Conventional Computed Tomography and Magnetic Resonance in Brain Concussion

Juan Nicolas Useche, MD*, Sonia Bermudez, MD

KEYWORDS

• Head injury, closed • Craniocerebral trauma • Brain injuries, traumatic • Contrecoup injury • Brain concussion • Brain contusion • Multidetector computed tomography • Magnetic resonance imaging

KEY POINTS

- Brain concussion is responsible for approximately 2.5 million emergency department visits, hospitalizations, and deaths in the United States, accounting for $76.5 billion in health care–related costs in 2010.
- Computed tomography (CT) is the preferred imaging modality for the initial assessment of acute mild traumatic brain injury (mTBI), for repeat evaluation in the presence of neurologic deterioration, and for cautious use in pediatric patients.
- Magnetic resonance (MR) imaging is mostly used in patients with acute mTBI with persistent neurologic findings despite normal initial CT and in the subacute and chronic settings.
- The use of standardized clinical criteria to identify patients who can safely forego unnecessary CT studies has greatly reduced radiation exposure and health care–related costs.
- Advanced MR imaging techniques enable the identification of subtle brain lesions that are not visualized on conventional neuroimaging; however, their routine clinical use is still an area of intense research.

INTRODUCTION

There is a renewed global interest in concussion, not only because the causes and effects are not completely understood but also because of its increased incidence. In 2010, the US Centers for Disease Control and Prevention (CDC) estimated that traumatic brain injuries (TBIs) accounted for approximately 2.5 million emergency department (ED) visits, hospitalizations, and deaths in the United States, either as an isolated injury or in combination with other injuries.[1] The incidence of TBI may be underestimated, especially mild TBI (mTBI), for 2 main reasons: first, patients may too easily dismiss their symptoms, and, second, they may believe that their work situation could be compromised (eg, military personnel and athletes).[2,3]

TBI can have cognitive, behavioral, emotional, and physical effects on a person's quality of life. Estimates based on data from 2 states in the United States indicated that 3.2 million to 5.3 million people live with a TBI-related disability.[4] In addition, the economic impact is significant; it was estimated to be $76.5 billion in 2010.[5]

Diagnostic and Interventional Imaging Department, El Bosque University, Hospital Universitario Fundacion Santa Fe de Bogota, Calle 119 # 7 – 75, Bogota DC 110111, Colombia
* Corresponding author.
E-mail address: nicolas.useche@radiologiafsfb.org

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However, this interest is far from new. Theodore Roosevelt in 1905 was the first president of the United States to convene a White House Conference on concussion in sports, after the American college football season of 1905 left 18 dead and 159 seriously injured.[6] The US government authorized research and public health activities related to TBI with the Traumatic Brain Injury Act of 2008, and, in May 2014, President Barack Obama said, during the White House Conference on Sports Concussions, "Let's keep encouraging our kids to get out there and play sports that they love, and doing it the right way. That's not a job just for parents, but it's a job for all of us."[1,7]

Radiologists and neuroradiologists should also be part of the team, not only through involvement in patient evaluations but also by fostering awareness as parents of young athletes.

CONCUSSION VERSUS MILD TRAUMATIC BRAIN INJURY

TBI has traditionally been classified according to severity. The standardized clinical scale most widely used is the Glasgow Coma Scale (GCS), since its creation in 1974 by Teasdale and Jennet.[8] Classically, an mTBI has been defined as a GCS score of 13 to 15, a moderate TBI is one with a GCS score of 9 to 12, and a severe TBI is indicated by a GCS score of 3 to 8.[9] Some investigators have stated that a GCS score of 13 should not be considered an mTBI, including the American College of Emergency Physicians and the CDC.[10,11] Others require normal noncontrast head computed tomography (NCCT) results or the presence of clinical conditions, such as loss of consciousness (LOC) and amnesia, to make an mTBI diagnosis, thus hampering the collection of comparable epidemiologic and surveillance data.

Some investigators have used the terms concussion and mTBI interchangeably; however, in sports, the last available update in the definition of concussion was at the Fourth International Conference on Concussion in Sport in 2012. Concussion is a complex pathophysiologic process affecting the brain that is caused by biomechanical forces stemming from a direct blow to the head, face, neck, or elsewhere on the body. It results in a spontaneously resolving neurologic impairment of rapid onset, which may evolve over minutes to hours or may present a protracted course, and it may or may not be accompanied by an LOC.[12]

In summary, mTBI is defined as a GCS score between 13 and 15, an LOC of less than 30 minutes, and amnesia of less than 1 day.[1,13] Alternatively, concussion is defined as a brain injury resulting in a short period of functional neurologic impairment, without conventional neuroimaging evidence of structural damage.[12] This article focuses on conventional neuroimaging techniques and usage in mTBI assessment, considering concussion to be the mildest form of mTBI. In addition, the emphasis is on the acute phase and follow-up of mTBI, because chronic concussion is further discussed elsewhere in this issue.

CONVENTIONAL NEUROIMAGING IN CONCUSSION AND MILD TRAUMATIC BRAIN INJURY

The screening of sport concussions is largely based on the injury mechanism and on the signs and symptoms of neurologic impairment. However, neuroimaging should be used whenever suspicion of an intracerebral or structural lesion exists. These situations include a prolonged disturbance of consciousness, a focal neurologic deficit, or worsening of the initial clinical presentation.[12] Although LOC has been associated with early cognitive findings, its role as a measure of injury severity is controversial. The Zurich Consensus of 2012 determined that an LOC of more than 1 minute should be considered a factor that may modify management.[14,15] Persistent symptoms over more than 10 days are reported in approximately 10% to 15% of patients with concussions and are a reason for further investigation with neuropsychological testing and conventional neuroimaging.[12]

Alternatively, in mTBI, computed tomography (CT) abnormalities, which are also referred to as complicated mTBI, have been detected in up to 5% of patients with a GCS score of 15 and could be as high as 30% in patients with a GCS score of 13.[16–18] According to a meta-analysis by af Geijerstam and Britton,[19] from every 1000 patients arriving with mTBI at a hospital, 1 dies, 9 require surgery, and 80 show pathologic findings on a CT scan. In children with sports-related head trauma who undergo NCCT, 4% had CT abnormalities and 1% were considered clinically significant.[20] Furthermore, patients with abnormal CT findings and a GCS score of 13 or 14 are considered to be at a high risk of undergoing more neurosurgical interventions and having worse outcomes.[21]

Conventional neuroimaging is used as part of the assessment of TBI in the acute, subacute, and chronic settings and during follow-up. The imaging modalities most widely used to assess head trauma CT and magnetic resonance (MR) imaging.

CT is the preferred imaging modality for acute mTBI, for repeat assessment in acute TBI with

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