Neuroimaging of Concussion

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KEYWORDS

• Concussion • mTBI • Magnetic resonance imaging • Diffusion tensor imaging
• Functional MRI • Spectroscopy

KEY POINTS

- There is a strong need to develop objective measures to ensure accurate and timely diagnosis of concussion and mild traumatic brain injury (mTBI) and to guide subsequent management decisions. Neuroimaging is likely to play an important role in this process.
- Despite the superior soft tissue contrast available by MRI, computed tomography (CT) remains the first-line imaging modality of choice in the acute setting due to its speed, ubiquitous availability, lower cost, and infrequent contraindications precluding the need for screening procedures.
- Although microstructural sequelae of concussion/mTBI are mostly below the threshold for standard CT and conventional MRI techniques, advanced MRI techniques (diffusion tensor imaging, functional MRI, perfusion, spectroscopy) and PET provide insight into these injuries.

INTRODUCTION

The phenomenon of concussion has received increasing attention in recent years primarily due to increased awareness of sports-related concussion (SRC) in adolescent and professional athletes, and in military personnel. The incidence of SRC is estimated at 1.6 to 3.8 million annually,[1] and during the wars in Iraq and Afghanistan, up to 25,000 mild traumatic brain injuries (mTBIs) were reported each year in the US Armed forces.[2] It is estimated that direct medical costs and indirect costs, such as lost productivity related to concussion and mTBI, total $12 billion per year in the United States alone.[3] This increased attention and the substantial societal costs have led to the recent publication of new or updated practice guidelines and position statements from multiple medical and professional societies addressing the prevention,

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diagnosis, and management of concussion.[4–8] The variations in these guidelines make clear that there is still a need to develop objective measures to ensure accurate and timely diagnosis of concussion and to guide subsequent management decisions. Neuroimaging is likely to play an important role in this process.

Concussion and mTBI labels are often used interchangeably; however, they should be considered distinct entities, at least for now.[6,9,10] According to the 4th International Conference on Concussion in Sport, concussion is defined as the syndrome resulting from low-velocity injuries to the head that result in clinical symptoms but do not demonstrate visible structural abnormalities on conventional neuroimaging studies.[6] Symptoms, which include headaches, dizziness, blurry vision, and difficulty concentrating typically, demonstrate rapid onset and are relatively short lived. mTBI is characterized by greater clinical symptoms and demonstrates some evidence of structural injury on conventional neuroimaging studies, but without the degree and duration of symptoms that would qualify as moderate TBI. Thus, concussion and mTBI occupy adjacent positions on the spectrum of TBI, with similar and overlapping clinical symptoms and distinguished by the presence or absence of findings on conventional neuroimaging. How long this differentiation will last is uncertain as more sensitive MRI techniques and higher magnet field strengths become available for clinical use, allowing for the detection of subtle injuries not visible with older techniques.[11,12] As such, in this review we discuss the literature regarding both concussion and mTBI.

When athletes or military personnel experience concussive symptoms, there are 2 major questions that need to be answered acutely. The question of most immediate importance is whether there is an associated structural abnormality, such as intracranial hemorrhage or fracture, which may need immediate intervention. These are typically detected by computed tomography (CT). The second major question to be addressed is what is the appropriate time to return to play or return to active duty. This decision is not trivial given that were a new head injury to occur before the symptoms of the previous injury have resolved, there is increased risk of severe brain injury and potentially death, even in the setting of a relatively mild trauma. This is known as "second impact syndrome."[13] Currently, the decision to return to the field is guided by symptoms and various sideline assessment tools,[14] but there is potential for neuroimaging techniques to help guide these decisions, both acutely and in the long term.

In this review, we focus on the role for neuroimaging in the concussed patient and describe the recommended practices related to imaging in concussion. This discussion first focuses on the exclusion of severe injuries and is followed by a discussion of the potential utility of various advanced imaging techniques in research and clinical practice.

DECIDING WHEN/IF TO IMAGE THE CONCUSSED PATIENT

Consensus recommendations from the 4th International Conference on Concussion in Sport, the American Medical Society for Sports Medicine, the American Academy of Neurology Concussion Guidelines, and the American College of Emergency Medicine/Centers for Disease Control and Prevention joint practice guidelines recommend that head CT be performed for individuals with more than 30 seconds of loss of consciousness, prolonged altered mental status, severe headache, focal neurologic deficits, or seizure.[4–6,15] There is, however, substantial overlap in the clinical symptoms of patients both with and without radiologically evident acute traumatic injuries on CT, and patients may be found to have acute intracranial findings on head CT in the setting of an unimpressive examination.[16] An additional consideration is the radiation dose from imaging. Most relevant is the stochastic effect, which is the likelihood of radiation