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Mild Traumatic Brain Injury: A Review of Terminology, Symptomatology, Clinical Considerations and Future Directions

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<http://dx.doi.org/10.5772/57208>

1. Introduction

Traumatic Brain Injury (TBI) is a leading cause of morbidity and mortality, with estimates of prevalence varying between 100-1000 per 100,000 [1, 2]. Among these figures, 70-90% will be classified as mild TBI (mTBI) [2]. While only 10% of those with a history of mTBI will have any ongoing problems [2], the sheer volume of incidents means that these events represent a major health concern. Accurate identification and diagnosis of those with mTBI is the first step in providing care and treatment [3-6]. However, the evaluation, management and diagnosis of mTBI represent an ongoing challenge for clinicians [3, 4].

Many of those who experience mTBI do not seek medical attention [7] or do not consult their clinician for many days after the injury event [8]. Delays often prevent accurate identification of those with mTBI due to the commonly rapid resolution of symptoms [8], subtle neurological signs and symptoms [9], and typical absence of evidence on neuroimaging [8]. Diagnosis of mTBI involves the detection of injury characteristics and symptoms established during a clinical interview with the patient, and in the case of children, with their guardian/carer [8]. Therefore, the primary source of information obtained is generally subjective in nature, leading to further diagnostic issues [4]. In addition, in some cases the information regarding the TBI may be based on a historical event for which the patient must rely on their own memory to recall, which can lead to the reporting of incorrect information [4]. However, for most of those assessed for mTBI, the assessment is conducted in the emergency department (ED) [3, 10], which does not specialise in diagnosis or treatment of mTBI. This presents a further problem in the case of children who are frequently admitted to the ED for orthopaedic injuries but not assessed for mTBI, and any potential mTBI in such children therefore goes unrecognised [11]. Finally, less severe forms of injury, including those for which a loss of consciousness (LOC)

was not sustained, may be overlooked or may receive little attention [5], despite potentially being a clinically important injury warranting assessment and treatment.

Currently, there is no “gold-standard” process of evaluation and diagnosis of mTBI, with structured clinical interviews as a commonly accepted standard procedure [5, 9]. It is mistakenly thought that anyone can detect and diagnose mTBI [12], however determining the clinical importance and potential effects this injury will have on each individual provides a distinct challenge. This chapter will highlight the issues associated with the evaluation, management and diagnosis of mTBI, and the factors that need to be considered during a structured clinical interview. These will include definitions and terminology, symptomatology, evaluating these symptoms during an interview, the importance of a concussive blow, brain imaging techniques, medical intervention, and complex concussion. Moreover, special consideration will be given to the evaluation of children with mTBI, given their heightened vulnerability to the negative effects of such an injury [13].

2. Definitions and terminology

A major clinical concern is the lack of a uniform definition for mTBI [8, 14]. Studies apply different definitions and inconsistent criteria to identify mTBI, resulting in varying findings and conclusions [15-17]. Furthermore, the terminology used to describe mTBI is inconsistent and may include concussion, minor head injury, minor brain injury, minor head trauma and minor TBI [6, 10]. This presents an issue for clinical diagnosis and evaluation as non-shared terminology across clinicians can lead to misinterpretation and misunderstanding among patients [4, 6]. Accurate and consistent use of terminology is essential to reduce confusion among clinicians and ensure the identification of patients with mTBI in an acute setting, so they can receive appropriate care [15] and are able to better understand their condition [4].

There are three main indicators most commonly used to identify mTBI – length of LOC, duration of post-traumatic amnesia (PTA), and a patient’s Glasgow Coma Scale (GCS) score [18]. The GCS involves the summation of scores from three measures including eye opening, and best motor and verbal responses, with 15 indicating the best possible response (and lowest injury severity) [12]. Based on this information, the American Congress of Rehabilitation (ACRM) [18] advocated four specific criteria when defining mTBI [8]. Since then, additional definitions have been suggested, mostly consisting of some variation of the ACRM’s initial criteria. Table 1 outlines definitions of mTBI put forward by the ACRM [18], the World Health Organisation (WHO) Collaborative Task Force [19], and the Centres for Disease Control and Injury Prevention (CDC) [11].

When comparing the definitions displayed in Table 1, similarities and inconsistencies are evident, particularly with terminology, across the standardised definitions of mTBI. The WHO’s definition was derived from the ACRM and CDC definitions [8], with the addition of the presence of confusion/disorientation, and the ruling out of symptoms manifested from other problems. However, the purpose behind these additions was not discussed or explained, and although these definitions are similar, slight differences among the terminology may result in different clinical decisions. When considering the CDC definition, different terminology is

Defining Body	Definition
American Congress of Rehabilitation Medicine (ACRM)	<p>Traumatically induced physiological disruption of brain function with at least one of:</p> <p>a) LOC (\leq 30mins)</p> <p>b) PTA - loss of memory for events before/after injury (\leq 24 hours)</p> <p>c) alteration in mental state at time of accident; transient or non-transient focal neurological deficits</p> <p>d) initial GCS score of 13 to 15 after 30 mins</p>
World Health Organisation (WHO) Task Force	<p>Brain injury due to mechanical energy to head from external physical forces and includes:</p> <p>a) 1 or more of confusion/disorientation, LOC \leq 30 mins, PTA \leq 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure and intracranial lesions not requiring surgery;</p> <p>b) initial GCS score of 13-15 30 mins after injury</p> <p>c) manifestations not due to drugs, alcohol, medications, or other injuries, treatments for injuries or problems</p>
Centres for Disease Control and Prevention (CDC)	<p>An injury to the head due to blunt trauma or acceleration/deceleration forces resulting in one or more periods of observed or self-reported:</p> <p>a) Transient confusion, disorientation, or impaired consciousness;</p> <p>b) Dysfunction of memory around the time of injury;</p> <p>c) LOC \leq 30 minutes.</p>

Table 1. Comparison of definitions for mild traumatic brain injury

used again, with no use of the term PTA, no time frame of PTA symptoms and no emphasis placed on a GCS score. Therefore, even among the most used and standardised definitions of mTBI, there are important discrepancies which will impede the process of identifying patients with mTBI.

2.1. The Glasgow coma scale

The GCS has been deemed the best initial score of injury severity [12]; however, there are noted problems with this. The scoring system often results in ceiling effects, with 15 being the upper limit of mTBI and also the highest possible score obtained on the scale [15]. People often therefore mistake a score of 15 to represent normal neurological functioning, which is sometimes not the case. The GCS is arguably not sensitive to the defining criteria of mTBI [15] in that a patient without mTBI who receives a score of 15 will likely be very neurologically different to a patient who has sustained a mTBI and also obtains this score. Another problem resides with the definition criteria involving GCS, in that an initial score of 13-15 is required 30 minutes after injury. The issue here refers to the fact that most patients with mTBI will present to the ED and will not be evaluated within this time frame [20]. As such, a practical issue arises in that the GCS cannot capture symptoms retrospectively or reflect neurological status immediately following the mechanical blow [14], therefore less emphasis should be placed on the GCS for identifying mTBI, especially where patients are assessed more than 30 minutes following their injury.

2.2. Clinical considerations

To obtain an understanding of recovery and response to treatment for mTBI, there needs to be a consistent definition and definitively shared terminology used across clinicians [10]. However, as discussed above this is yet to be the case. Over-inclusive definitions may lead to false positives, where mTBI is mistakenly diagnosed in unaffected patients, whereas restrictive definitions may result in patients with mTBI going unrecognised [15]. While most clinicians and research studies refer to the ACRM or WHO definitions for identifying mTBI, it is clear that some will place more or less emphasis on GCS scores or duration of LOC. When considering structured clinical interviews, it is important that clinicians adopt a more uniformed approach for defining mTBI and for the terms used to describe it, to avoid confusion among patients regarding the importance of their injury and also misdiagnosis.

3. Short-term symptoms of mild TBI

When assessing mTBI, it is often difficult for clinicians to evaluate symptomatology and to relate these to the injury as they are characterised as broad and non-specific, and often experienced in other disorders [8, 9]. However, the short-term symptoms of mTBI are typically grouped according to four categories: 1) physical, such as headaches and fatigue, 2) cognitive, such as poor concentration, 3) emotional, such as poor emotional control, and 4) sleep problems [3, 8, 11]. In addition, there may be transient and focal neurological signs present in those who have experienced mTBI, including seizures, visual problems, balance and/or gait problems, acute aphasia, anosmia/hyposmia, cranial nerve defects and intracranial lesions [8, 9]. The most commonly referred to list of symptoms experienced by those following mTBI are those reported by the CDC [11], as displayed in Table 2.

	Physical	Cognitive	Emotional	Sleep
Adults	<ul style="list-style-type: none">• Headache• Nausea• Vomiting• Balance Problems• Dizziness• Visual Problems• Fatigue• Light Sensitivity• Noise Sensitivity• Numbness/Tingling• Dazed/Stunned	<ul style="list-style-type: none">• Feeling “foggy”• Feeling “slowed down”• Difficulty Concentrating• Forgetful• Confusion• Slower Information Processing	<ul style="list-style-type: none">• Irritability• Sadness• More emotional• Nervousness	<ul style="list-style-type: none">• Drowsiness• Sleeping less• Sleeping more• Trouble falling asleep
Additional symptoms in children	<ul style="list-style-type: none">• Seizures• Change in nursing/eating habits	<ul style="list-style-type: none">• Personality Change• Poor attention• Lack interest in favourite toys/items	<ul style="list-style-type: none">• Crying• Cannot be consoled• Restlessness• Upset easily• Temper tantrums• Lethargic mood	<ul style="list-style-type: none">• Change in sleep patterns

Table 2. Short-term symptoms of mild traumatic brain injury in adults and children proposed by the CDC

While the CDC provides a comprehensive list of symptoms commonly reported by those following mTBI, similarly to the definition of mTBI there are differences among criteria and terminology. Some are more broad when discussing the symptoms of mTBI, using terms such as differences in 'higher-cognitive functioning' [21] and 'cognitive deficits' [9]. Further, although the CDC has put forward a list of symptoms, not all clinicians will consult this list during assessments. While it is near impossible to create an exhaustive list of symptoms one is expected to experience after mTBI, it is important to consider the validity of certain symptoms when using them to ascertain a diagnosis.

3.1. Validity of specific symptoms for diagnosis

Initial diagnosis of mTBI is usually based on LOC, PTA, or neurological signs [8, 22], with often greatest emphasis placed on LOC [22]. LOC is believed to be a symptom essential for diagnosis [8], however with this come practical concerns. Many patients are usually unable to report a period of LOC and the associated time frame, which means they must rely on others' reports of the incidents or make assumptions [8]. Patients will often mistake periods where they are unable to recall information as periods of LOC [8], or alternatively, where LOC is only experienced for brief seconds, it will go unreported [22]. There are additional difficulties when determining confusion/disorientation or PTA, as a strong emotional reaction evoked by the traumatic event may also produce these symptoms as secondary to the insult, which cannot be attributed to the injury itself [8, 23]. Therefore, mTBI can often be misdiagnosed when basing decisions on symptoms alone [24].

3.2. Special considerations for children

As is demonstrated in Table 2, children and adults will present differently following a TBI. While children may experience the same general symptoms as adults, they may also experience additional symptoms or express their symptoms in a different way [11]. Headaches, dizziness and fatigue are common symptoms of mTBI [11], and are often seen in both children and adults; however these specific symptoms tend to resolve more rapidly in child patients [20]. Furthermore, even when children are suffering the same symptoms as adults, they may not be able to explain or express them [11]. For instance, a young child may feel nauseous but not experience vomiting, and without the verbal expression of this feeling this symptom would go unrecognised. It is therefore recommended that when assessing symptoms of patients following mTBI, the threshold should be lower for children when deciding whether to proceed with follow-up evaluations and management [11].

3.3. Clinical considerations

Considering the unreliable nature of symptom reporting from patients, using this as the basis for diagnosis is not ideal [23]. Due to the patient's psychological impairment following their injury, their reports of LOC and PTA would not provide accurate evidence for mTBI [23]. It is recommended that in the case of LOC, collateral reports from others close to the incident may provide more valid information and aid diagnosis and evaluation [8]. In addition, the WHO collaborating task force [25] state that for the identification of mTBI, vomiting, seizures and

anterograde amnesia may be the important symptoms to consider following the injury. However, in addition to symptomatology, at a minimum, information pertaining to age, mechanism of injury, GCS score, skull fracture, and evidence of trauma above the clavicles should be assessed and recorded [25].

4. Evaluating symptoms during an interview

As discussed above, there are issues associated with the evaluation of symptoms during the diagnosis of mTBI. However, in addition to certain symptoms being unreliable for the identification of mTBI, there are also problems regarding how to elicit this list of symptoms from patients during a clinical interview [24]. The process of evaluation of mTBI requires patients to volunteer any symptoms they are experiencing and to answer questions in a subjective manner [9], but there are limits to these self-report methods such as problems with recall, stigma or secondary gains [24]. Furthermore, it is not uncommon that patients find it difficult to communicate their symptoms and problems, particularly in the early stages of their injury [11].

It has now been found in multiple studies that there is a difference in the number of symptoms reported by patients to their clinicians depending on whether their symptoms are assessed through self-report checklists or in an open-ended questioning format [24, 26-28]. For example [24], in a study with mTBI patients, it was found that participants were more likely to endorse more symptoms when completing a symptom checklist compared to during a clinical interview [24]. Similarly, in another study, patients reported significantly more symptoms per symptom category on a symptom checklist than when responding spontaneously [27]. Table 3 outlines studies investigating how the type of symptom evaluation can affect symptom reporting, and the results validate the finding that patients are more likely to report symptoms when completing a questionnaire than when answering questions during an interview [24, 26-28].

The findings in Table 3 raise the question of whether patients exaggerate their symptoms when using a checklist, or whether having a specified list reminds them of symptoms they would have otherwise forgotten to mention. It has been suggested that individuals may be less likely to report sensitive information face-to-face due to embarrassment, or simply believe that certain symptoms are trivial and not necessary to mention or are unrelated to their injury [24]. It is also possible that specific symptom questions may either result in a patient feeling pressured to provide a response, even if inaccurate [28], or alternatively, may cue an individual to identify and have the ability to label an otherwise ambiguous experience or problem [26]. While it appears that questionnaires may promote over-endorsement of symptoms, the issue may be that clinical interviews result in under-reporting of symptoms that appear unimportant or embarrassing, but are actually clinically important for diagnosis and evaluation.

4.1. Clinical considerations

The question is whether it is more important to have the patient over-report symptoms, even if not completely accurate, or to under-report their symptoms, thereby disregarding potentially important clinical problems. Over-reporting can lead to issues associated with malingering

Authors	Aims	Participants	Results
Gerber and Schraa (1995)	Compare mTBI patients with orthopaedic patients and healthy controls on measures of injury severity, symptoms and disability at time of injury and 6 months following	22 consecutive mTBI patients, 22 matched orthopaedic injury patients, 22 matched uninjured controls	The method for evaluating symptoms (volunteered versus elicited) had a significant effect on symptom frequency for mTBI patients, compared to the control participants
Nolin et al. (2006)	Identify role of spontaneous response versus suggested response methods for evaluating mTBI symptoms	108 mTBI patients contacted through follow-up phone interview	Participants reported significantly more symptoms and any given symptom when list was given to them Both the number and type of symptoms reported were different across the two methods
Stapleton and Mills (2008)	Explore the usefulness of open-ended questionnaires for evaluating balance symptoms	54 consecutive patients at specialist balance clinic	Open-ended questionnaire did not provide adequate information for diagnosis Patients more likely to respond affirmative if asked about symptoms directly
Iverson et al. (2010)	Examine the different outcomes between spontaneous, interview-based symptom reporting and standardised symptom questionnaires	61 patients in concussion clinic with mTBI	Patients endorsed 3.3 symptoms during open-ended interview compared to 9.1 on symptom questionnaire

Table 3. Overview of studies investigating how method of symptom evaluation affects symptom reporting

and financial gain, and also the use of unnecessary treatment, rehabilitation and management resources. However, under-reporting may result in patients not receiving the care they need, and it may therefore be more effective to have an over-inclusive list to avoid missing important symptoms. It has been suggested that clinicians have patients freely narrate their own stories [8] through answering open-ended questions and follow-up probes [4]. While encouraging a patient-centred response to specific symptom questions may result in an inaccurate diagnosis or decision [28], using both open-ended questioning and validated symptom checklists during a structured clinical interview may enhance the accuracy and value of clinical evaluations [27]. Although there remains to be inconsistencies in which approach clinicians use regarding the evaluation of symptoms following mTBI, it appears clear that neither will be a sufficient tool on their own in determining a diagnosis.

5. Importance of a concussive blow

Previously mentioned, the symptoms of mTBI are non-specific and are often also experienced by others with different injuries or disorders [8, 9]. Therefore, it is important to note that for mTBI to have occurred there must have existed a mechanically induced disruption to brain physiology due to external forces [8, 18, 19]. At the least, the signs and symptoms that may

warrant evaluation of mTBI require evidence of direct or indirect force and/or blow to the head [3], potentially severe enough to alter brain functioning [3]. The main area of controversy for this topic involves the effects of whiplash in the evaluation of mTBI [29]. Consequentially, the importance of a 'minimum biomechanical threshold' for mTBI to have occurred has been put forward [15] when determining whether the injury event was sufficient to result in the presenting signs and symptoms in a patient with potential mTBI.

Mild TBI is described as a biomechanically induced neurological injury, whereby acceleration and deceleration forces to the head results in a cascade of neurochemical and metabolic events [30]. It is argued that to determine the presence of mTBI, there must be some uniform acceleration or deceleration applied to a fluid body, thereby generating a pressure gradient, and in extreme enough cases, causing trauma to the brain [31]. Pure translation of a rigid body, such as in the case of shaking, will not cause any strain to the head [31]. Further, it has been estimated that when the head is struck by a force, the impact is 50-100 times greater than the result of shaking (and therefore no blow to the head) alone [31, 32]. Extensive reviews have also concluded that no impact produced by translational movement alone will be greater than that caused by an acceleration/deceleration force to the head [29, 32, 33].

It has been mandated that for mTBI to be present, a credible force must have been applied to the head, and that trauma to the brain is more likely if the force is rotary in nature [29]. This is due to the fact that a pressure gradient is generated transiently through the brain when there is a concussive blow resulting in rotational movement [33]. In effect, this is the reason behind the necessity of the presence of a concussive blow when diagnosing mTBI, to avoid diagnosis based on symptoms which may otherwise be attributed to causes such as acquired brain injury, drug/alcohol induced intoxication, tumour, stroke, or other problems [18, 29].

5.1. Special considerations for children

While research has been conducted concerning adults when determining the biomechanical nature of mTBI, the biomechanics of paediatric mTBI are less well-defined [31]. The hypothesis that smaller brains may require more angular accelerational force to produce the effects of mTBI has been studied. With the use of primates, the results have revealed that larger brains are actually more vulnerable to lower levels of angular velocity and acceleration [31], meaning they require a larger concussive blow than smaller brains. It has been suggested that in infants and very young children, the skull is not as rigid and therefore upon impact the structure will undergo elastic and potentially plastic deformation, resulting in various skull fractures [31], however the meaning and effects of this are not well studied or understood. Further studies are required to clarify the differences in the biomechanics of paediatric mTBI compared to that of adults, especially considering the enhanced vulnerability of children to the long-term effects of mTBI [13, 31].

5.2. Clinical considerations

Therefore, during a structured clinical interview it is important to determine whether the mechanism of injury is likely to be associated with significant acceleration/deceleration force,

and not pure translational movement [32]. Clinicians should confirm that the mTBI was induced by traumatic biomechanical forces, which are secondary to forces to the head [11]. Further, it must be ascertained how the injury occurred, the type of force sustained, and the location on the head or body where the force was received [11]. In particular, the clinician should search for evidence of injury or assault to regions above the clavicles to be certain the symptoms being reported were a result of a forcible blow to the head, potentially resulting in neurological disruption.

6. Brain imaging techniques for mild TBI

The use of neuroimaging techniques is sometimes adjunctive to other testing for diagnosis [8], however compared to their effectiveness in evaluating moderate and severe TBI they appear to provide the poorest sensitivity in detecting neurological abnormalities for milder forms of TBI [15]. This is because the results of imaging procedures for mTBI are often inconclusive and difficult to interpret [34], and while computerised tomography (CT) remains the technique of choice [15, 35], scans may still appear normal [18]. Typically, length of LOC and/or PTA, and results of the physical and neuropsychological examination, will guide the decision to order head scanning for mTBI [25]. However the challenge is how to detect which apparently intact patient has an intracranial lesion requiring surgical intervention [36]. Studies have therefore looked into how to predict which CT scans will result in positive findings such as intracranial lesions in mTBI patients [35].

When deciding whether to evaluate a patient for neurological abnormalities, clinicians will most often use a CT or magnetic resonance imaging (MRI) scan [12]. While MRI scanning will reveal more abnormalities, both early and late after mTBI, it is easier to use a CT scan for an unstable patient [12] due to the physical restraints and uncomfortable nature associated with an MRI. However, although MRI is useful for providing structural appearance of the brain, it cannot provide us with information that functional MRI (fMRI) may provide [21]. Moreover, symptoms of mTBI may more likely reflect functional as opposed to structural damage to the brain [16], and so fMRI could be used to map clinical symptoms to specific damaged brain regions; however, clinical access to CT scans is much easier to obtain than that of fMRI.

Studies have sought to determine the utility of brain imaging techniques following mTBI. For instance, the use of MRI and CT scanning for mTBI patients has been explored and compared [37]. Consecutive patients under 50 years presenting at an ED for mTBI were evaluated, and the results demonstrated a relatively high sensitivity of both CT and MRI for posttraumatic lesions [37]. However, when the negative predictive value of CT scanning and the necessity of hospital admission for patients without positive CT findings were examined in 2152 mTBI patients, the results indicated that no single variable, or combination of variables, could predict which patients would have a positive or negative CT scan [38]. Therefore, the utility of brain imaging techniques in the evaluation of mTBI remains to be questionable.

6.1. Prevalence of medical imaging use in mild TBI patients

The use of imaging for mTBI requires some consideration given that no standardised procedure exists, and the use of brain imaging techniques is extremely variable [25]. Nonetheless, it has been reported that in mTBI patients, the prevalence of CT scan abnormalities is 5% among those with a GCS score of 15, 20% for those with a GCS of 14, and over 30% for those with a GCS of 13 [25]. Furthermore, 6-8% of those with mTBI will have specific injuries displayed through CT, including subarachnoid haemorrhage, hematoma, cerebral contusion, intraparenchymal haemorrhage and evidence of axonal injury [16]. In a study exploring the prevalence of abnormal CT scans following mTBI [39], 15.8% of patients exhibited injuries on their 'day of injury' CT scan, but nearly 25% did not undergo scanning at all (without justification). The use of CT scanning should be regulated across clinicians, which may only be done so with the introduction of more standardised decisional criteria.

6.2. Special considerations for children

While the imaging techniques used to evaluate children will be the same as for adults, the procedures are likely to be more difficult with very young children [40]. These children may require sedation [40] to obtain accurate clinical information due to the need to be still while undergoing scanning. This can lead to further problems such as exacerbation of symptoms, prolonged lowered consciousness and problems with breathing [40]. A study [41] investigated CT scan results in children following mTBI, revealing that up to 38% exhibited abnormalities. Furthermore, even among those with a GCS score of 15, there was evidence of abnormalities on the CT scans [39]. This may suggest GCS score should not be a quantitative indicator of whether a child should undergo brain imaging. Furthermore, it has been reported in some children for whom an intracranial injury was present, some had no signs or symptoms before the imaging [40]. Therefore, the threshold for deciding whether to conduct brain imaging procedures should potentially be lower for children if they are likely to experience intracranial lesions without associated symptoms.

6.3. Clinical considerations

There is a commonly held perception that there is an undefined, but clinically important, false-negative rate when scanning patients with mTBI [36]. Also, it is hard to determine whether the expensive cost of using CT scans regularly can be outweighed by the diagnostic and intervention benefits that come with it. Moreover, remote regions and smaller practices may not even have regular access to such facilities. In an acute setting, one of the primary concerns is identifying intracranial lesions that may require surgical intervention [9]. Many have therefore put forward suggestive criteria in deciding which patients should undergo brain imaging, as displayed in Table 4.

As is clear in Table 4, emphasis has been placed on GCS scores [25]. However, as mentioned above the GCS may not be valid for determining this decision in children. Among the proposed criteria and decisional rules suggested by authors, difficulty still remains in making this decision as no clinical guidelines have been universally applied. This may result in a propor-

Authors	Suggestions
Borg et al. (2004)	<ul style="list-style-type: none"> • Patients with mTBI presenting with GCS of 15 and one or more risk factors should undergo CT scan; • mTBI with GCS 13 or 14 should undergo CT scan and be admitted for hospitalised observation
Jagoda et al. (2002) and Haydel et al. (2002)	Presence of one or more of: <ul style="list-style-type: none"> • Headache • Vomiting • Age greater than 60 • Drug/alcohol intoxication • Short-term memory deficits • Physical evidence of trauma above the clavicles • Seizure
Schutzman et al. (2001)	<ul style="list-style-type: none"> • Younger age may require lower threshold for imaging; • Greater the severity and number historical symptoms the stronger the consideration; • Discrete cut offs can't be provided for signs along continuum, however the greater the force involved, the greater the physical findings and the greater the risk of intracranial injuries; • All children with head trauma should be evaluated for extracranial injuries

Table 4. Suggestions of criteria for deciding to evaluate a mTBI patient using CT scan

tion of mTBI patients with potential intracranial injuries still going untested in the ED and acute settings [15, 40]. It is therefore important that a specified and universal set of guidelines or rules be applied for clinicians wanting to evaluate a patient with mTBI, so that there are no waste or resources and no patients needing intervention who go un-tested.

7. Medical and surgical intervention following mild TBI

During a structured clinical interview for evaluating a patient with potential mTBI, a clinician may be concerned with detecting intracranial injuries not detectable through the assessment of symptoms alone [25]. It is imperative clinicians be aware that certain intracranial complications may be present following mTBI, and how to detect which patients are likely to be affected [42]. There are many neurological disorders associated with mTBI, including seizures or cranial nerve defects, potentially requiring surgery [42]. The most common types of medical intervention required are craniotomy, elevation of depressed skull fracture, intracranial pressure monitoring and intubation [25]. However, other issues the clinician would need to address involve detecting operative lesions and cerebrospinal leaks [42], all of which are not easily detected and may therefore be missed in the ED.

7.1. Prevalence of cases requiring intervention

In patients with mTBI, it is estimated that surgical intervention is required in 1% [20, 25], with skull fractures seen in around 5% of treated mTBI cases [25]. A study [43] examining the

prevalence of those with CT abnormalities and in need of medical intervention following mTBI revealed that 44 (1%) patients required neurological intervention, 254 (8%) displayed clinically important brain injury, and 94 (4%) had unimportant lesions. Furthermore, of those receiving intervention, 27.9% underwent craniotomy, 9.3% received elevation of skull fracture and 5.2% required intubation (4.1% died secondary to injury) [43]. Therefore, although only a small percentage, some individuals with mTBI will require some sort of surgical intervention following their injury. Considering the large number of individuals who will experience a mTBI in their lifetime [1, 2], this small percentage will still equate to a significant amount of morbidity and mortality, and therefore clinicians should be aware of which patients may be in need of this intervention.

7.2. Predicting the need for intervention

A small proportion of seemingly intact mTBI patients may deteriorate and require neurosurgical intervention [44] and so early diagnosis by CT followed by early surgery is important [43]. However, controversy exists whereby normal CT scans do not always equate to the patient not needing later intervention [43]. Indeed, a study [43] revealed that five patients with subdural hematoma did not undergo CT scanning [43] which means many medical problems requiring intervention may often go unnoticed at immediate assessment. A clinical concern is that clinicians will apply different rules and criteria to aid their decision in ordering scans [43, 44], which results in varying outcomes for patients [25, 45].

Researchers have consequentially aimed to provide criteria for classifying patients at risk of intracranial complications to aid early identification and intervention [25, 45]. Factors that have been associated with this likelihood is the mechanism of head injury, such as being hit by a vehicle, increasing age, and the finding of focal neurological deficits [45]. Others also discuss the presence of clinical 'high risk factors' for detecting the need for intervention, and clinical 'medium risk factors' for indicating the likelihood of a clinically important brain scan [25].

7.3. Special considerations for children

An additional issue regarding paediatric mTBI is that an epidural hematoma can develop in the absence of LOC or skull fracture [45], making the need for medical intervention even harder to detect. While clinical factors can be used to predict cranial abnormalities in adults, the evidence is lacking for children [20, 46]. Furthermore, although skull fracture has been reported as a significant risk for intracranial complications, up to 50% of paediatric intracranial complications can occur in the absence of skull fracture [46].

Therefore, the clinical factors used to predict individuals likely to need medical intervention will not be the same for children as they are for adults. It has been suggested that a neurosurgeon be consulted for any child displaying intracranial injury on a CT scan, and any skull fractures, so that a lower threshold for making the decision is applied than would be for adults [40]. It is particularly important that appropriate and specific guidelines be developed and applied for children due to the negative long-term effects of delayed surgery for acute hematoma or haemorrhage [40, 46].

7.4. Clinical considerations

Due to the variable clinical findings and criteria used when determining who will be likely to require medical intervention following mTBI, a number of studies have proposed guidelines for clinicians to consider [25, 43, 45]. Patients are often classified as ‘high risk’ or ‘medium risk’ for requiring later medical intervention, and depending on this risk these patients are either sent home or admitted for observation [45]. Those with high-risk factors are likely to need intervention and may require brain imaging, whereas those with medium risk-factors may have clinically important lesions apparent on CT but not at risk for medical intervention [43].Table 5 displays criteria proposed by two studies in predicting patients who will need intervention following mTBI [43, 45].

Authors	Proposed Criteria
Servadei et al. (2001)	a) adult patients with GCS 13-14, and 15 where there is skull fracture, or; b) GCS 13-14 and 15 with abnormal mental status, or; c) GCS 15 with skull fracture, or; d) GCS 13-14 and history of LOC, or; e) mandatory with GCS 13, recommended for 14-15, or; f) one or more of: - neurological deficits - basilar skull structure - scalp injury - > 60years
Stiell et al. (2001)	High Risk: a) GCS <15 2 hours after injury b) suspected open or depressed skull fracture c) sign of basal skull fracture d) vomiting (>twice) e) >65 years. Medium Risk: a) amnesia before impact >30min b) dangerous mechanism of injury

Table 5. Proposed guidelines for predicting patients that will require medical or surgical intervention following mTBI.

As evident in Table 5, differences are apparent in the literature regarding how to appropriately evaluate and assess patients presenting with potential mTBI. The inconsistencies in the literature prevent clinicians from following a standardised procedure when examining patients with mTBI during a structured clinical interview. Therefore, the process of decision-making is commonly quite subjective in nature. For accurate diagnosis and consistent decisions, a universally applied procedure and list of criteria needs to be developed for all clinicians.

8. Complex concussion

Complex concussion, or complicated mTBI, is where an individual has a GCS score of 13-15 but shows 1) specific problems such as convulsive convulsions, 2) LOC of more than 1 minute, 3) persistent symptoms or prolonged impairment, and 4) history of multiple mTBIs [15, 39, 47, 48]. More specifically, mTBIs with associated symptoms lasting more than 10 days will be classified as complex [15, 47]. Patients with complex concussion are more likely to suffer from persistent cognitive and psychological symptoms, and their recovery pattern will be more similar to those with more moderate head injuries [39].

Since complex concussion is associated with an extended recovery time, and therefore more morbidity, it is important for clinicians to be able to identify those who are likely to suffer from the disorder, possibly through the use of 'concussion modifiers' [47]. Such concussion modifiers which may allude clinicians to the type of patients who will develop complex concussion include intrinsic factors (such as age of the patient, phenotype of symptoms, prolonged duration of LOC) and extrinsic factors (such as type of injury sustained, location of injury on head or neck) [47].

8.1. Risk factors and predictors for complex concussion

Many studies have attempted to delineate the specific risk factors and predictors for developing a complex concussion [22, 49-51]. In one study [50], 172 mTBI patients were assessed in the ED, 37 of which developed complex concussion symptomatology. Reported risk factors in this study were skull fracture, serum protein S-100B, dizziness, headache on admission, childhood psychiatric illness, LOC and PTA [50]. However, it was also found that LOC, PTA, extracranial injury, prior TBI, employment status, insurance, psychotropic drugs, current heavy drinking, smoking and prior use of illicit drugs were not independent risk factors for the development of prolonged mTBI symptoms [50]. Therefore, although LOC and PTA appear to at least partially predict who may suffer from complex concussion, they alone cannot be used as definitive markers for such patients. It was suggested that the association between the serum protein and prolonged symptoms of mTBI may indicate an organic aetiology for the disorder [50], however further research is needed. Table 6 displays commonly reported risk factors and predictors suggested to have a role in determining who will develop complex concussion following mTBI.

Although studies have sought to determine which factors are associated with complex concussion in mTBI patients, there is still uncertainty over how and why some patients do not recover after the 10 day mark [49]. However, it is likely that based on the above predictors, those at risk of experiencing prolonged symptoms can be identified as early as the ED room during acute care [50]. This is important to consider as a clinician when assessing mTBI patients during a structured clinical interview.

8.2. Special considerations for children

It has been noted that recovery time following mTBI may be longer for children and adolescents [11] compared to adults. However, persistent symptoms that need to be addressed and

Authors	Risk Factors/Predictors
Erlanger et al. (2003)	<ul style="list-style-type: none"> • Cognitive impairment at initial evaluation relative to baseline measurements
	<ul style="list-style-type: none"> • Abnormal brain imaging findings • Prior mTBIs • Greater LOC/PTA
Williams et al. (2010)	<ul style="list-style-type: none"> • Longer duration of initial symptoms • Younger age • Female • Previous psychiatric history
	<ul style="list-style-type: none"> • Female • Digit span forward scores
Bazarian et al. (1999)	<ul style="list-style-type: none"> • Verbal learning scores • Retrograde or anterograde amnesia -- all associated with the absence of complex concussion
Centres for Disease Control and Injury Prevention	<ul style="list-style-type: none"> • History of mTBI • History of headaches • Developmental disorders (e.g. Attention-Deficit/Hyperactivity Disorder) • Psychiatric problems (e.g. history of anxiety, depression, sleep disorders)

Table 6. Reported risk factors/predictors of developing complex concussion.

monitored when evaluating children at follow-up are persistent headaches, poor attention, change in nursing/eating habits, being easily upset/having tantrums, lethargic mood, lack of interest in favourite toys, and excessive crying [11]. Considering this, it is important that children only return to school and leisure-play when their symptoms fully resolve and they have completely recovered. Unfortunately, many children do in fact return to school without rehabilitation and almost 1/3 of schools are unaware that the child has suffered a TBI [13]. Furthermore, teachers are rarely aware of the potential long-term effects associated with mTBI and that it can lead to problems which will impede on a child’s learning and development [13]. Therefore, it is important that the clinician take special care when assessing and evaluating a child for complex concussion to ensure they do not return to school or play too early, where they may not get the rest and care they need. Further, it may be beneficial for a clinician to notify the school of the child’s injury to enable adequate recovery time.

8.3. Clinical considerations

Patients “at risk” of developing complex concussion need to be identified early, even in the ED [50]. Therefore, a functional evaluation by the clinician during a clinical interview should be conducted and include activities of daily living, mobility skills, linguistic-pragmatic abilities, sexuality issues, vocational/academic status and psychosocial issues [42]. This would ensure estimates of the patient’s ability to return to school, work or recreational activity are obtained to avoid further injury and enhance recovery. It has been found that the presence of

complaints of headaches, balance problems, dizziness, fatigue, depression, anxiety, irritability, and memory and attention difficulties may moderate a patient's outcomes following mTBI [52]. It is clear that a clinician must consider all factors when evaluating a patient with mTBI in the ED, to ensure they are not at heightened risk of experiencing complex concussion and therefore providing immediate prevention and intervention.

9. Conclusions

It is often falsely assumed that mTBI is not associated with any significant health burden, however considering the large number of individuals affected per year, accurate identification of the problem is paramount. Along with being difficult to define, mTBI is also difficult to evaluate, detect and diagnose. The non-specific symptomatology associated with the injury, and issues with self-report of these symptoms during clinical evaluation, suggest that mTBI cannot be diagnosed through the consideration of symptomatology alone. Moreover, it has been established that a certain threshold for concussive blow to the head, causing trauma and potential neurological disruption, is required for an accurate diagnosis. The use of brain imaging techniques such as CT and MRI scans may aid the diagnosis of mTBI and help identify those who require surgical and medical intervention; however, these remain inconclusive and more work needs to be done regarding their clinical utility for very mild injuries. And finally, the potential for mTBI patients to suffer from a complex concussion, whereby prolonged symptoms can impede on everyday life and functioning, is an important factor to consider when evaluating individuals in an acute setting. It is clear that controversies surround identifying the most effective and successful procedures for assessing mTBI in a structured clinical interview, and more work needs to be done so that patients with mTBI can be accurately detected and treated accordingly.

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