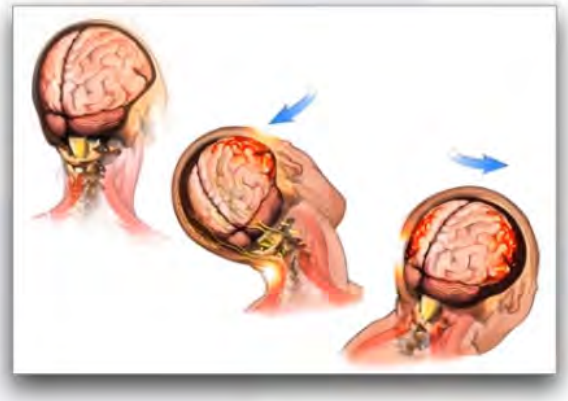
Biomechanics of Concussion

(Meaney et al, 2011)

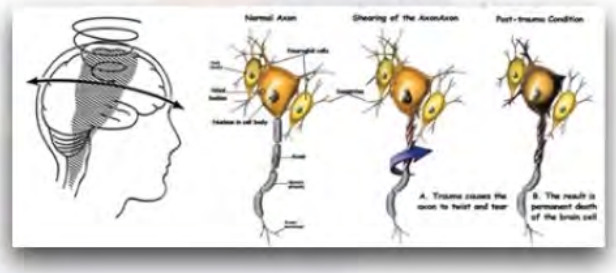
- Many different head motions can occur from a concussion. This complex variety of responses makes each concussion unique.
- Two broad categories of forces, contact and inertial forces, occur during concussions.
- The primary cause of concussive injuries is the inertial/ acceleration loading experienced by the brain at the moment of impact.
- Linear and rotational acceleration occur with every concussion.
- Brain tissue deforms more readily in response to shear forces compared to other biological tissue.
- Rapid head rotations generate shear forces throughout the brain causing tissue damage.
- **If the head motion is constrained to exclude any rotational motion, it is difficult to produce traumatic unconsciousness.**
- In comparison, **introducing or allowing a rotational component after impact substantially increases the likelihood of an unconscious episode.**



Neuropathology and Neurobiology of Traumatic Brain Injury

(Blennow et al, 2012)

- There are two main categories of brain damage due to trauma: **focal damage and diffuse injury.**
- **Focal injury includes cortical or subcortical contusions and lacerations, as well as intracranial bleedings** (subarachnoid hemorrhage and subdural hematoma).
- **Focal injury is due to severe direct impact on the brain** and is thus mainly seen in severe cases of TBI.
- **Diffuse injury is caused by stretching and tearing of the brain tissue and does not need any skull fracture or direct impact or crush injury to the brain surface and is therefore also seen in cases with mild TBI.**
- The main form of diffuse injury is called diffuse axonal injury (DAI), which is due to acceleration/ deceleration forces that lead to shearing of axons.



Injury of the CRP in mTBI

(Lee et al, 2015)

- The corticoreticulospinal tract consists of the corticoreticular pathway (CRP) and reticulospinal tract
- The CRP originates primarily from the premotor cortex (PMC) and terminates at the pontomedullary reticular formation
- The CRP is involved in control of muscles of extremities and axial muscles
- **Injury of the CRP was demonstrated** in patients who showed proximal weakness **following mTBI**
- This result **indicates the importance of CRP evaluation** to elucidate the cause of proximal weakness in patients with mTBI.

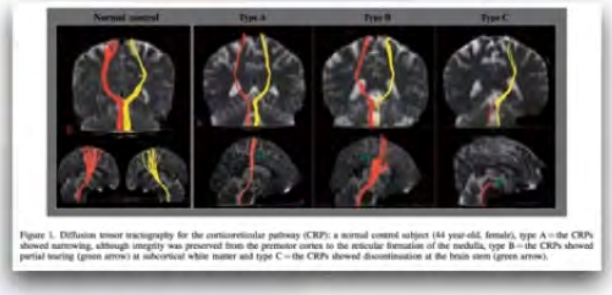
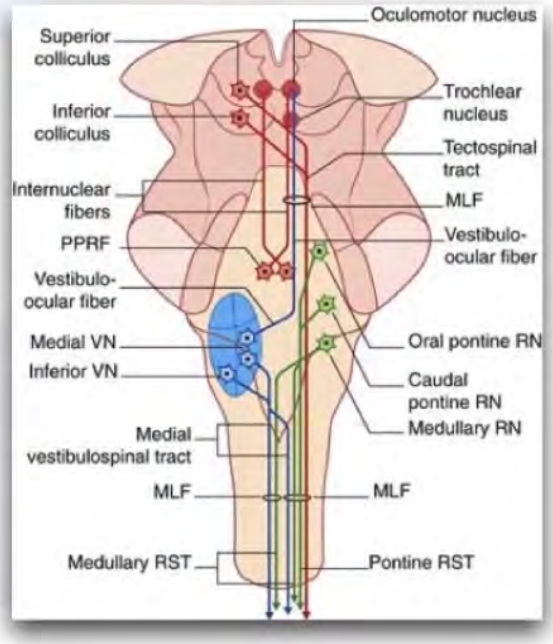
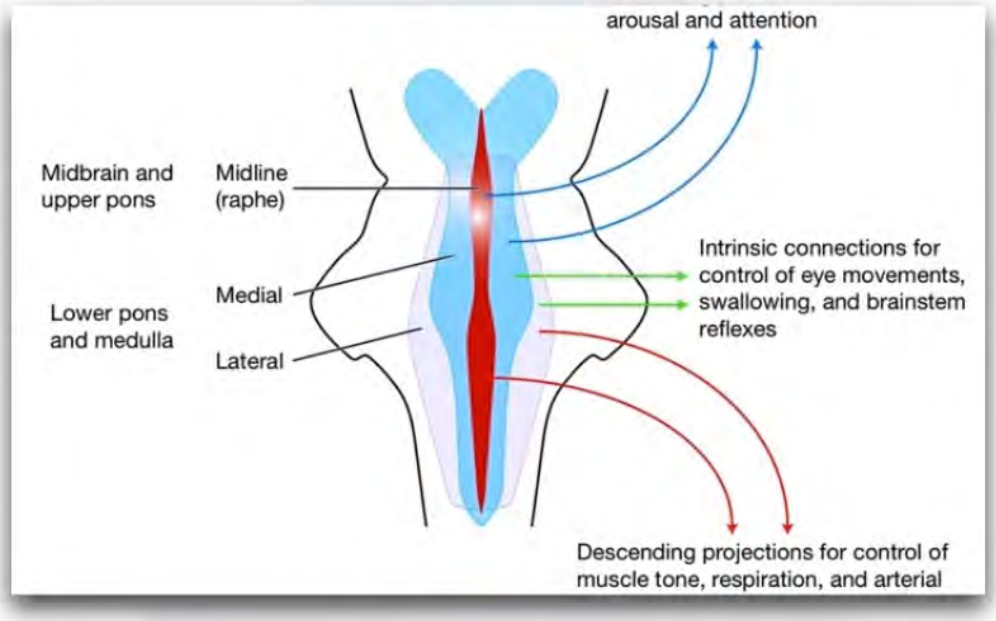


Figure 1. Diffusion tensor tractography for the corticoreticular pathway (CRP): a normal control subject (44 year-old, female), type A = the CRPs showed narrowing, although integrity was preserved from the premotor cortex to the reticular formation of the medulla, type B = the CRPs showed partial tearing (green arrow) at subcortical white matter and type C = the CRPs showed discontinuation at the brain stem (green arrow).

Reticular Formation

- **Somatic motor control** via reticulospinal tracts of the spinal cord
  - Tone, balance, and posture—especially during body movements.
- **Eye and ear signals to the cerebellum** so that the cerebellum can integrate visual, auditory, and vestibular stimuli in motor coordination.
- **Other motor nuclei include gaze centers**, which enable the eyes to track and fixate objects
- **Cardiovascular control**
  - cardiac and vasomotor centers of the medulla oblongata.
- **Pain modulation**
  - the origin of the descending analgesic pathways.
- **Other functions**, but not limited to:
  - Sleep and consciousness
  - Habituation





Keep the neuroscience in mind when you are assessing sport related concussion, and importantly, when prescribing rehabilitation strategies.

11 'R's of SRC Management

(McCrory et al, 2017)

The Concussion in Sport Group's (CISG) **11 'R's of SRC management** to provide a logical flow of clinical concussion management.

1. Recognise
2. Remove
3. Re-evaluate
4. Rest
5. Rehabilitation
6. Refer
7. Recover
8. Return to sport
9. Reconsider
10. Residual effects and sequelae
11. Risk reduction.

Re-evaluate

(McCrory et al, 2017)

- An athlete with SRC may be evaluated in a doctor's office as a point of first contact after injury or may have been referred from another care provider.
- Key features of follow-up examination should encompass:
    A. A medical assessment including a **comprehensive history and detailed neurological examination** including a thorough **assessment of mental status, cognitive functioning, sleep/wake disturbance, ocular function, vestibular function, gait and balance**.
    B. **Determination of the clinical status of the patient**, including whether there has been **improvement or deterioration since the time of injury**. This may involve seeking additional information from parents, coaches, teammates and eyewitnesses to the injury.
    C. **Determination of the need for emergent neuroimaging** to exclude a more severe brain injury (eg, structural abnormality).

Neuropsychological Assessment

(McCrory et al, 2017)

- Previously described as a 'cornerstone' of SRC management.
- Neuropsychological assessment (NP) **should not be the sole basis of management decisions.**
    - Provides an aid to the clinical decision-making process in conjunction with a range of assessments of different clinical domains and investigational results.
- All athletes should have a clinical neurological assessment (including evaluation of **mental status/cognition, oculomotor function, gross sensorimotor, coordination, gait, vestibular function and balance**) as part of their overall management.
    - This will normally be performed by the treating physician, often in conjunction with computerised NP screening tools.

Clinical Assessment

Vestibular/Ocular Motor Screening (VOMS) for Concussion

(Mucha et al, 2014)

- **Baseline Symptoms** rated on a scale of **0 (none) - 10 (severe)**
  - Headache, Dizziness, Nausea, Fogginess
- **Smooth Pursuits**
  - Horizontal and Vertical
- **Saccades**
  - Horizontal and Vertical
- **Near-Point Convergence**
- **VOR**
  - Horizontal and Vertical
- **Visual Motion Sensitivity Test**

VOMS for Concussion

(Mucha et al, 2014)

Vestibular/Ocular Motor Test:	Not Tested	Headache 0-10	Dizziness 0-10	Nausea 0-10	Fogginess 0-10	Comments
BASELINE SYMPTOMS:	N/A					
Smooth Pursuits						
Saccades – Horizontal						
Saccades – Vertical						
Convergence (Near Point)						**(Near Point in cm):** Measure 1: _____ Measure 2: _____ Measure 3: _____
VOR – Horizontal						
VOR – Vertical						
Visual Motion Sensitivity Test						

- **Record:** Headache, Dizziness, Nausea and Fogginess on 0-10 scale **prior to screening**
- **Record:** Headache, Dizziness, Nausea and Fogginess ratings **after each test**

VOMS - Smooth Pursuits

(Mucha et al, 2014)

- Patient is instructed to maintain focus on a target (3 ft. from patient) as the examiner moves the target smoothly in the horizontal direction 1.5 ft. to the right and left of midline.
  - Target moved at a rate of ~2 seconds from one-side-to-the-other
- Perform 2 repetitions
- Repeat the test in a vertical direction
  - **Record:**
    - Headache, Dizziness, Nausea & Fogginess ratings after the test
  - **Observe for:**
    - Saccadic eye movements; Evidence of a cranial nerve deficit. (Ellis et al, 2015)

VOMS - Saccades

(Mucha et al, 2014)

- The examiner holds two single targets (fingertips) *horizontally* at a distance of 3 ft. from the patient, and 1.5 ft. to the right and 1.5 ft. to the left of midline
- Instruct the patient to move their eyes as quickly as possible from target to target
- Perform 10 repetitions
- Repeat for *Vertical Saccades*
  - **Record:**
    - Headache, Dizziness, Nausea & Fogginess ratings after each test
  - **Observe for:**
    - Overshooting; > 2 saccadic corrections; Gross dysconjugate eye movements (Ellis et al, 2015)

VOMS - Near Point Convergence

(Mucha et al, 2014)

- The patient focuses on a small target at arm's length and slowly brings it toward the tip of their nose.
- The patient is instructed to stop moving the target when they see two distinct images or when the examiner observes an outward deviation of one eye.
  - Blurring of the image is ignored.
- Measure distance in cm. between target and the tip of nose
  - Repeat and record 3 times
  - **Record:**
    - Headache, Dizziness, Nausea & Fogginess ratings after the test
  - **Observe for:**
    - Inability of the eyes to converge; convergence >6cm. (Ellis et al, 2015)

VOMS - VOR

(Mucha et al, 2014)

- Examiner holds a target in front of the patient in midline at a distance of 3 ft.
- The patient is asked to rotate their head *horizontally* while maintaining focus on the target.
    - The head is moved at an amplitude of 20° to each side and a metronome 180 bpm to ensure the speed of rotation (one beat in each direction).
- Perform 10 repetitions
- Repeat for *Vertical VOR*
    - **Record:**
        - Headache, Dizziness, Nausea & Fogginess ratings after the test
    - **Observe for:**
        - Ability to maintain gaze stability (Casa Della et al, 2014)

VOMS - Visual Motion Sensitivity

(Mucha et al, 2014)

- The patient stands with feet shoulder width apart (facing a busy area of the clinic) with their arm outstretched and focusing on their thumb.
- Maintaining focus on their thumb, the patient rotates - together as a unit - their head, eyes and trunk at an amplitude of 80° to the right and left.
- A metronome 50 bpm to ensure the speed of rotation (one beat in each direction).
- Perform 5 repetitions
    - **Record:**
        - Headache, Dizziness, Nausea & Fogginess ratings after the test

VOMS for Concussion

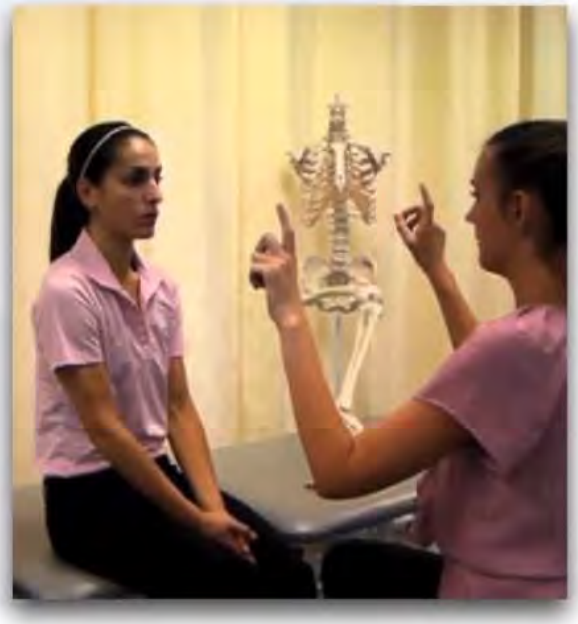
(Mucha et al, 2014)

- VOMS is designed for use in patients aged 9-40.
  - When used with patients outside this age range, interpretation may vary.
- Abnormal findings or provocation of symptoms with any test may indicate dysfunction
  - …and should trigger a **referral to the appropriate health care professional for more detailed assessment and management.**

Antisaccade Test

(Balaban et al, 2016)

- **Computer 'Bedside' Test** (Hellmuth et al, 2012)
  - Subjects are seated with their eyes ~80 cm in front of a 15 inch laptop screen.
  - The examiner is seated behind the computer and watches the subject's eyes for the direction of the first saccade
  - The examiner scores the direction of each saccade on a standardized scoring sheet
- **Bedside Test** (Khan et al, 2016)
  - Examiner sits at arm's length from patient with eyes at the same level
  - Examiner snaps fingers in either hand randomly and the patient is required to look to the opposite hand.
  - Any eye movement ipsilateral to the snap (prosaccade) was considered an error.
  - Two sets of 10 finger snaps were administered and errors averaged.



Head Impulse (Halmagyi) Test

(Balaban et al, 2016; Hides et al, 2017; Sealy, 2014; Jorns-Haderli et al, 2007; Brandt et al, 2005)

- Position yourself in front of the patient and instruct the patient to look at your nose.
- Grasp the patient's head and bring the head into 30° flexion
- Rotate the patient's head slowly left and right ensuring cervical muscles are relaxed and gaze remains fixed on the tester's nose during slow rotations.
- Suddenly rotate the patient's head ~10 degrees from mid-line while watching the patient's eyes.
    - Rightward rotation tests the right vestibular response.
    - Leftward rotation tests the left vestibular response.
- **Abnormal:**
    - Loss of fixation

"…This work has allowed us to identify some oculomotor, vestibular and reaction time (OVRT) characteristics of mTBI and to show that a small subset of this panel can be utilized to achieve high specificity and sensitivity for the current diagnosis of mTBI. This objective OVRT pattern can then be utilized to help confirm diagnosis…"

– Balaban et al, 2016

Clinical Assessment

Summary

- **Mental Status/Cognition**
  - SCAT5, STMS, 3MS, PHQ-9
- **Autonomic Dysregulation**
  - Orthostatic Vital Signs
  - Tilt Table Test
  - Graded Exercise Test
- **Vestibulo-Ocular**
  - Gaze holding
  - HIT (Halmagyi)
  - Smooth Pursuits
  - Accomodation/Convergence
  - Saccades
  - Antisaccades
  - Dynamic Visual Acuity
- **Balance/Coordination**
  - Postural Stability (SET, BTrackS)
  - Tandem Gait
- **Cervical Sensorimotor**
  - Cranio-Cervical Flexion Test
  - Modified Cervical Joint Position Sense
  - Smooth Pursuit Neck Torsion