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Mild Traumatic Brain Injury: Contemporary Approaches to Diagnosis and Prognostic Assessment

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Abstract

Mild traumatic brain injury (mTBI) or concussion is the most common type of traumatic brain injury in the world and a significant cause of long-term disability and healthcare expenditure even though routine neuroimaging may show normal results. Most individuals recover, although some do have long-term symptoms in terms of both cognitive, mood and ability, with the most significant being the persistent post-concussion syndrome (PPCS) that lasts more than three months; risk factors interact between biological, psychological and socioeconomic factors: the female sex, pre-existing mental issues, anxiety, headache burden, previous TBI, and social stressors, with military populations that received a blast identified as the most vulnerable. This narrative review was used to summarize the major predicaments and developments in the diagnosis and prognostication of mTBI and treatment with gaps in emerging biological and clinical supports and research. Targeted clinical assessment, neuroimaging (CT, MRI, DTI, functional imaging), neuroinflammation, and blood biomarkers (S100B, GFAP, UCH-L1, NfL, tau) were searched in PubMed and Google Scholar and included peer-reviewed human research studies that reported clinical presentation, diagnosis techniques, biomarkers, imaging, or recovery data during both acute and protracted stages of the disease process; only studies that contained primary data, were non-review studies, case report/commentary, or had major The literature suggests that symptom based-assessment and scales like GCS (usually 13-15 in mTBI), SCAT5, and ACE are the baseline, but not adequate in identifying subtle deficits and CT should be used to rule out intracranial hemorrhage and MRI as it has limited practical uses in acute conditions. Modern modalities (e.g. DTI) and fluid biomarkers have potential to indicate microstructural injury and triage imaging necessity, but do not have adequate specificity, standardization, and cross-population validation to be conclusive

diagnostic or prognostic measures. Neuropsychological testing, eye-tracking, balance assessment, EEG, and comorbidity and context-sensitive mobile health tools could offer functional sensitivity. All in all, in heterogeneous definitions, varying results and methodological constraints hinder comparability and prediction, so there is a need to establish a set of standard diagnostic criteria and a large and diverse, multimodal, longitudinal study to facilitate a clinically relevant risk model and specific rehabilitation trajectory.

Keywords: Traumatic brain injury (TBI), Mild traumatic brain injury (mTBI), Prolonged post-concussion syndrome (PPCS), Neuroinflammation, Neuropsychological assessment.

Introduction

Traumatic brain injury (TBI) is a significant health problem in the world with millions of people being affected annually and it ranks as one of the primary causes of long-term disability, morbidity and mortality (1). Approximately 10 million individuals are either hospitalized or die due to TBI every year. In the U.S. alone, there are between 1.4 and 1.7 million emergency room visits annually for this condition (2).These figures might be an underestimate, as many less severe cases don't reach hospitals but are seen in general practice (3).Mild TBI (mTBI), or concussion, makes up a large part of these injuries, ranging from 58% to 90% of all cases. Incidence rates are high, over 500–600 per 100,000 yearly, and these numbers increase when considering unreported cases outside of military, athletic, or general medical settings (4). Those at risk include young children, teenagers, young adults, construction workers, seniors, and military personnel (5). For instance, in U.S. children, there were over two million clinic visits and nearly three million emergency room trips for possible mild brain injury over a four-year period (6). Whether in daily life or conflict zones, even minor head traumas play a big part in the financial cost of brain injuries, making up around half of all long-term expenses related to such conditions nationwide.

Although mTBI is mild, it may have a number of short-term effects such as headache, dizziness, nausea, fatigue, sleeping difficulties, mood changes, anxiety, low mood, problems in thinking, light sensitivity, and sound sensitivity. It may also lead to balance and eye movement issues, neck difficulties and postural issues, and normal Romberg test does not exclude these latter symptoms. The injury is usually manifested in attention, speed of processing, decision making, memory, self-awareness, speech, and comprehension after the injury (7). Many people recover in a few days or weeks; however, there are those who continue with the symptoms for months or even longer. The findings on long-term effects are very diverse as the definitions used by different studies are different. Nevertheless, approximately 5-30 percent of the people experience persistent problems which influence their working, education, relationships, and psychological well-being. Some of them develop prolonged symptoms, which can take up to more than three months, as known as prolonged post-concussion syndrome (PPCS). According to the recent reviews, it has been shown that there are some risk factors of PPCS, such as

female gender, history of mental health issues, anxiety, headache during recovery, some personality traits and social factors (8).

Such results suggest the necessity of thorough assessments, which consider all the biological, psychological, and socioeconomic factors to determine those at a greater risk of chronicity and provide specific intervention (9). Long-term evidence shows that although adults with mTBI can initially show cognitive deficits, the majority of them can recover significantly in the first three months, including children, but there are definitely numerous variations (10). Soldiers and veterans seem especially susceptible; the injuries sustained by blasts tend to cause poorer recovery because of the unique patterns of injuries and the presence of other mental health problems that they tend to co-occur with. The pathophysiology of mTBI is complicated and is associated with numerous interrelations. Although normal brain scans are not exhibited, there may be delayed responses like inflammation, energy disturbances, or blood-brain barrier issues due to the trauma. The participation of activated microglia and astrocytes and signaling molecules, such as cytokines or danger signals, are added to the current problems following the initial physical impact. The existing medical examinations merely present a part of what is occurring (9,10). CT scans usually fail to detect minor differences in the brain and MRI can give more details, but it is not practical to use these markers in the acute clinical setting (11). The inflammatory markers are more difficult to depend on since they are low in the blood, their measurements are not consistent, and a head injury or the rest of the body affects the markers. Such gaps indicate that to examine recovery of mild traumatic brain injury, one must consider all factors, both biological, mental and environmental.

Diagnosis and prediction have common problems. The small issues are usually missed during normal examinations conducted on the brain, which results in cases being missed or poor treatment. Most individuals who experience mild head injuries do not undergo specialized tests and thus problems such as poor attention, weak memory, slow thinking, and mood control may be ignored unless keenly looked into. It is worth mentioning that healthy people may score high on numerous neuropsychological assessments, and, therefore, such results should be interpreted cautiously, and only after that, specialists conduct elaborate examinations to reveal any latent mental impacts and subsequently develop individual recovery strategies (12). But such comprehensive analysis is not always available in different regions. Doctors in emergency rooms have the dilemma of searching for serious but uncommon brain issues yet they are aware that a majority of scans will reveal no abnormality. In order to deal with patients effectively, employees are to screen them attentively, document the initial neurological condition, employ appropriate imaging methods, and inform families about some of the symptoms that could appear in the future.

It is still a challenge when it comes to predicting the recovery of people. Instruments such as the Glasgow Coma Scale are applicable in severe brain injuries; however, they are unproductive in mild cases since majority of the patients record high scores, and the scans usually do not depict any damage. In its turn, recovery appears to be conditioned by a set of biological, psychological, and social factors, including the level of anxiety or prior mental disorders. Others such as age, background, occupation

status, description of the trauma, financial status, and life stressors are also involved. Studies looking for specific signs that might predict results often disagree; for example, some papers mention gender differences, but others do not confirm them (13). Common symptoms are similar to those found in many other injuries or health problems, which makes diagnosis harder. Instead of working with individual predictors, models have begun to work with a combination of very large numbers of variables. Although the tools unite physical, mental, and environmental data to inform treatment, enhance risk evaluation, guide therapies, and enhance the study design, most of them have drawbacks such as poor procedures, vague results criterion, or the absence of testing in various populations. The long-term outcomes of the blast-related mild brain injury among the military personnel demonstrate that there is a need to detect people at risk earlier, as mental health issues can tend to happen simultaneously (12,13).

One of the main difficulties in this area has to do with ambiguity or the constant alteration of definitions. It is frequently the case that the concepts of concussion, mild TBI, and minor head injury just melt into each other without well-defined boundaries. There are small differences in the definitions and standards among different areas such as children's health, sports medicine, general practice, and military medicine. Although major classification systems from the American Congress of Rehabilitation Medicine and the WHO task force exhibit similar characteristics, like short period of unconsciousness, temporary memory loss, short-lived neurological issues, and a Glasgow Coma Scale score of 13 to 15, they are however applied inconsistently in practice (14). The plaintiff's differences lead to the grouping of subjects in studies being very different, hence the results being unclear. In pediatrics, loose terms have frequently resulted in no diagnosis being made and the quality of care varying, which is a strong indication for a national standard to be set. The inconsistency of definitions and terminologies in concussion research and related areas makes the design of the study weaker, the results comparison more difficult, and the identification of different recovery groups more complex (14). The increased public awareness of concussion has been partly due to sports-related injuries in youth and professional athletes, which have resulted in legislative and return-to-play policies in the U.S. Nonetheless, there are still no comparable standards in the school setups for identifying and supporting students with concussion.

Research on treatment and rehabilitation is met with huge restrictions. The reason for this is that mTBI is a complex issue, thus patients have to see many different specialists. Their services might be cognitive rehabilitation, vestibular rehabilitation, visual rehabilitation, psychology, or physical therapy (15). On the other hand, the strength of evidence for particular treatments is very different. In fact, many clinical trials treat participants with mild, moderate or severe brain injury as one group and apply the different success criteri a, poor definition of mTBI, improper participant blinding, no random assignment, or sometimes even ignoring bias (15). A number of systematic literature reviews limit their scope to symptom education, cognitive behavioral therapy or current problems, while very few provide comprehensive summaries that include all recovery approaches specific to mTBI.The main goal of this narrative review is to present the most important issues in the diagnosis of mTBI, prediction of outcomes and treatment of mTBI. Furthermore, it introduces the new biological and clinical methods

which are still in the process of development, and it also points out the areas where more studies are needed for further improvement of recovery results (14,15).

Methodology

In order to gather the most recent and reliable insights about mild traumatic brain injury, PubMed and Google Scholar were used as main credible sources for the review. To be as specific and comprehensive as possible, a wide range of targeted key words were used for this search: mild traumatic brain injury, concussion, mTBI diagnosis, post-concussion symptoms, biomarkers, serum biomarkers, S100B, GFAP, UCH-L1, NfL, tau, neuroinflammation, neuroimaging, CT, MRI, DTI, functional imaging, prognostic factors, persistent symptoms and recovery outcomes as well as head injury, mild head trauma, brain injury biomarkers and post-concussive syndrome to ensure including all of the relevant information present (1,2,3). As for the inclusion criteria, the peer-reviewed articles were considered, only if they involved human participants, with provided data on clinical presentation, diagnostic assessment, biomarker evaluation, imaging findings, or recovery outcomes after head injury. Both the acute phase and the long-term studies were taken into consideration. The studies were excluded if they lacked primary data, were centered around non-human models, were case reports and commentaries, or had serious flaws in study design. Besides, to eliminate confusion and uncertain associations, studies with ambiguous diagnostic criteria, for example, inconsistent use of the terms concussion and mTBI were also left out (4,5).

The search covered articles from the past 15 years, but exceptions have been made for some older studies, for historical value or for containing significant methodological foundations. Although a structured framework was used, this review was designed as a narrative, instead of it being systematic, allowing more diversity in integrating study types such as- observational cohorts, randomized trials, systematic reviews, and case series. Nevertheless, it is important to note that using this study design naturally allows some degree of selection bias (4,5).

Once the eligible studies had been determined, the data extraction process was centered on the study design, population characteristics, diagnostic methods, biomarker tests, imaging protocols, symptom assessment (where applicable) and reported outcomes. The studies were mostly classified into four main themes. In the case of diagnosis, studies were compared by the criteria that were applied, clinical assessment tools, and precise definitions of the symptoms, thereby showing a certain extent of variability between cohorts and reporting standards. For biomarkers, the data were classified according to the type of marker (e.g., S100B, GFAP, UCH-L1, NfL, tau), the time of sample collection against the time of the injury, the patient's demographic such as age, and the stated predictive or diagnostic value. Imaging the injuries was done using different techniques of imaging (CT, MRI, DTI, functional imaging), then separated into structural versus functional findings, and timing of the imaging, that is, whether it was done immediately after the injury or later, during a follow-up, making common patterns more visible, and limitations easily detectable. Finally, outcomes were generated according to measures

used (e.g., Glasgow Outcome Scale Extended, return to work, symptom persistence), follow-up duration, and variability in recovery outcomes. By structuring the review in this way, methodological gaps, inconsistencies, and areas where further advanced research is needed has become evident, urging further actions for higher quality research for a clearer guidance (6,7).

Discussion

Pathophysiology of Mild Traumatic Brain Injury & Clinical Manifestations

Mild Traumatic brain injury commonly known as concussion is an acute condition when due to external mechanical forces disruption of normal nervous function occurs, resulting in wide spectrum of symptoms. Despite being labeled as mild, traumatic brain injury can have very serious consequences, ranging from brief episodes of altered mental status to persistent cognitive, emotional and physical symptoms (1). The consequence of quick acceleration of the brain and deceleration results in diffuse axonal trauma, disturbed cerebral blood flow and impaired cell membrane integrity (2). The clinically significant changes of cellular level can be translated to symptoms such as dizziness, headache, attention and memory impairment and many individuals recover within several days-weeks, but a large number are still left with persistent post-concussive symptoms that may limit daily functional ability. Diagnostic mTBI still lacks a definitive diagnostic test that is universally accepted, with most victims being diagnosed only by initial clinical assessment, physical examination, inspection and history of the patient (3). Apart from considering mechanism of injury, excluding red flags such as altered consciousness, post traumatic amnesia or seizure, is non-negotiable.

Role of the Glasgow Coma Scale in Severity Assessment

It is pivotal to calculate Glasgow coma scale, really the only reliable clinical assessment tool for diagnosing and differentiating between severities of traumatic brain injury. A GCS ranging between 13 and 15 is usually representative of mild traumatic brain injury (4). Acute assessment may not depict all the clinical features of mTbI but it is very important to note serious changes. A GCS ranging between 13 and 15 is usually representative of mild traumatic brain injury. Characteristic features such as, history of prolonged loss of consciousness, profound alterations in behavior, inexplicable agitation or aggression, and signs of deterioration of the nervous system, such as the growing somnolence, excessive drowsiness, frequent or uncontrolled seizures or severe confusion, including the inability to identify familiar faces should not be accepted as part of the diagnostic process as this factor adds subjectivity, and the quality of diagnostic results and the ability to predict a realistic prognosis with certainty (5,6).

mTBI is most commonly encountered during sports events, which consequently created the need for standardized tools to evaluate athletes during their performance. The Sport Concussion Assessment Tool, Fifth Edition (SCAT5) is one such tool, that is used by qualified medical professionals to assist with diagnosing people in a structured and timely manner (7,8). SCAT5 can be divided into two major phases. The so called, on-field assessment, that mostly focuses on discovering red-flags, such as neck

pain, open injury, seizures, diplopia, motor weakness or numbness in extremities (8). Doctors also assess consciousness using the Glasgow Coma Scale. The following stage is referred as off-field assessment, that ideally is conducted in clinical settings, which gives better opportunity to conduct detailed physical examination of the patient and get thorough history. Athletes who have clear signs of neurological deterioration demonstrate confusion or report severe headaches should promptly be removed from the event or competition (7,8).

Another similar diagnostic tool is The Acute Concussion Evaluation (ACE), which consists of well-structured questions that focuses on diagnosing mTBI in suspected patients (9). It evaluates injury characteristics, has symptom checklists, looks for risk factors, identifies red flags, formulates diagnosis, and gives recommendations for follow-up care. It can be used for adults as well as for pediatric patients (9). While there are many means of checking structural integrity of brain, there must be a clear indication for either CT or MRI to be used as diagnostic tool for mTBI. Doctors always try to balance the risk and the benefits of the diagnostic methods they use (10). Considering clinical manifestation of the patient, CT or MRI can alleviate with the process of diagnosing mTBI. Patients who satisfy the criteria for neuroimaging should undergo a non-contrast CT scan of the head as the initial investigation to exclude more severe intracranial injuries. The CT imaging in patients with bleeding disorders like hemophilia is recommended even in those with a normal Glasgow Coma Scale of 15 or the neurological examination is not remarkable. Risk factors that require urgent imaging are a Glasgow Coma Scale score below 15 at 2 hours after injury, open skull injury, evidence of basilar skull injury, two or more cases of vomiting, and age 65 years (10). Medium-risk features include retrograde amnesia lasting ≥ 30 minutes and injuries resulting from high-risk accidents. Although MRI provides limited additional value for mTBI evaluation, advanced neuroimaging modalities have been developed for detecting even minor brain changes. Such diagnostic tool is Diffusion tensor imaging (DTI), which enables us to detect microstructural changes and is specifically sensitive to white matter abnormalities (11). Common measures of DTI are fractional anisotropy (FA), the mean diffusivity (MD), radial diffusivity (RD), and the axial diffusivity (AD). The goal of this method is to explore myelin damage. Even though This imaging modality had shown high sensitivity, it still lacks specificity. The outcomes have been different among populations, and this is why diffusion tensor imaging study cannot be used as a singular diagnostic method for mTBI yet. The common neuroimaging methods such as CT and MRI do not always identify the abnormalities in mTBI because they are only intended to produce the macroscopic structural injuries. This has increased the need for other methods to be developed, to make diagnosing mTBI somewhat easier (12,13).

Advanced Neuroimaging and White Matter Injury

Fluid biomarkers promise completely new ways of making mTBI diagnosis. There are many different fluid biomarkers, but some have more significance when it comes to brain injury (12). S100B is a calcium-binding protein, which is mainly located in astrocytes. High S100B levels in serum correlate with the damage of the blood-brain barrier. It is, however, rather specific and it can be found in extracerebral locations like the adipose tissue and skeletal muscle. Another significant biomarker is the

Glial fibrillary acidic protein (GFAP), again specific to the astrocytes. Its level upsurges in serum and cerebrospinal fluid after mTBI, as evidence of neuron damage (13). There is also evidence that the level of GFAP is associated with the severity of the injury, and it can be used to differentiate mTBI and other neurological disorders. Ubiquitin carboxyl-terminal hydrolase L1 (UCH-L1) and Neurofilament light chain (NfL) have also be reported to be elevated after axonal injury has happened. Tau, which is a microtubule-associated protein, necessary in maintaining the stability of cytoskeleton of neurons and is also an increase in mTBI, as a manifestation of neuronal injury, is also under study as possibly related to chronic neurodegenerative processes (12,13).

Despite promising progress these biomarkers have created, there still is ongoing doubt whether they should be used as gold standard for diagnosing mTBI. Continuous effort to research fluid markers is decisive, in order to intergrade them into patient care. Patients presenting with a Glasgow Coma Scale score below 13 or evidence of neurological deterioration should undergo CT imaging to exclude intracranial hemorrhage (13). In contrast, for patients with a GCS of 13-15 who lack red-flag symptoms, such as progressive headache, focal neurological deficits, recurrent vomiting, or seizures, biomarker assessment may be considered as a alternative to CT scanning. Biomarker measurements can stratify patients into low, moderate, and high-risk categories based on their levels (13). Patients with low biomarker concentrations can be discharged without CT imaging. Those with moderately elevated biomarkers may require closer observation and reassessment within several hours, and CT imaging should be considered, especially in patients with worsening symptoms or a history of repeated loss of concussions. Elevated S100B, GFAP, and UCH-L1can be indication for neuroimaging and potential hospitalization (14). Individuals with persistently elevated NfL or Tau may also require specialist referral given their association with chronic post-concussive disorder and increased neurodegenerative risk. The best treatment for mTBI is through an integrated approach which includes clinical evaluations, neuroimaging, and the use of biomarkers which all together will increase diagnostic accuracy and thereby improve the patient's prognosis both in the short term and in the long run (14).

Neuropsychological and Functional Assessment

One very useful testing is neuropsychological testing ,which is a critical component in the evaluation of patients with mTBI, as it provides information about cognitive function that may not be apparent through standard clinical assessment alone .The mTBI assessment is founded upon a structured methodology that permits the performance of cognitive and behavioral functions to be measured. The first step of the evaluation is a conversation with the doctor, who will collect an in-depth patient's history and, if it is feasible, information from relatives or people who are close to the patient (15).Standardized cognitive tests are then used to assess functions commonly affected by mTBI, including attention and processing speed, memory, executive functions such as planning, problem-solving, and goal directed behavior. Depending on the severity of the injury and the recovery stage of patient, different screening measures can be used.One important way to estimate cognitive function in a person suffering from mTBI is the use of neuropsychological testing. However, these assessments have some limitations. Results may be influenced by external factors such as age, recent physical

activity, motivation, fatigue or pain. Additionally, comorbid conditions, including depression, post-traumatic stress disorder, substance use, and other psychiatric disorders can affect the direction of the interview (15).

Incorporating eye-tracking and balance testing into mTBI diagnosis is another way of ensuring better patient outcomes. Our visual system is very vulnerable to even slight injury. After hemispheric injury, there were fewer individuals with visual signs.Eye tracking tests can detect abnormal oculomotor nerve functioning, disturbing papillary reactivity and saccadic movements. Traumatic brain injury patients often complain about balance disturbances, such as vertigo, alterations in posture, and walking difficulties. These symptoms may last over a long period and are usually associated with injury to the vestibular system (16).

Early identification of individuals with concussion or mild traumatic brain injury (mTBI), as well as timely support, should always remain a significant priority. Mobile technologies represent a promising avenue for addressing several of these needs in TBI care. Over the past decade, mobile health has gained increasing popularity as a supportive tool for both patients and clinicians. Mobile platforms have been used to screen sports-related concussion and to distribute educational resources related to TBI management (16). Electroencephalography (EEG) was the earliest diagnostic modality to demonstrate functional abnormalities in the brain following traumatic brain injury. Electroencephalography can possibly be even more sensitive in diagnosing brain diseases compared to the standard neurological system. Following mild traumatic brain injury, majority of patients demonstrated EEG abnormalities. They are observed more frequently in individuals who experience loss of consciousness lasting longer than two minutes. Mild traumatic brain injury associated with changes in electroencephalography can be classified into acute, subacute and chronic phases. The electroencephalogram usually shows initial epileptiform discharges, then a 1–2-minute lasting cortical suppression, followed by generalized slowing that normalizes within 10 minutes to one hour immediately after the injury. Most acutely appearing EEG changes disappear within weeks. By the end of the three months, most of the changes have disappeared and about 90% of them have disappeared within a year. However, chronic abnormalities may persist in some individuals (16).

Just as considering multiple individual factors is essential for accurately predicting the prognosis of any disease, it is equally important to examine key demographic characteristics of patients. Among these, age and gender are typically the first and most critical variables to assess (17). Sex has not been extensively investigated as a prognostic factor, although minor sex related differences have been observed. It has been found that females are likely to suffer from post-mTBI epilepsy during childhood and young adulthood, thereby facing higher risks related to suicide, and at the same time making more frequent visits to health care facilities, while (13).Age is also another important determinant for the prognosis of traumatic brain injury (17). Incidence of mTBI is higher in a young population. The aging process is thought to interact with the pathological consequences of mTBI, exacerbating cognitive and functional impairments. Recovery time in children after injury is generally faster than in older patients and it is thought to be associated with better neuroplasticity of the brain in younger age. Having history

of prior traumatic brain injury is also an important predictor factor for recurrent mTBIs.The probability of long-lasting cognitive and mood disturbances, slower recovery, and in extreme cases, death, is increased.

Continuous TBIs may render the brain susceptible and are linked with enduring issues like impaired memory, pain in the head, and emotional disorders. Healthcare professionals should never underestimate good history taking in order to underline prior cases of mild traumatic brain injury. Pre-existing psychiatric conditions, including mood disorders, anxiety, ADHD, and substance use disorders increase both the risk and severity of post traumatic psychiatric complications following a traumatic brain injury (18,19). TBI itself frequently precipitates to new psychiatric disorders such as depression and anxiety, that can emerge even years after the injury. It testifies that TBI individuals who are also suffering from substance abuse have demonstrated poor results compared with TBI evident. According to the evidence, people suffering from traumatic brain injury and having the disorder of drug abuse undergo a much worse prognosis than those having TBI alone (18,19).

Traumatic brain injuries have a high occurrence rate in sports, with the most significant ones being in contact with sports like rugby, judo, and football. Sports injuries or those from falls are mainly caused by blunt force or rotational mechanisms due to rapid acceleration-deceleration. The absolute most focal brain injury caused by these situations is due to direct impact, which might be either a collision with another player or falling on the ground. In comparison, blast-related TBIs have complicated mechanisms, and the primary shock wave transmits mechanical energy to the brain, causing harm. The mentioned conditions can be the result of neurological injuries among which and most serious is the disruption of the blood-brain barrier, microvascular damage and finally diffused axonal injury in the whole affected region. One of the most common complications of mTBI is Post concussive syndrome (PCS), which is combination of physical, cognitive, behavioral, and emotional symptoms that frequently follow mild traumatic brain injury (18,19).

Individuals who have undergone multiple injuries are more predisposed to developing post concussive syndrome. The most prevalent situations are headaches, tiredness, problems with seeing, being unsteady, tinnitus, disorientation, not being able to sleep, and not being able to focus. Though about 90% of symptoms caused by concussion are temporal, meaning they usually go away in 10 to 14 days, still some patients may have the ones that last for several weeks. In case the symptoms last for over three months, it is called Persistent PCS and has an association with considerable deterioration in cognitive functions such as thinking, memory, learning, and logical reasoning. As a rule, women report more symptoms related to post-concussion syndrome like headaches, irritability, or fatigue. Advancing age is also risk factor for developing post concussive syndrome Effective evaluation and management of PCS may require several different medical field professionals to check patients, emphasizing collaboration among healthcare team members to optimize patient outcomes (19).

Limitations and Future Directions

In general, post concussive syndrome (PCS) has a good prognosis. The signs and the disturbance of the normal function are the most clear-cut in the first week after the injury, then they improve after a month, and by that time most of the symptoms disappear completely. Some elements, like the history of head trauma or more severe presentation of symptoms at onset, can foretell the extent of injury and the odds of symptoms being around for a long time. Predicting which group of patients will develop PCS can be very challenging due to its mild nature, overlapping features with many other medical conditions and underreporting of symptoms. Limitations at varying stages of diagnosing and treating patients create many challenges (20). First main issue is having no actual gold standard for diagnosis of mild traumatic brain injury. Nowadays, we combine different means of diagnosis such as biochemistry, neuroimaging, clinical assessment, which overall gives us general idea of patient's current condition. Both Neuroimaging and biomarkers have low sensitivity. The extensive dissimilarities among the studies, which consist of varying study designs, different patient populations, dissimilar assessment methods, and diverse outcome definitions, make it difficult to compare the results directly and thus, to arrive at uniform conclusions. One of the major problems that arise from mild traumatic brain injury is that it is underreported. This is mainly true for sports and military populations, where people might not recognize or even think about the symptoms to the full extent (20). As a result, the problem of mTBI diagnosis continues to be encountered in a very difficult way. It typically depends on a nonscientific interpretation of the symptoms, there are no diagnostic biological markers that are uniformly accepted, and so on. It is also affected by the differences in the way it shows up, different illnesses that might be present at the same time, and delay in the appearance of symptoms. All these things together cause difficulty in diagnosis, and consequently, in treatment by identifying the right symptoms and giving the needed intervention on time (20).

Conclusion

The accessible literature we have noticed demonstrates both improvement and development of knowledge regarding mild traumatic brain injury, but what is available is still rather disparate, patchy and is sufficiently constrained by methodological anomalies. Throughout the literature, it is stunning that clinical manifestation, biomarker alterations, and imaging results can be helpful, but none of these areas are presently reliable as a criterion that can be objectively utilized to diagnose or to predict. Numerous results are encouraging especially around new biomarkers and state-of-the-art neuroimaging modalities, though, once again, a variability exists among cohorts. The subjective nature of symptom-based assessment still prevails in clinical practice thus leading to inaccurate outcome prediction hence unreliable in cases of patients with subtle deficits or long-term recovery. Those gaps demonstrate the complexity of the condition as well as the necessity to conduct much larger and more standardized studies involving a variety of people with consistent and objective diagnostic definitions and tight follow-up guidelines. Despite the positive progress achieved, the area continues to be short of the quality evidence required to construct definite clinical trajectories, and future studies should aim

at lessening variability, and integrate multimodal data to create a more reliable and clinically applicable view of mTBI.

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