance or motor incoordination (stumbles, slow/laboured movements, etc.)?	Y	N
Disorientation or confusion (inability to respond appropriately to questions)?	Y	N
Loss of memory:	Y	N
"If so, how long?"		
"Before or after the injury?"		
Blank or vacant look:	Y	N
Visible facial injury in combination with any of the above:	Y	N

1 Glasgow coma scale (GCS)

Best eye response (E)	
No eye opening	1
Eye opening in response to pain	2
Eye opening to speech	3
Eyes opening spontaneously	4
Best verbal response (V)	
No verbal response	1
Incomprehensible sounds	2
Inappropriate words	3
Confused	4
Oriented	5
Best motor response (M)	
No motor response	1
Extension to pain	2
Abnormal flexion to pain	3
Flexion/Withdrawal to pain	4
Localizes to pain	5
Obeys commands	6
Glasgow Coma score (E + V + M)	of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

2 Maddocks Score[3]

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions (1 point for each correct answer)

At what venue are we at today?	0	1
Which half is it now?	0	1
Who scored last in this match?	0	1
What team did you play last week/game?	0	1
Did your team win the last game?	0	1
Maddocks score		of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not used for serial testing.

Notes: Mechanism of Injury ("tell me what happened"?):

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle until cleared to do so by a medical professional. No athlete diagnosed with concussion should be returned to sports participation on the day of Injury.

Fig. 1 (continued)

BACKGROUND

Name: _____ Date: _____
Examiner: _____
Sport/team/school: _____ Date/time of injury: _____
Age: _____ Gender: ☐ M ☐ F
Years of education completed: _____
Dominant hand: ☐ right ☐ left ☐ neither
How many concussions do you think you have had in the past? _____
When was the most recent concussion? _____
How long was your recovery from the most recent concussion? _____
Have you ever been hospitalized or had medical imaging done for a head injury? ☐ Y ☐ N
Have you ever been diagnosed with headaches or migraines? ☐ Y ☐ N
Do you have a learning disability, dyslexia, ADD/ADHD? ☐ Y ☐ N
Have you ever been diagnosed with depression, anxiety or other psychiatric disorder? ☐ Y ☐ N
Has anyone in your family ever been diagnosed with any of these problems? ☐ Y ☐ N
Are you on any medications? If yes, please list: ☐ Y ☐ N

_____

SCAT3 to be done in resting state. Best done 10 or more minutes post excercise.

SYMPTOM EVALUATION

3 How do you feel?

"You should score yourself on the following symptoms, based on how you feel now".

	none		mild		moderate		severe
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

Total number of symptoms (Maximum possible 22) _____
Symptom severity score (Maximum possible 132) _____

Do the symptoms get worse with physical activity? ☐ Y ☐ N
Do the symptoms get worse with mental activity? ☐ Y ☐ N

☐ self rated ☐ self rated and clinician monitored
☐ clinician interview ☐ self rated with parent input

Overall rating: If you know the athlete well prior to the injury, how different is the athlete acting compared to his/her usual self?

Please circle one response:

no different	very different	unsure	N/A

Scoring on the SCAT3 should not be used as a stand-alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion. Since signs and symptoms may evolve over time, it is important to consider repeat evaluation in the acute assessment of concussion.

COGNITIVE & PHYSICAL EVALUATION

4 Cognitive assessment

Standardized Assessment of Concussion (SAC)[4]

Orientation (1 point for each correct answer)

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1
Orientation score		of 5

Immediate memory

List	Trial 1		Trial 2		Trial 3		Alternative word list		
elbow	0	1	0	1	0	1	candle	baby	finger
apple	0	1	0	1	0	1	paper	monkey	penny
carpet	0	1	0	1	0	1	sugar	perfume	blanket
saddle	0	1	0	1	0	1	sandwich	sunset	lemon
bubble	0	1	0	1	0	1	wagon	iron	insect
Total									

Immediate memory score total of 15

Concentration: Digits Backward

List	Trial 1		Alternative digit list		
4-9-3	0	1	6-2-9	5-2-6	4-1-5
3-8-1-4	0	1	3-2-7-9	1-7-9-5	4-9-6-8
6-2-9-7-1	0	1	1-5-2-8-6	3-8-5-2-7	6-1-8-4-3
7-1-8-4-6-2	0	1	5-3-9-1-4-8	8-3-1-9-6-4	7-2-4-8-5-6
Total of 4					

Concentration: Month in Reverse Order (1 pt. for entire sequence correct)

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan	0	1
Concentration score		of 5

5 Neck Examination:

Range of motion Tenderness Upper and lower limb sensation & strength
Findings: _____

6 Balance examination

Do one or both of the following tests.
Footwear (shoes, barefoot, braces, tape, etc.) _____

Modified Balance Error Scoring System (BESS) testing[5]

Which foot was tested (i.e. which is the **non-dominant** foot) ☐ Left ☐ Right
Testing surface (hard floor, field, etc.) _____

Condition

Double leg stance:	Errors
Single leg stance (non-dominant foot):	Errors
Tandem stance (non-dominant foot at back):	Errors

And/Or

Tandem gait[6,7]
Time (best of 4 trials): _____ seconds

7 Coordination examination

Upper limb coordination

Which arm was tested: ☐ Left ☐ Right
Coordination score of 1

8 SAC Delayed Recall[4]

Delayed recall score of 5

Fig. 1 (continued)

INSTRUCTIONS

Words in *Italics* throughout the SCAT3 are the instructions given to the athlete by the tester.

Symptom Scale

"You should score yourself on the following symptoms, based on how you feel now".

To be completed by the athlete. In situations where the symptom scale is being completed after exercise, it should still be done in a resting state, at least 10 minutes post exercise.
For total number of symptoms, maximum possible is 22.
For Symptom severity score, add all scores in table, maximum possible is 22 x 6 = 132.

SAC[4]

Immediate Memory

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."

Trials 2 & 3:

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

Complete all 3 trials regardless of score on trial 1 & 2. Read the words at a rate of one per second. **Score 1 pt. for each correct response.** Total score equals sum across all 3 trials. Do not inform the athlete that delayed recall will be tested.

Concentration

Digits backward

"I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."

If correct, go to next string length. If incorrect, read trial 2. **One point possible for each string length**. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

Months in reverse order

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November … Go ahead"

1 pt. for entire sequence correct

Delayed Recall

The delayed recall should be performed after completion of the Balance and Coordination Examination.

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Score 1 pt. for each correct response

Balance Examination

Modified Balance Error Scoring System (BESS) testing[5]

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[5]. A stopwatch or watch with a second hand is required for this testing.

"I am now going to test your balance. Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."

(a) Double leg stance:

"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance:

"If you were to kick a ball, which foot would you use? [This will be the dominant foot] Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

(c) Tandem stance:

"Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

Fig. 1 (continued)

Balance testing – types of errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the athlete. The examiner will begin counting errors only after the individual has assumed the proper start position. **The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum total number of errors for any single condition is 10.** If a athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once subject is set. Subjects that are unable to maintain the testing procedure for a minimum of **five seconds** at the start are assigned the highest possible score, ten, for that testing condition.

OPTION: For further assessment, the same 3 stances can be performed on a surface of medium density foam (e.g., approximately 50 cm x 40 cm x 6 cm).

Tandem Gait[6,7]

Participants are instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 meter line with an alternate foot heel-to-toe gait ensuring that they approximate their heel and toe on each step. Once they cross the end of the 3m line, they turn 180 degrees and return to the starting point using the same gait. A total of 4 trials are done and the best time is retained. Athletes should complete the test in 14 seconds. Athletes fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object. In this case, the time is not recorded and the trial repeated, if appropriate.

Coordination Examination

Upper limb coordination

Finger-to-nose (FTN) task:

"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended), pointing in front of you. When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose, and then return to the starting position, as quickly and as accurately as possible."

Scoring: 5 correct repetitions in < 4 seconds = 1
Note for testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. **Failure should be scored as 0.**

References & Footnotes

1. This tool has been developed by a group of international experts at the 4th International Consensus meeting on Concussion in Sport held in Zurich, Switzerland in November 2012. The full details of the conference outcomes and the authors of the tool are published in The BJSM Injury Prevention and Health Protection, 2013, Volume 47, Issue 5. The outcome paper will also be simultaneously co-published in other leading biomedical journals with the copyright held by the Concussion in Sport Group, to allow unrestricted distribution, providing no alterations are made.

2. McCrory P et al., Consensus Statement on Concussion in Sport – the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. British Journal of Sports Medicine 2009; 43: i76-89.

3. Maddocks, DL; Dicker, GD; Saling, MM**.** The assessment of orientation following concussion in athletes. Clinical Journal of Sport Medicine. 1995; 5(1): 32 – 3.

4. McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sport Medicine. 2001; 11: 176 – 181.

5. Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24 – 30.

6. Schneiders, A.G., Sullivan, S.J., Gray, A., Hammond-Tooke, G. & McCrory, P**.** Normative values for 16-37 year old subjects for three clinical measures of motor performance used in the assessment of sports concussions. Journal of Science and Medicine in Sport. 2010; 13(2): 196 – 201.

7. Schneiders, A.G., Sullivan, S.J., Kvarnstrom. J.K., Olsson, M., Yden. T**.** & Marshall, S.W. The effect of footwear and sports-surface on dynamic neurological screening in sport-related concussion. Journal of Science and Medicine in Sport. 2010; 13(4): 382 – 386

ATHLETE INFORMATION

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

Signs to watch for

Problems could arise over the first 24–48 hours. The athlete should not be left alone and must go to a hospital at once if they:

- Have a headache that gets worse
- Are very drowsy or can't be awakened
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused; are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on their feet; have slurred speech

Remember, it is better to be safe.
Consult your doctor after a suspected concussion.

Return to play

Athletes should not be returned to play the same day of injury.
When returning athletes to play, they should be **medically cleared and then follow a stepwise supervised program,** with stages of progression.

For example:

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective of each stage
No activity	Physical and cognitive rest	Recovery
Light aerobic exercise	Walking, swimming or stationary cycling keeping intensity, 70 % maximum predicted heart rate. No resistance training	Increase heart rate
Sport-specific exercise	Skating drills in ice hockey, running drills in soccer. No head impact activities	Add movement
Non-contact training drills	Progression to more complex training drills, eg passing drills in football and ice hockey. May start progressive resistance training	Exercise, coordination, and cognitive load
Full contact practice	Following medical clearance participate in normal training activities	Restore confidence and assess functional skills by coaching staff
Return to play	Normal game play	

There should be at least 24 hours (or longer) for each stage and if symptoms recur the athlete should rest until they resolve once again and then resume the program at the previous asymptomatic stage. Resistance training should only be added in the later stages.

If the athlete is symptomatic for more than 10 days, then consultation by a medical practitioner who is expert in the management of concussion, is recommended.

Medical clearance should be given before return to play.

Scoring Summary:

Test Domain	Score		
	Date:	Date:	Date:
Number of Symptoms of 22			
Symptom Severity Score of 132			
Orientation of 5			
Immediate Memory of 15			
Concentration of 5			
Delayed Recall of 5			
SAC Total			
BESS (total errors)			
Tandem Gait (seconds)			
Coordination of 1			

Notes:

CONCUSSION INJURY ADVICE

(To be given to the **person monitoring** the concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. Recovery time is variable across individuals and the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

If you notice any change in behaviour, vomiting, dizziness, worsening headache, double vision or excessive drowsiness, please contact your doctor or the nearest hospital emergency department immediately.

Other important points:

- Rest (physically and mentally), including training or playing sports until symptoms resolve and you are medically cleared
- No alcohol
- No prescription or non-prescription drugs without medical supervision. Specifically:
  - No sleeping tablets
  - Do not use aspirin, anti-inflammatory medication or sedating pain killers
- Do not drive until medically cleared
- Do not train or play sport until medically cleared

Clinic phone number

Patient's name

Date/time of injury

Date/time of medical review

Treating physician

Contact details or stamp

Fig. 1 SCAT3 assessment tool

Table 1 Indications for urgent hospital referral and/or neuroimaging

Fractured skull	Confusion or impairment of consciousness >30 min
Penetrating skull trauma	Loss of consciousness >5 min
Deterioration in conscious state following injury	Persistent vomiting or increasing headache post-injury
Focal neurological signs	Any convulsive movements
More than one episode of concussive injury in a session	Where there is assessment difficulty (e.g., an intoxicated patient)
Children with head injuries	High-risk patients (e.g., hemophilia, anticoagulant use)
Inadequate post-injury supervision	High-risk injury mechanism (e.g., high-velocity impact)

The clinical management may involve the treatment of a disorientated, confused, unconscious, uncooperative, or convulsing patient. The immediate treatment priorities remain the basic first aid principles. Once this has been established and the patient stabilized, a full medical and neurological assessment should follow. On-site physicians are in an ideal position to initiate the critical early steps in medical care to ensure optimal recovery from a head injury.

When examining a head-injured athlete, a structured and focused neurological examination is important. Because the major management priorities at this stage are to establish an accurate diagnosis and exclude a catastrophic intracranial injury, the examination should focus on key clinical findings such as (a) the level of consciousness (measured using the GCS), (b) pupil response and conjugate eye movement, (c) motor function, and (d) thorough examination of the skull and scalp for evidence of trauma.

A baseline measurement of the GCS, preferably after initial resuscitation but before additional medications such as sedatives or paralytics are given, should be performed in all head-injured patients. The importance of this initial neurological exam is that it serves as a reference to which other repeated neurological examinations may be compared. It is necessary to record all clinical findings so that an overall trend in improving or deteriorating mental function can be clearly and objectively documented.

Vital signs must be recorded following an injury. Hypotension is rarely due to brain injury, except as a terminal event, and alternate sources for the decrease in blood pressure should be aggressively sought and treated. This includes major scalp lacerations especially in young children or a cervical spinal cord injury. Restlessness is a frequent accompaniment of brain injury and can be an early indicator of increased ICP, intracranial bleeding, or hypoxia, all of which can aggravate any underlying brain injury. If the patient is unconscious but restless, attention should be given to the possibility of increasing hypoxia, a distended bladder, or painful injuries elsewhere. When time permits, a more thorough physical exam should be performed to exclude coexistent injuries elsewhere in the body, a sensory evaluation, and to detect the late developing signs of skull injury.

Who Should Be Referred to a Hospital?

The treating clinician at a sporting event also must decide who should be referred to a hospital emergency facility or neurosurgical center. There are a number of urgent indications that are listed in Table 1. While it is acknowledged that a number of these indications are based on anecdotal rather than evidence-based information, these are widely accepted. The overall approach should be "*when in doubt, refer*." Where no physician is present and the initial management is in the hands of an athletic trainer, physical therapist, or paramedic, then an urgent medical referral should be considered mandatory in all cases of head injury.

Who Needs Diagnostic Investigations?

The indications for emergent cranial computerized tomography (CT) imaging in the initial evaluation of the head-injured patient are outlined in Table 1. The primary goal of imaging is to establish whether there is an intracranial hemorrhage.

A depressed level of consciousness and, in particular, a GCS ≤8 are the strongest predictors of intracranial hemorrhage. Other signs that suggest surgical pathology include focal motor weakness and an asymmetrical pupil exam. There may be situations however where the clinical examination is obscured by alcohol, drugs, metabolic derangement, or postictal state or where the ability to access the patient for serial neurological examinations is problematic. In such cases, early CT or MR imaging is recommended to enable accurate decision-making.

An important and more difficult question is who needs a head CT scan when their level of consciousness is normal (i.e., GCS is 15). Guidelines such as the Canadian Head CT Rules and the New Orleans Criteria suggest that factors such as age >60 years, headache, vomiting, intoxication, retrograde amnesia, confusion, loss of consciousness, seizures, visible trauma above the clavicles, and injury mechanism indicate a need for a head CT (Stiell et al. 2005). However, a normal head CT scan does not always exclude a TBI or the need for neurosurgical consultation. About 20 % of patients admitted to a hospital after even mild TBI may develop posttraumatic abnormalities on subsequent imaging even after the initial head CT scan was normal.

Skull radiographic series (AP, Caldwell, Waters, and lateral views) have been replaced by the use of head CT and are very rarely obtained. However, plain skull radiographs are inexpensive and can easily be obtained in an emergency room, and if a fracture is present particularly when there is a focal finding or depressed level of consciousness, it suggests an extradural hemorrhage. The overall predictive value of skull radiographs is low.

Differential Diagnoses

When considering an athlete who has suffered an acute head or brain injury, the differential diagnosis is limited, and the critical diagnostic problem is to sort out the different types of intracranial injury (e.g., subdural hematoma) that may initially present with identical clinical features and then determine the most appropriate management priorities.

In mild brain injury and, in particular, sports concussion, the diagnosis is often missed because the symptoms are subtle, the athlete does not seek medical attention, or the athlete recovers rapidly before a full assessment can be made. Most sports-related head injuries occur without loss of consciousness. In this situation, the most common differential diagnosis is that of posttraumatic migraine that may manifest similar early symptoms. The key clinical symptom of concussion used to establish the presence of this injury is cognitive disturbance that may include altered memory, reaction time, or judgment.

Specific Diagnoses

Brain Concussion: Commotio Cerebri

Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces, either by a direct blow to the head, face, neck, or elsewhere on the body with an "impulsive" force transmitted to the head (McCrory et al. 2013). Research suggests that linear acceleration or rotational shearing forces may result in short-lived neurochemical, metabolic, or gene-expression changes (Giza and Hovda 2001). Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. Although concussion may result in neuropathological changes, the acute clinical symptoms reflect a functional disturbance rather than an underlying structural injury. As part of the definition, no abnormality is seen on standard structural neuroimaging studies although more detailed functional imaging modalities may reveal pathophysiological disturbance in some cases. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course; however, it is important to note that in a small percentage of cases, post-concussive symptoms may be prolonged (McCrory et al. 2013).

Frequently, in episodes of mild concussion ("bell ringers"), the athlete will be dazed or

stunned for a period of seconds only and continue playing. Alert medical and training staff should closely observe the actions of a player who has received a knock to the head for any signs of impaired performance.

Common symptoms of concussion include headache, nausea, dizziness and balance problems, blurred vision, memory loss, and a feeling of slowness or fatigue. A more complete list of symptoms is shown in the SCAT3 (Fig. 1). These symptoms are not specific to concussion and in some cases may present in a delayed fashion. Clinical features that are more specific to a diagnosis of concussion include loss of consciousness/impaired conscious state, concussive convulsions/impact seizures, confusion or attention deficit, memory disturbance (unaware of period, opposition, game score), and balance disturbance. These features however may not be present in all cases and in some cases may present in a delayed fashion.

The Pocket Concussion Recognition Tool (CRT) (Fig. 2) can be used by lay people (e.g., parents, coaches, trainers, etc.) on the sideline to screen for concussion, and once concussion is suspected, then the player is removed for medical assessment. The SCAT3 assessment tool (Fig. 1) is then used by a physician for the formal medical assessment. The SCAT3 is a more detailed medical assessment form that also incorporates additional cognitive questions and physical examination findings. This tool incorporates the Maddocks questions (Maddocks et al. 1995) and the SAC (McCrea 2001). Any abnormality on any component of this test would indicate a concussive injury. Generally, an uncomplicated concussion does not need routine neuroimaging. However, imaging has a role in the exclusion of suspected intracranial injury (Table 1).

Once concussion is diagnosed, then the player should be removed from the game or training and not return to play on that day. A variety of immediate motor phenomena (e.g., tonic posturing) or convulsive movements may accompany a concussion. Although dramatic, these are generally benign and require no specific management beyond the standard treatment of the underlying concussive injury. The principal concern of premature return to play of a concussed athlete is that due to the impaired cognitive function (e.g., slowed information processing, reduced attention), the athlete will sustain further injury (both concussive and other) when returning to a dangerous playing environment (Makdissi et al. 2009).

Furthermore, if a player recommences playing while symptomatic, post-concussive symptoms may be prolonged. This may also increase the chance of developing the "post-concussive syndrome," in which fatigue, difficulty in concentration, and headaches persist for some time, often months, following the original injury. This syndrome is uncommon in sports. These patients should undergo formal neuropsychological testing as well as an MRI brain scan. If these tests are normal, there is no specific treatment other than rest and reassurance. Following a concussive injury, players should be returned to play in a graduated fashion once clinical features have resolved and cognitive function returned to "baseline." When considering return to play, the athlete should be off all medications at the time of commencement of the rehabilitation phase or at the final medical clearance.

Most sports-related concussive injuries are uncomplicated and recover fully over 1–3 weeks. However, it is worth noting that detailed neuropsychological testing shows that 20 % of athletes will still have unrecognized cognitive deficits 10 days after concussion. For this reason, reliance on nonscientific nostrums ("miss a week") or symptoms alone to guide return to play is not recommended as best practice care. This fact highlights the important role of neuropsychological testing to inform clinical decision-making and as one of the cornerstones of management. In post-concussive athletes with persistent symptoms or cognitive deficits (>14 days), consideration of referral to a multidisciplinary concussion program may be worthwhile. At the end of the day, good clinical judgment should prevail over written guidelines.

One of the key problems to consider in this setting is mental health issues (such as depression, anxiety, and suicide) that have been reported as consequence of TBI including sports concussion. Neuroimaging studies using functional MRI

Pocket CONCUSSION RECOGNITION TOOL

To help identify concussion in children, youth and adults

RECOGNIZE & REMOVE

Concussion should be suspected **if one or more** of the following visible clues, signs, symptoms or errors in memory questions are present.

1. Visible clues of suspected concussion

Any one or more of the following visual clues can indicate a possible concussion:

Loss of consciousness or responsiveness
Lying motionless on ground/Slow to get up
Unsteady on feet / Balance problems or falling over/Incoordination
Grabbing/Clutching of head
Dazed, blank or vacant look
Confused/Not aware of plays or events

2. Signs and symptoms of suspected concussion

Presence of any one or more of the following signs & symptoms may suggest a concussion:

- Loss of consciousness
- Seizure or convulsion
- Balance problems
- Nausea or vomiting
- Drowsiness
- More emotional
- Irritability
- Sadness
- Fatigue or low energy
- Nervous or anxious
- "Don't feel right"
- Difficulty remembering
- Headache
- Dizziness
- Confusion
- Feeling slowed down
- "Pressure in head"
- Blurred vision
- Sensitivity to light
- Amnesia
- Feeling like "in a fog"
- Neck Pain
- Sensitivity to noise
- Difficulty concentrating

Fig. 2 (continued)

3. Memory function

Failure to answer any of these questions correctly may suggest a concussion.

"At what venue are we at today?"
"Which half is it now?"
"Who scored last in this game?"
"What team did you play last week/game?"
"Did your team win the last game?"

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, and should not be returned to activity until they are assessed medically. Athletes with a suspected concussion should not be left alone and should not drive a motor vehicle.

It is recommended that, in all cases of suspected concussion, the player is referred to a medical professional for diagnosis and guidance as well as return to play decisions, even if the symptoms resolve.

RED FLAGS

If ANY of the following are reported then the player should be safely and immediately removed from the field. If no qualified medical professional is available, consider transporting by ambulance for urgent medical assessment:

- Athlete complains of neck pain
- Increasing confusion or irritability
- Repeated vomiting
- Seizure or convulsion
- Weakness or tingling/burning in arms or legs
- Deteriorating conscious state
- Severe or increasing headache
- Unusual behaviour change
- Double vision

Remember:

- In all cases, the basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the player (other than required for airway support) unless trained to so do
- Do not remove helmet (if present) unless trained to do so.

from McCrory et. al, Consensus Statement on Concussion in Sport. Br J Sports Med 47 (5), 2013

Fig. 2 Concussion Recognition Tool (*CRT*)

suggest that chronic symptoms and depressed mood following concussion may reflect an underlying pathophysiological abnormality consistent with a limbic-frontal model of depression. All players with ongoing symptoms or a prolonged clinical course should be screened for depression using standard clinical tools, for example, Hospital Anxiety and Depression Scale, Beck Depression Inventory, etc. (Golden et al. 2007).

Return to Sports After Concussion

Return-to-play decisions remain difficult. Expert consensus guidelines recommend that players should not be returned to competition until they have recovered completely from their concussive injury. Currently, however, there is no single gold standard measure of brain disturbance and recovery following concussion. Instead, clinicians must rely on a number of indirect measures to form a clinical judgment. In practical terms, this involves a multifaceted clinical approach, which includes assessment of symptoms, physical signs (such as balance), and cognitive function.

The general management principle is that no return to play on the day of injury should be contemplated for a concussed athlete. It is not within the scope or expertise of a physiotherapist, trainer, or other nonmedical person to manage a concussive injury or determine the timing of return to play. A player should never return to play while symptomatic. "When in doubt, sit them out!"

The cornerstone of concussion management is physical and cognitive rest until the acute symptoms resolve and a graded program of exertion prior to medical clearance and return to play (see SCAT3 form; Fig. 1). Similarly, the use of alcohol, narcotic analgesics, anti-inflammatory medication, or sedatives can exacerbate symptoms following head trauma, delay recovery, or mask deterioration and should also be avoided. Specific advice should also be given on avoidance of activities that place the individual at risk of further injury (e.g., driving).

Following a concussive injury, players should be returned to play in a graduated fashion once clinical features have resolved and cognitive function returned to "baseline." When considering return to play, the athlete should be off all medications at the time of considering commencement of the rehabilitation phase (depending on the medical assessment) or must be off all medications at the final medical assessment and return to play. In every case, the decision regarding the timing of return to training should be made by a medical doctor with experience in concussive injuries. There is no mandatory period of time that a player must be withheld from play following a concussion. However, at the very minimum, a player must be symptom-free at rest and with exertion and determined to have returned to baseline level of cognitive performance. A stepwise Graduated Return to Play Protocol is recommended. This is outlined in the SCAT3 (Fig. 1).

Children younger than 15 years may report different symptoms, so age and developmentally appropriate evaluation is recommended. An additional consideration in assessing the child or adolescent athlete with a concussion is that in the clinical evaluation by the healthcare professional, there may be the need to include parent input as well as teacher and school input when appropriate. Children should not be returned to practice or play until clinically completely symptom-free, which may require a longer time frame than for adults. Moreover, children should "*return to school*" successfully before "*return to play*" is contemplated. In addition, the concept of "cognitive rest" is highlighted with special reference to a child's need to limit exertion with activities of daily living and to limit scholastic and other cognitive stressors (e.g., text messaging, videogames) while symptomatic. School attendance and activities may also need to be modified to avoid provocation of symptoms.

Screening computerized cognitive tests are strongly encouraged in the routine management of concussion in sports. Computerized tests provide a quick, valid, and reliable measure of cognitive recovery following a concussive injury. These include test platforms such as Axon CCST (www.axonsports.com), ImPACT (www.impacttest.com), Headminders (www.headminders.com), and a tool developed by the US military – Automated Neuropsychological Assessment Metrics (www.armymedicine.army.mil/prr/anam.html). Overall, it is important to

remember that neuropsychological testing is only one component of assessment and, therefore, should not be the sole basis of management decisions.

Preventing Reinjury

It has become a widely held belief that having sustained a concussive injury, one is then more prone to future concussive injury. The evidence for this contention is limited at best. It would seem obvious that in any collision or contact sports, the risk of concussion is directly proportional to the amount of time playing the sports. Therefore, the likelihood of repeat injury may simply reflect the level of exposure to injury risk. The association of an increased risk of subsequent concussions reported in players with a past history of concussion is thought to reflect a player's style of play where his risk of injury may be increased by utilizing dangerous game strategies and illegal tackling techniques (Benson et al. 2013).

When assessing an injured player, details regarding protective equipment employed at the time of injury should be sought. The benefit of this approach allows for modification and optimization of protective behavior and an opportunity for head injury education. There are relatively few methods by which brain injury may be minimized in sports. The brain is not an organ that can be conditioned to withstand injury. Thus, extrinsic mechanisms of injury prevention must be sought. There is no good clinical evidence that currently available protective equipment will prevent concussion although mouth-guards have a definite role in preventing dental and orofacial injury (Benson et al. 2009). Biomechanical studies have shown a reduction in impact forces to the brain with the use of head gear and helmets, but these findings have not been translated to show a reduction in concussion incidence in published randomized controlled trials (McIntosh et al. 2009). For skiing and snowboarding, there are a number of studies to suggest that helmets provide protection against head and facial injury and hence should be recommended for participants in alpine sports. In specific sports such as cycling, motor, and equestrian sports, protective helmets may prevent other forms of head injury (e.g., skull fracture) that are related to falling on hard road surfaces, and these may be an important injury preventive issue for those sports.

Neck muscle conditioning may be of value in reducing impact forces transmitted to the brain. Biomechanical concepts dictate that the energy from an impacting object is dispersed over the greater mass of an athlete if the head is held rigidly. Although attractive from a theoretical standpoint, there is little scientific evidence to demonstrate the effectiveness of such measures.

The major concern with the recommendation for helmet use in sports is the phenomenon known as "risk compensation," whereby helmeted athletes change their playing behavior in the misguided belief that the protective equipment will stop all injury. This is where the use of protective equipment results in behavioral change such as the adoption of more dangerous playing techniques, which can result in a paradoxical increase in injury rates. This may be a particular concern in child and adolescent athletes where head injury rates are often higher than in adult athletes.

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues, and those working with them as well as the general public is a mainstay of progress in this field. Athletes and their healthcare providers must be educated regarding the detection of concussion, its clinical features, assessment techniques, and principles of safe return to play. Methods to improve education including various web-based resources (e.g., www.concussionsafety.com), educational videos, outreach programs, concussion working groups, and the support and endorsement of enlightened sports groups must be pursued vigorously.

Other Specific Diagnoses

Diffuse Cerebral Swelling and Second-Impact Syndrome

Second-impact syndrome is frequently mentioned in the concussion literature but, surprisingly, has little scientific evidence for its existence. It is a term used to describe the potential catastrophic

consequences resulting from a second concussive blow to the head before an individual has fully recovered from the symptoms of a previous concussion (Cantu 1998). The second head injury is believed to result in loss of cerebrovascular autoregulation, which in turn leads to brain swelling secondary to increased cerebral blood flow. There is a lack of evidence to support the claim that the second impact is a risk factor for diffuse cerebral swelling. However, there is evidence that acute (and delayed) brain swelling may occur following a single blow to the head, in association with a structural injury such as a subdural hematoma and also in disorders of calcium channels, suggesting a possible genetic basis for some of these cases. Such events are virtually only seen in children and adolescents (McCrory et al. 2012). The diagnosis is usually made with an urgent CT brain scan or MRI. Clinical examination, for example, papilledema on fundoscopy and decerebrate posturing, may also provide a clue to the diagnosis. If cerebral swelling is suspected or noted on imaging studies, an urgent neurosurgical consultation is required. Mortality in this condition approaches 100 %.

Chronic Traumatic Encephalopathy

Tremendous media attention surrounding sports-related concussion has been directed toward the potential for long-term problems in athletes with high exposure to head contact (i.e., both concussive and sub-concussive impacts) during a career in contact sports. This attention has been fuelled by the publication of autopsy case studies of retired professional athletes and research reporting increased mortality rate due to neurodegenerative diseases in former professional athletes. There is also evidence from retrospective surveys supporting an association between long-term cognitive, psychiatric, and neurobehavioral problems and participation in sports. In this setting, there is limited neurophysiological and radiological evidence to suggest that persistent disturbance of brain function in the absence of overt pathological change may occur following concussive injury. In recent years, chronic traumatic encephalopathy (CTE) has been redefined from the original condition resembling Alzheimer's disease in professional boxers to a new condition observed in athletes, military personnel, and other non-sporting individuals that shares many features with known psychiatric disorders and other forms of dementia. Although the clinical phenotype is not yet clarified, CTE is characterized by distinct neuropathological findings. The strongly presented causal assumptions in the literature relating to concussive and sub-concussive brain impact exposure derived from the case studies are scientifically premature, especially given the absence of cross-sectional, epidemiological, prospective, or longitudinal studies on the topic. In addition to the limitations associated with verifying clinicopathological correlation, further research is required in order to better delineate this putative disease process.

Cranial Fracture: Skull Fracture

All types of athletic activity in which trauma to the head occurs have the potential to cause a cranial fracture. Cranial fractures can be divided into three broad categories: linear fractures, skull base fractures, and depressed fractures. Skull fractures can be further classified as open (associated with an overlying scalp laceration) or closed. Fractures that involve air sinuses or overlie venous sinuses in the skull require special consideration. A depressed fracture caused by a blow to the head from even a relatively small object may cause the bone fragments to impact or tear the dura mater or the brain. These fractures can be associated with brain contusions, CSF leaks, and seizures. Basal skull fractures involve the floor of the anterior and middle cranial fossas. These fractures may be associated with cranial nerve and vascular injuries.

Athletes with a cranial fracture usually have a headache and may or may not have symptoms of an underlying brain injury. The scalp should be carefully inspected and palpated to establish whether the skull fracture is open or closed. Rhinorrhea and otorrhea indicate that skull fracture is associated with torn dural membranes. The diagnosis is usually made with a plain skull radiographs or CT of the brain.

In all cases of a skull fracture, especially if a CSF leak is present, an urgent neurosurgical consultation is required. When a skull fracture is suspected, the patient should always be hospitalized for observation and neurosurgical evaluation. Linear fractures heal in a few months to a year, and if no additional injury occurs, the athlete can often return to sports activity. The grade of brain injury will usually determine the outcome. The prognosis is often good when the brain and its membranes are uninjured.

Acute Subdural Hematoma

Subdural hematomas are typically associated with rapid acceleration and deceleration impact forces that tear small bridging veins between the brain and dura. Extravasation of blood into the subdural space causes hematoma formation. In addition, subdural hematomas frequently are associated with underlying brain injury, for example, contusions. These injuries are typically seen following falls on hard surfaces or assaults with non-deformable objects rather than low-velocity injuries. They are also more common in elderly subjects and should be considered into those taking medications such as anticoagulants. Acute subdural hematomas are the most common traumatic mass lesions and occur in 30 % of severely head-injured patients.

The clinical signs and symptoms depend on the size and location of the subdural hematoma and how quickly it developed. In general, the more severe the head injury, the more likely the presence of an acute subdural hematoma. Impaired alertness and cognitive function are frequently found on initial examination. Enlargement of the hematoma or an increase in edema surrounding the hematoma produces additional mass effect, with further depression of the patient's level of consciousness, increases in motor or speech deficit, and eventually ipsilateral compression of the third nerve and midbrain (i.e., herniation). The diagnosis is usually made with an MR or CT scan of the brain. A patient with a subdural hematoma requires urgent neurosurgical consultation and often surgical evacuation of the hematoma. Acute subdural hematoma is usually associated with underlying injury to the cerebral parenchyma and consequently the prognosis is poor.

Extradural Hematoma

Extradural hematomas are found in 10 % of comatose TBI patients. They generally result from head impact in the temporal region that deforms or fractures the skull. The adherent dura is forcefully detached and hemorrhage occurs, arterial (the middle meningeal artery), venous, or both sources. Injury to the brain under an extradural hematoma is rare. Extradural hematomas may have a varied clinical presentation that depends on the size and site of the hematoma, the rate of expansion, and the presence of associated intradural pathology. On brain CT scan, acute extradural hematomas are classically hyperdense and lenticular or biconvex in shape. Urgent neurosurgical consultation is required when an extradural hematoma is suspected. Rapid diagnosis and prompt surgical evacuation through a craniotomy are indicated when there are neurological findings and depressed consciousness. When rapidly treated, the chances of a full functional recovery are excellent even in patients with profoundly abnormal neurological findings before surgery.

Traumatic Intracerebral Hematoma/ Contusion

Intracerebral hematomas and contusions are bleeding within the brain that appears as mass lesions. Acute traumatic intracerebral hematomas occur at the time of the initial head injury, but in some cases, the bleeding may develop in the hours or days after initial injury. Intracerebral hematomas are more likely in more severe TBI, but the clinical signs and symptoms depend on the size and location of the intracerebral hematoma as well as the rapidity of its development. In many cases, there is a period of confusion or loss of consciousness, but only one-third of the patients remain lucid throughout their course. Focal findings are

frequent and depend on lesion location. The diagnosis is usually made with an MRI or CT of the brain. When this condition is suspected or diagnosed on imaging studies, an urgent neurosurgical consultation is required. Overall, mortality after traumatic intracerebral hematoma from all causes is about 30 %.

Traumatic Subarachnoid Hemorrhage

Subarachnoid hemorrhage often is found following severe or moderate head injury. Traumatic subarachnoid hemorrhage may occur in isolation but often occurs with other intracranial pathology. In addition, traumatic subarachnoid hemorrhage may result from blood vessel injury, for example, a vertebral artery dissection. Subarachnoid hemorrhage typically presents with meningeal symptoms such as headache, neck stiffness, and photophobia. When traumatic subarachnoid hemorrhage is suspected or diagnosed using imaging studies, an urgent neurosurgical consultation is required. Vascular imaging may be necessary to exclude a vascular injury particularly when there is penetrating injury or suspected vessel dissection that involves either the carotid or vertebral arteries. There is no specific treatment of traumatic subarachnoid hemorrhage although there is some suggestion that calcium channel antagonists may be useful in some patients. Subarachnoid hemorrhage is associated with the development of vasospasm (delayed narrowing of cerebral vessels) that can contribute to delayed cerebral ischemia. These patients therefore require very careful fluid management. In addition, hydrocephalus may occur and require ventricular drainage or a shunt. The presence of traumatic subarachnoid hemorrhage is a factor associated with poor outcome after TBI.

Return to Sports Following Catastrophic or Severe Head Injury

Return to sports following a severe of potentially life-threatening brain injury is controversial, and a few guidelines exist for the clinician to follow (Davis et al. 2009, 2010 Table 2). There are some situations where the athlete could place himself at an unacceptably high risk of sustaining further injury and hence should be counseled against participation in collision sports. In such situations, common sense should prevail.

Table 2 Conditions contraindicating return to contact sport

Persistent post-concussional or post-injury symptoms	Hydrocephalus with or without shunting
Permanent neurological sequelae – hemiplegia, visual deficit, dementia, or cognitive impairment	Spontaneous subarachnoid hemorrhage from any cause
Symptomatic neurological or pain producing abnormalities about the foramen magnum	Craniotomy for evacuation of intracerebral or subdural hematoma

Although sports physicians should keep an open mind when assessing neurological recovery from severe brain injuries, nevertheless, it is recommended that at least 12 months pass before such a decision is contemplated. Thoughtful deliberation and analysis of all the available medical evidence should occur when making such a decision. It is also recommended that the counsel of a neurologist or neurosurgeon experienced in sporting head injury management besought. This is an important point because a number of individuals who suffer a TBI may be left with a lack of insight and impaired judgment over and above their other neurological injuries. This in turn may make such an individual unreliable in gauging recovery. The assessment of cognitive performance and/or clinical symptoms when fatigued is often useful. The use of neuropsychological assessment as well as information from family and friends may assist the clinician in his deliberation.

Return to collision sports is relatively contraindicated in almost any situation where surgical craniotomy has been performed. In such situations, the subarachnoid space is traumatized, thus setting up scarring of the pia-arachnoid of the brain to the dura with both loss of the normal cushioning effect of the CSF and vascular adhesions that may subsequently bleed if torn during head impact. Even if neurological recovery is complete, a craniotomy for anything other than an extradural hematoma effectively precludes

return to collision sports. With an extradural hematoma without brain injury or other condition where surgery is not required, return to sports may be contemplated in selected cases as per the discussion in the preceding text after a minimum of 12 months assuming neurological recovery is complete.

Conclusion

Management of head injury in sports is a critical aspect of sports medicine care. The use of internationally accepted assessment tools for the assessment and management of concussion is critical. For more severe injury, while neurosurgical management is often required, the sports physician should have an understanding of the principles of management.

References

Benson BW, Hamilton GM, Meeuwisse WH, McCrory P, Dvorak J (2009) Is protective equipment useful in preventing concussion? A systematic review of the literature. Br J Sports Med 43(Suppl 1):i56–i67

Benson BW, McIntosh AS, Maddocks D, Herring SA, Raftery M, Dvorak J (2013) What are the most effective risk-reduction strategies in sport concussion? Br J Sports Med 47(5):321–326

Cantu RC (1998) Second-impact syndrome. Clin Sports Med 17(1):37–44

Davis G, Marion DWD, Roux PL, Laws ER, McCrory P (2010) Clinics in neurology and neurosurgery – extradural and subdural haematoma. Br J Sports Med 44:1139–1143

Davis G, Marion D, George B, Hamel O, Turner M, McCrory P (2009) Clinics in neurology and neurosurgery of sport: traumatic cerebral contusion. Br J Sports Med 43(6):451–454

Giza CC, Hovda DA (2001) The neurometabolic cascade of concussion. J Athl Train 36(3):228–235

Golden J, Conroy RM, O'Dwyer AM (2007). Reliability and validity of the hospital anxiety and depression scale and the Beck Depression Inventory (full and FastScreen scales) in detecting depression in persons with hepatitis C. J Affect Disord 100(13):265–269

Jennett B, Bond M (1975) Assessment of outcome after severe brain damage: a practical scale. Lancet 1:480–484

Langlois JA, Rutland-Brown W, Wald MM (2006) The epidemiology and impact of traumatic brain injury: a brief overview. J Head Trauma Rehabil 21(5):375–378

Maddocks DL, Dicker GD, Saling MM (1995) The assessment of orientation following concussion in athletes. Clin J Sport Med 5(1):32–35

Makdissi M, McCrory P, Ugoni A, Darby D, Brukner P (2009) A prospective study of postconcussive outcomes after return to play in Australian football. Am J Sports Med 37(5):877–883

McCrea M (2001) Standardized mental status testing on the sideline after sport-related concussion. J Athl Train 36(3):274–279

McCrory P, Davis G, Makdissi M (2012) Second impact syndrome or cerebral swelling after sporting head injury. Curr Sports Med Rep 11(1):21–33

McCrory P, Meeuwisse WH, Aubry M, Cantu B, Dvorak J, Echemendia RJ, Engebretsen L, Johnston K, Kutcher JS, Raftery M, Sills A, Benson BW, Davis GA, Ellenbogen RG, Guskiewicz K, Herring SA, Iverson GL, Jordan BD, Kissick J, McCrea M, McIntosh AS, Maddocks D, Makdissi M, Purcell L, Putukian M, Schneider K, Tator CH, Turner M (2013) Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, November 2012. Br J Sports Med 47(5):250–258

McIntosh AS, McCrory P, Finch CF, Best JP, Chalmers DJ, Wolfe R (2009) Does padded headgear prevent head injury in rugby union football? Med Sci Sports Exerc 41(2):306–313

Stiell I, Clement C, Rowe B, Schull M, Brison R, Cass D, Eisenhauer M, McKnight R, Bandiera G, Holroyd B, Lee J, Dreyer J, Worthington J, Reardon M, Greenberg G, Lesiuk H, MacPhail I, Wells G (2005) Comparison of the Canadian CT head rule and the New Orleans criteria in patients with minor head injury. JAMA 294(12):1511–1518