Comprehending concussion: evolving and expanding our clinical insight

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Concussion in sport has been defined as a "*complex pathophysiological process affecting the brain, induced by biomechanical factors*".(1) The condition is characterised by "*a graded set of clinical symptoms that may or may not involve loss of consciousness*".(1)

Casting the net wide

The current consensus definition provides a broad clinico-pathological description of concussion. It encompasses the wide range of clinical presentations that result from traumatic forces transmitted to the brain. In its most literal interpretation, *any* post-traumatic symptom or sign fits the definition of concussion.(2) Consequently, the current definition has high sensitivity, but lacks specificity. This issue has been highlighted in recent papers.(3)

The purpose of "casting a large net" is to capture all possible concussions and manage these injuries conservatively. This position is driven by a lack of reliable and specific diagnostic markers and concerns related to potential complications associated with concussion. Compounding this, risk factors for complications remain unclear and currently there are few prognostic factors to accurately predict outcome following concussion.(4)

Athletes don't like sitting out

From the athletes' perspective, a significant downside to the broad definition of concussion is the major time loss implication as the player is withheld until fully recovered. This may adversely affect compliance and the willingness to report symptoms. In others, it may heighten anxiety regarding risks of potential long-term adverse outcomes (such as mental and cognitive health issues), particularly on retirement from sport.

Does pathophysiology determine outcome?

At present, it is unclear as to why some athletes go on to develop problems following concussion and others don't. It is likely that there is a range of intrinsic and extrinsic risk factors, beyond the trauma itself.

As we continue to advance our thinking, it is important to take a broader view of concussion and try to understand the pathophysiological mechanisms that underlie various clinical presentations. This may help us identify different subtypes of concussion and/or provide important prognostic information to help identify injuries associated with a higher risk of complications.

Studies using animal models of head trauma have provided an insight into the potential pathophysiological mechanisms of concussion. Some of the changes identified include alterations in neurotransmission, ionic shifts, metabolic changes, alterations in blood flow and vascular reactivity, as well as microstructural damage.(5) Results from human studies using advanced

neuroimaging techniques such as magnetic resonance spectroscopy and diffusion tensor imaging, demonstrate similar changes following concussion.(6)

It is possible that varying pathophysiological mechanisms underpin different clinical presentations, and result in diverse clinical courses. We need to move from simply thinking of concussion as a single diagnostic entity, to trying to differentiate the injury based on presentation, clinical course and possible underlying pathophysiological mechanisms. Ideally, we would also like to be able to differentiate clinical features that may be attributable to other causes, such as injury to the cervical spine, vestibular dysfunction, post-traumatic migraine, etc.

Current clinical inadequacies

The problem with current assessment tools (such as the SCAT3) is that they rely heavily on assessment in a limited number of domains. Currently this assessment is biased towards commonly reported symptoms (in somatic, cognitive and psychological or behavioural/emotional domains), balance disturbance and changes in cognitive function (e.g. confusion, memory disturbance). More recently, there has been an increased emphasis on broadening the assessment, for example to include tests of vestibular function, visual pathways, etc.(7) There is also ongoing interest in new technologies such as biomarkers, impact sensors, quantitative EEG, etc to facilitate a diagnosis of concussion.(8) In time, these technologies may also facilitate a greater understanding of the underlying pathophysiology of different concussion

presentations. A risk, however, is that they further increase the sensitivity of the process, "widening the net" even further.

A role for transcranial Doppler ultrasound?

The recent systematic review by Gardner et al, investigates the use of transcranial Doppler ultrasound in the assessment and monitoring of cerebral blood flow following concussion in sport.(ref) Although, only 3 studies on a small number of athletes were included in the analysis, the results draw attention to the potential role of autonomic changes in the development and maintenance of post-traumatic symptoms.

Physiological stress, such as exercise, has long been recognised to exacerbate symptoms following concussion. The pathophysiological mechanism underlying this phenomenon remains unclear. It is possible that altered vascular reactivity may be a contributing factor. It is also possible that vascular changes may account for the persistence of symptoms in some cases, as is the case with conditions such as migraines. There is also a theory that disordered vascular autoregulation is the mechanism for acute cerebral oedema observed in rare cases following concussion in children and adolescents. Hence vascular reactivity may be important in terms of acute assessment and determination of recovery from injury, or identification of a subgroup of concussions that may be at higher risk in the short term and may be at risk of prolonged symptoms.

Trans-cranial Doppler ultrasound may prove to be another technology that facilitates assessment and further understanding of post-concussion symptoms.

More tools at our disposal

Continuing to improve the scope of the assessment will potentially help identify different "subtypes" of injury, which demand different management protocols. Moreover, it will help identify factors that may be contributing to prolonged symptoms in some patients. The long-term aim is to be able to provide accurate diagnosis and prognosis to patients who suffer from concussion. This will facilitate appropriate management and provide opportunities for more targeted interventions.

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