Neuropsychological Differential Diagnosis of Mild Traumatic Brain Injury

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The diagnosis and evaluation of mild traumatic brain injury (mTBI) is reviewed from the perspective of meta-analyses of neuropsychological outcome, showing full recovery from a single, uncomplicated mTBI by 90 days post-trauma. Persons with history of complicated mTBI characterized by day-of-injury computed tomography or magnetic resonance imaging abnormalities, and those who have suffered prior mTBIs may or may not show evidence of complete recovery similar to that experienced by persons suffering a single, uncomplicated mTBI. Persistent post-concussion syndrome (PCS) is considered as a somatoform presentation, influenced by the non-specificity of PCS symptoms which commonly occur in non-TBI samples and co-vary as a function of general life stress, and psychological factors including symptom expectation, depression and anxiety. A model is presented for forensic evaluation of the individual mTBI case, which involves open-ended interview, followed by structured interview, record review, and detailed neuropsychological testing. Differential diagnosis includes consideration of other neurologic and psychiatric disorders, symptom expectation, diagnosis threat, developmental disorders, and malingering. Copyright © 2013 John Wiley & Sons, Ltd.

DEFINITION AND OUTCOME OF mTBI

Mild traumatic brain injury (mTBI) is the most frequent type of case seen by neuropsychologists doing forensic work in personal injury settings (Ruff & Richardson, 1999). These cases can be misdiagnosed by clinicians who do not understand how to evaluate the clinical evidence that indicates an mTBI has occurred. Many cases seen by the authors that have been diagnosed as having suffered mTBI, or post-concussion syndrome (PCS), do not show acute injury characteristics consistent with TBI, and the opposing neuropsychologist often fails to consider non-neurologic factors that can account for symptomatic complaints and test performance, including evidence for probable malingering.

Although varying definitions of mTBI have been offered, most definitions require the presence of an alteration of ongoing mental processing, either due to loss of consciousness or due to post-traumatic amnesia (PTA), the period of confusion and disorientation that follows a neurologically significant trauma to the head. mTBI definitions typically require that loss of consciousness is restricted to 30 minutes or less, that PTA

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does not persist beyond 24 hours, and that the initial post-resuscitation Glasgow Coma Scale (GCS) is in the range of 13–15 (Mild Traumatic Brain Injury Committee, ACORM, 1993; World Health Organization, Carroll et al., 2004). However, the largest TBI outcome study examining all ranges of severity, up to and including injured persons who took up to 30 or more days to follow commands, defined mTBI as being able to follow commands up to one hour post-trauma (Dikmen, Machamer, Winn, & Temkin, 1995). This mTBI group showed no neuropsychological performance differences at one year follow-up in comparison to the performance of a group of orthopedic trauma controls, suggesting that the period of loss of consciousness could be expanded to just under one hour (i.e., 59 minutes). Last, there is evidence suggesting that cases who would otherwise match criteria for mTBI, with brief loss of consciousness, GCS of 13–15, and/or PTA of less than 24 hours, but who have evidence of contusion on CT may comprise a category better characterized as “complicated” mTBI (Williams, Levin, & Eisenberg, 1990). Persons with “complicated” mTBI may have outcomes that are more similar to those experienced by persons classified as having sustained moderate TBI (GCS of 9–12; loss of consciousness (LOC) up to 24 hours, PTA < 7-days; Kashluba, Hanks, Casey, & Millis, 2008; Williams, Levin, & Eisenberg, 1990). Others, however, have not found performance differences between persons who have suffered “complicated” mTBI and those who have suffered mTBI (Lange, Iverson, & Franzen, 2009). Indeed, the investigation by Dikmen, Machamer, Winn, & Temkin (1995) did not exclude subjects from their mild group on the basis of abnormal CT scan findings.

The typical neuropsychological outcome of a single, uncomplicated mTBI is full recovery of general neuropsychological abilities by three months post-trauma. This has been demonstrated in numerous meta-analytic investigations of outcome of mTBI (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Binder, Rohling, & Larrabee, 1997; Frencham, Fox & Maybery, 2005; Pertab, James, & Bigler, 2009; Schretlen & Shapiro, 2003). Meta-analysis combines data from previously conducted research, specified as meeting certain minimum methodological standards, by aggregating effect sizes across studies. Effect sizes are computed by dividing the difference between the target group mean and control group by the pooled standard deviation (SD), thereby representing the distance between groups in SD units (Lipsey & Wilson, 2001). Thus, a one SD difference would yield an effect size, \( d \), of 1.00, and a half of an SD difference would yield a \( d \) of 0.50. Very large values of \( d \) are associated with greater differences between the groups, with very small values representing significant overlap between the target group and the control group. Cohen (1988) published non-overlap statistics associated with various magnitudes of effect sizes. For example, an effect size \( (d) \) of 1.00 results in a non-overlap of 55.4% of the two distributions. Similarly, for an effect size of 2.00, 81.9% of the two distributions do not overlap. Stated differently, for \( d = 1.0 \), there is a 44.6% overlap of mTBI and control group performance, dropping to an 18.1% overlap for \( d = 2.0 \). Returning to the five meta-analyses of mTBI reported earlier, the effect sizes ranged from \(-0.11\) to \(0.04\), at over 93 days post-trauma, with none of these values significantly different from zero. The median effect size of \(-0.07\), based upon overall neuropsychological functioning from these five different studies, was associated with 5% non-overlap (i.e., 95% overlap) of the mTBI and control group samples (Cohen, 1988).

Outcome data have also been meta-analyzed as a function of neuropsychological test domain and time post-trauma (Rohling et al., 2011). Domains showing the greatest effect sizes within the first week post-trauma included working memory, verbal and visual
learning and memory. At 93 days, only the working memory domain effect size of −0.19 was significantly different from zero, but the magnitude of this effect was too small to be useful diagnostically, as it represented an 86% overlap between mTBI and control samples. Moreover, this effect size is equivalent to a Wechsler Adult Intelligence Scale-IV Working Memory Index value of three points, essentially the same magnitude as the measurement error of this index score. Although the majority of meta-analytic research focused on neuropsychological outcome, good outcome without residual psychological problems was reported in a meta-analysis by Panayiotou, Jackson, and Crowe (2010), who calculated an overall effect size of 0.05 for measures of depression, anxiety, coping and psychosocial disability, with no domain significantly different from zero. Good outcome is also seen in children as well as in older adults (Babikian, Satz, Zaucha, Light, Lewis, & Asarnow, 2011; Goldstein & Levin, 2001).

Despite these well-conducted meta-analyses demonstrating no persistent effects of mTBI, many studies not included in these meta-analyses due to methodological flaws have reported significant findings. The major meta-analytic outcome investigation by Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg (2005) addressed the contribution of research design to effect size. These authors showed that prospective studies, with enrollment at the time of trauma, yielded a chronic (≥ 3 months) effect size of −0.04, contrasted with the effect sizes of −0.74 for clinic samples presenting with persisting complaints, and −0.78 for samples of persons in litigation. Furthermore, Belanger et al. (2005) found that presence of litigation was predictive of either stable or worsening cognitive function over time. Consequently, non-prospective subject recruitment (i.e., recruited at some delayed time post-trauma or recruitment from specialized concussion clinics) and studies of persons in litigation did not yield data that are representative of outcome from mTBI.

Recruitment of persons for mTBI research on the basis of self-reported history of mTBI can lead to spurious findings due to expectancy effects and what is known as “diagnosis threat.” Recognition of “diagnosis threat” as a biasing effect in mTBI litigation cases is of critical importance. Mittenberg, DiGiulio, Perrin and Bass (1992) demonstrated that non-injured persons imagining that they had sustained an mTBI endorsed the same symptom complaints as did persons who actually suffered an mTBI. Suhr and Gunstad (2002, 2005), in studies of “diagnosis threat,” found that persons with a history of mTBI who associated the reason for evaluation as due to their history of mTBI performed significantly worse than did persons with a history of mTBI who did not perceive the assessment to be related to their history of mTBI.

Use of orthopedic trauma controls provides the smallest effect sizes for mTBI versus control comparisons (e.g., −0.02 in Dikmen et al., 1995), as the orthopedic trauma controls themselves show evidence of reduced neuropsychological abilities of approximately 0.50 SDs compared with demographically adjusted normative data (e.g., see Larrabee, Binder, Rohling, & Ploetz, 2013). Larrabee et al. (2013) discussed additional evidence of pre-existing neuropsychological differences in persons sustaining mTBI, as provided by studies showing that mTBI subjects produced reduced scores on measures of pre-morbid estimates of intellectual function in comparison to demographically matched controls (Heitger, Jones, Macleod, Snell, Frampton, & Anderson, 2009, effect size for Wechsler Test of Adult Reading is −0.75; Mathias & Coats, 1999, effect size for National Adult Reading Test is −0.53). Pre-existing psychiatric problems are predictive of persistent symptoms 3 months post-injury in both mTBI and orthopedic trauma control subjects, whereas, mTBI itself was only predictive of post-concussive symptoms at one week but not at three months (Ponsford et al., 2012). In a study of
military veterans who sustained an mTBI after military service, the strongest predictors of post-mTBI outcome were early life psychiatric difficulties, limited social support, and lower pre-mTBI intelligence as measured by pre-military induction aptitude tests (Luis, Vanderploeg, & Curtiss, 2003). This underscores the importance of using an orthopedic trauma control group to compare to an mTBI group: this controls for pre-existing psychological and neuropsychological differences that could relate to the experience of becoming injured, as well as potential differences in reaction to injury that are due to injury in general, but not specifically due to brain trauma.

The importance of orthopedic trauma controls extends to neuroimaging investigations. For example, Aoki, Inokuchi, Gunshin, Yahagi, and Suwa (2012) reported an effect size of \(-0.25\) for diffusion tensor imaging (DTI) fractional anisotropy in the corpus callosum of mTBI patients compared with controls, but only one of the 13 studies included in the meta-analysis used an orthopedic trauma control group, and the effect size for this study was \(-0.07\), the second smallest effect size in the study. This particular study also found no DTI differences between those mTBI subjects meeting criteria for PCS and those who did not meet these criteria (Lange, Iverson, Brubacher, Madler, & Heran, 2012).

It is likely that poorly designed mTBI research, lacking appropriate subject recruitment and failing to include orthopedic trauma control subjects, has contributed to the belief in the existence of a “miserable minority” (i.e., a subgroup of mTBI patients who do not recover). Ruff and colleagues (Ruff, Camenzuli, & Mueller, 1996; Ruff et al., 1994) first coined this term to define a subgroup of persons suffering mTBI followed by chronic symptomatic complaint. Pertab, James, & Bigler (2009) were unable to statistically define a subgroup characterized by poor outcome, but also presented two hypothetical distributions, one of which contained an mTBI and control group, and the other that contained both of these groups as well as a third smaller group with poorer outcome. Pertab et al. (2009) offered these hypothetical distributions to illustrate how the same overall effect size might occur with an impaired subgroup of mTBI that is masked by the overall outcome of the larger mTBI group. Rohling, Larrabee, and Millis (2012) demonstrated statistically, based on published meta-analytic data, that an impaired subgroup masked within a larger group experiencing full recovery simply does not occur. Not only did the two hypothetical figures offered by Pertab et al. not yield identical effect sizes, but the effect size of the impaired subgroup was implausibly large at \(d = -4.06\) [note the effect size for the Dikmen et al. (1995) severe TBI group that took more than 30 days to follow commands was \(-2.31\), as per Rohling, Meyers, & Millis, 2003]. Using the overall effect size of \(-0.07\) obtained by Rohling et al. (2011); Rohling et al. (2012) computed the effect size necessary for an impaired subgroup that would yield the same overall effect size as outcome data that did not assume the existence of an impaired subgroup. This is displayed graphically in Figure 1. As can be seen, the primary mTBI and control samples overlap nearly completely, and the nested impaired subgroup brackets the mean of both the mTBI and control samples, falling completely underneath these distributions, as well as far from the extremes of both distributions.

To summarize, meta-analytic investigations of well-conducted outcome studies of mTBI are consistent in demonstrating no significant neuropsychological differences at three months or longer post-trauma. The literature reviewed here shows that there are many other factors independent of mTBI that can be related to impaired neuropsychological test performance (see Larrabee et al., 2013 for more detailed review of these
non-TBI issues). Before considering the separate, but related, issue of chronic PCS, factors that may contribute to persistent neuropsychological deficits in persons who have not suffered a single, uncomplicated mTBI will be addressed: complicated mTBI, and mTBI in a person with a history of multiple prior mTBIs.

OUTCOME OF COMPLICATED mTBI AND MULTIPLE mTBIs

Complicated mTBI has been reviewed in the earlier discussion of the definition of mTBI. As originally described by Williams et al. (1990), persons who would otherwise meet criteria for mTBI but have abnormal CT scans, characterized as “complicated” mTBI, have outcomes that are more similar to those of persons with moderate TBI (e.g., persons with day-of-injury post-resuscitation GCS of 9–12). More recently, Kashluba, Hanks, Casey, & Millis (2008) reported similarities between the neuropsychological outcome of persons with “complicated” mTBI and those with moderate TBI. By contrast, Hanlon, Demery, Martinovich, and Kelly (1999) found no differences in neuropsychological test performance or vocational outcome between mTBI patients with positive and those with negative computed tomography (CT) scans at six months post-injury. Hughes, Jackson, Mason, Berry, Hollis, & Yates (2004) found neuropsychological differences at 72 hours comparing positive and negative magnetic resonance imaging (MRI) mTBI patients, but at six months the groups did not differ neuropsychologically, nor did they differ on return to work or on PCS endorsement. In summary, persons who otherwise meet criteria for mTBI but who show abnormal CT or MRI on acute radiologic studies may have outcomes more similar to those
associated with moderate TBI. Persons with complicated mTBI may or may not make the full recovery characteristic of persons sustaining a single, uncomplicated mTBI.

Persons with mTBI who have history of pre-existing mTBIs may have a different outcome than typical, with evidence of persisting deficits. Belanger, Spiegel, and Vanderploeg (2010) found a non-significant overall effect size of $-0.06$ for athletes sustaining more than one self-reported mTBI compared with those sustaining only one mTBI. Follow-up analyses of specific domains of function showed significant effect sizes for executive functions ($-0.24$) and delayed memory ($-0.16$). While significant, these values are quite small and associated with low percentage non-overlap (17% and 12% non-overlap, respectively, per Cohen, 1988). One pediatric investigation suggested that persons who sustain multiple mTBIs may differ pre-morbidly from those with histories of no prior mTBI. Bijur, Haslam, and Golding (1996) found no evidence for the cumulative effects of mTBI in comparing children with histories of one, two or three mTBIs with non-head-injured orthopedic trauma controls who had a history of one, two or three orthopedic injuries. Bijur, Haslum, and Golding (1996) suggested that cognitive deficits associated with multiple mTBIs were secondary to social and personal factors related to multiple injuries rather than resulting from damage to the head. The results from Bijur, Haslam, & Golding (1996) underscore the present authors’ recommendations for including orthopedic trauma controls as the most appropriate comparison group in prospective research on mTBI (Larrabee et al., 2013).

Summarizing, existing research is equivocal regarding both persistent effects of “complicated” mTBI and cumulative effects of multiple mTBIs. This requires careful analysis of the individual case showing evidence for either of these clinical histories. History of pre-existing mTBI or someone with LOC of 15 minutes followed by GCS of 14, PTA < 24 hours, but who has a CT scan showing a contusion or a subdural hematoma with minimal mass effect is not guaranteed to have evidence of persisting neuropsychological deficits. Rather, early records should be scrutinized for evidence of prolonged confusion, and for documentation of cognitive deficits in the acute and subacute period of time following trauma. Rapid resolution of disorientation, within two hours post-trauma, with subsequent rapid return to normal mentation may predict a recovery pattern no different from uncomplicated mTBI. Prolonged evidence for abnormal mentation and symptomatic complaints extending to several days post-trauma may be more predictive of a more significant TBI. Importantly, these data must be collected contemporaneously, as documented in the acute and subacute records, and not based on the examinee’s recollection several months post-trauma. The exception would be determination of clearing of PTA based on retrospective interview, corroborated with comparison to description of orientation in the contemporaneous medical records, as will be discussed further in the section dealing with the evaluation of the individual forensic mTBI case.

**POST-CONCUSSION SYNDROME**

Post-concussion syndrome refers to a constellation of somatic (e.g., headache), cognitive (e.g., memory), and emotional (e.g., irritability) symptoms following mTBI (Alexander, 1995; Axelrod et al., 1996). There has been a long-standing controversy about whether PCS results from neurologic factors or psychogenic factors. Data reported by McCrea et al. (2003) support a physiologic basis to PCS over the first week.
following sports concussion. At seven days post-trauma, PCS symptoms abate, concurrently with normalization of both cognitive function and balance testing. A neurologic basis to long-term or chronic PCS is not supported by the normalization of neuropsychological function by three months post-trauma, referenced earlier. Rather, the evidence is substantial that persistent PCS can be explained on the basis of psychological factors, provided that malingering can be ruled out (Larrabee et al., 2013).

A significant issue is the lack of specificity of PCS symptoms due to their common occurrence in everyday life. For example, symptoms of forgetfulness, irritability, and headache are common everyday human phenomena that are more likely to occur in the presence of distress. Lees-Haley and Brown (1993) had 50 non-litigating medical outpatients and 170 persons in litigation for psychological stress or distress but without neurological claims or injuries complete a neuropsychological symptom checklist, and found high rates of endorsement of symptoms such as headache (62% medical controls, 88% psychiatric claim litigants), irritability (38% of medical controls, 77% of psychiatric claim litigants), and poor memory (20% of medical controls, 53% of psychiatric claim litigants). These endorsement percentages can be compared with those of persons who actually sustained mTBI as reported by Mittenberg, DiGiulio, Perrin, & Bass (1992): 59.1% reported headache, 65.9% reported irritability, and 50.6% reported forgetting why they entered a room, the most frequently endorsed memory complaint. It is noteworthy that the endorsement percentages of the mTBI subjects are all lower than those of the psychiatric claimants studied by Lees-Haley and Brown (1993). Garden and Sullivan (2010) reported high rates of endorsement of PCS symptoms in healthy university students and healthy community volunteers (e.g., 81% endorsed headache, 78% endorsed irritability, and 56% endorsed memory problems). Moreover, a subsample of the Garden and Sullivan study that was depressed produced even higher endorsement of headache (96%) and memory problems (75%). Other investigators have noted the similarity of PCS endorsement by patients with chronic pain (Iverson & McCracken, 1997), and depression and headache (Gunstad & Suhr, 2004). Research on self-reported cognitive function in groups other than mTBI showed stronger associations with level of depression than with actual cognitive performance (e.g., Larrabee & Levin, 1986; Larrabee, West, & Crook, 1991; Williams, Little, Scates, & Blockman, 1987) or secondary to somatization (Hanninen et al., 1994). Minnesota Multiphasic Personality Inventory-2 (MMPI-2) items purported to “correct” for endorsement secondary to legitimate neurologic problems showed no association with initial GCS, duration of post-traumatic amnesia, or actual neuropsychological test performance in persons with TBI but, rather, showed significant associations with the MMPI-2 Depression Content scale (Brulot, Strauss, & Spellacy, 1997). If PCS symptoms are not related to test performance, acute indices of coma or PTA, and are not seen only in persons with TBI, the entire construct of chronic PCS comes into question.

Moreover, symptoms may also be non-specific on an acute basis. Lees-Haley, Fox, and Courtney (2001) found that 67% of an mTBI sample reported being confused and 71% reported feeling dazed at the time of injury, but 65% and 52%, respectively, of the “other injury” group reported these same symptoms. This calls into question the symptoms of feeling dazed and confused that are included in the American Congress of Rehabilitation Medicine’s (ACORM, 1993) definition of mTBI; the symptoms may not reflect the presence of mTBI. Instead, one should rely upon GCS and direct mental status testing, rather than patients’ subjective complaints.
The afore-cited investigation by Mittenberg et al. (1992), which showed similar PCS symptom endorsement for persons imagining they suffered mTBI and those who actually suffered mTBI, explained these results on the basis of a selective attentional bias to common internal states, stress, and arousal. Putnam and Millis (1994; see also Putnam, Millis & Adams, 1996) provided a similar explanation of PCS symptom endorsement, and characterized chronic PCS as a somatoform disorder, drawing parallels between the selective attentional bias in persons with chronic PCS and the self-directed selective attention to bodily sensations in persons with elevated health concerns [see Watson and Pennebaker (1989) and Delis and Wetter (2007) describing cogniform disorder]. Actually, the fact that PCS symptoms commonly occur in everyday life and are not specific to mTBI or other neurologic dysfunction creates a “perfect storm” in a patient who is unduly somatically preoccupied. If such a patient encounters a provider who diagnoses these symptoms as due to mTBI, the patient will now misattribute these common occurrences as evidence of their brain trauma, experiencing greater stress, and thereby more frequent occurrence of these “symptoms” of PCS. As demonstrated by the diagnosis threat research of Suhr and Gunstad (2002, 2005), the belief that one has sustained a brain injury can have a negative effect on actual neuropsychological test performance. This sequence of influences can be considered a form of iatrogenesis (treatment caused disorder; Roth & Spencer, 2013). Drawing on this expectation-as-etiology model of PCS, Mittenberg and colleagues have developed a cognitive behavioral treatment of PCS that has, as a main component, correction of misattribution of symptoms (Mittenberg, Tremont, Zielinski, Fichera, & Rayls, 1996; Mittenberg, Zielinski & Fichera, 1993).

FORENSIC EVALUATION OF mTBI

There are three components to the forensic neuropsychological evaluation, referred to as the evidentiary tripod by Greiffenstein and Kaufmann (2012): record review, interview, and direct neuropsychological and psychological testing.

Thus, in working up a forensic case, a clinician can begin with evaluation of the acute injury characteristics (from record review and by interview). Important records include those from the emergency transport (EMS) and hospital services and early post-injury doctors’ visits. The forensic examiner looks for spontaneous expression of symptoms, not responses to symptom checklists that can be leading, particularly for somatically preoccupied persons. One should not ask, “Were you stunned?” as this is a common reaction in persons who are not brain-injured (Lees-Haley et al., 2001). Rather, look for EMS records documenting confusion or disorientation. Clinical interview, in an open-ended format, should include asking examinees to provide a step-by-step description of the accident, including the time the accident occurred, how long they were in hospital, when they were discharged and how they returned home from the hospital (which is then cross-checked with the records). Records should note GCS (best eye opening + verbal + motor response). Uncomplicated mTBI is indicated by a GCS of 13–15 without abnormal day-of-injury CT or MRI. Some would also include normal neurologic examination. PTA is the period of confusion and disorientation following a TBI. Research has shown that for about two-thirds of subjects, PTA clears once orientation to time returns (i.e., orientation in the three realms of person, place and time is the typical order of recovery of orientation, prior to resolution of
PTA; High, Levin, & Gary, 1990). Consequently, GCS of 15 marks the end of PTA, as does the notation "A and O × 3." It is common to see cases where a patient’s return of recollection of events, established in careful clinical interview, corresponds to notations of "O × 3" in the medical records. Other medical records that are noteworthy include reports of normal CT or MRI. Procedures such as quantitative electroencephalogram (QEEG), positron emission tomography (PET) and single photon emission tomography (SPECT) are not recognized and accepted mainstream procedures for evaluation of mTBI (Granacher, 2008; Nuwer, 1997). DTI imaging remains investigational, with some studies showing no clinically meaningful discrimination of mTBI from orthopedic trauma control subjects (Lange et al., 2012), and a meta-analysis showing a small effect size of 0.25 with high (82%) overlap of DTI values with a non-mTBI comparison sample (Aoki et al., 2012).

Detailed interview of a plaintiff not only provides information relevant to assessment for PTA, but also provides evidence for evaluation of potential post-traumatic stress disorder (PTSD). Specifically, does the subject become aroused and obviously distressed upon describing the event in detail? Do they spontaneously comment about feelings of terror and horror when viewing a severely injured/deceased person at the scene of the accident, or offer comments of guilt that a family member or friend was more seriously injured? Can they report in sequence the doctors seen and what their understanding was of each doctor’s diagnosis? What are their spontaneous complaints? Do they have pain complaints (many do)? Examinees can be asked to describe pains using a 0–100 scale with the anchor points “no pain at all,” versus “pain so severe they would want to die to escape it.” (Larrabee, 2003a). Current pain is rated, as well as pain at its worst, pain at its least, what makes it better, what makes it worse, is there any daily, weekly, monthly or seasonal pattern to pain, and is there any way to predict it. What are their current medications? When was the last time they took narcotic analgesics, anxiolytics, and muscle relaxers? Background history is also important, in particular for ruling out pre-existing problems such as attention deficit hyperactivity disorder (ADHD), major psychiatric disorder, and history of physical or emotional trauma. Questioning about family history, parents, health of parents, siblings, and their educational, social, occupational and health histories is important. Following questioning about the claimant’s nuclear family, it is usually opportune to ask questions about the plaintiff’s early childhood and whether or not they experienced any physical or emotional trauma. Plaintiffs’ educational, social, occupational, and health histories should be carefully reviewed.

Use of a structured interview can be informative, for example, the structured interview published in Levin, Benton, and Grossman’s (1982) book on closed head injury. There are many advantages of going from open-ended questioning in the main interview to specific questions in the structured interview. First, the open-ended interview gives you the concerns that are primary for the plaintiff. The structured interview can sometimes lead to a global over-endorsement of problems not previously mentioned. Whereas this may be due to neurological factors related to anosognosia in a severely injured subject, mTBI is not characterized by denial or minimization of deficits. Rather, there is a tendency of those with persistent problems that have led to litigation to be either suggestible individuals or persons not seriously injured who are trying to exaggerate deficits, in which case many more symptoms are elicited by structured than by open-ended interviewing. The difference in symptoms elicited in open-ended versus structured interview may then aid in differential diagnosis.
The third component of the forensic evaluation of mTBI is the actual testing portion of the examination. Since the direct testing portion of the examination is dependent upon the accuracy of symptom report and whether the test data accurately represent actual level of ability, there should be a direct assessment of symptom validity using symptom validity tests (SVTs), and of performance validity using performance validity tests (PVTs; Larrabee, 2012a). Accuracy of symptom report can be evaluated by specialized SVT validity scales on omnibus personality tests such as the F-r (the MMPI-2-RF version of the F scale, Infrequent Response Scale on the MMPI-2), Fp-r (the MMPI-2-RF version of the MMPI-2 Infrequent Psychopathology Response Scale), Fs, FBS-r (the MMPI-2-RF version of the MMPI-2 Symptom Validity Scale) and RBS (Response Bias Scale of the MMPI-2-RF), as well as by over-endorsement patterns on pain scales (Larrabee, 2003a). Accurate representation of actual ability can be assessed by free-standing PVTs such as the Test of Memory Malingering (Tombaugh, 1996), or by procedures that are embedded in or derived from traditional neuropsychological tests such as Wechsler Adult Intelligence Scale-Revised Digit Span (Greiffenstein, Baker, & Gola, 1994), the Auditory Verbal Learning Test (Barrash, Suhr, & Manzel, 2004), the Continuous Visual Memory Test (Larrabee, 2009) or Finger Tapping (Arnold et al., 2005). These embedded or derived PVTs represent performances that are atypical in pattern or degree for bona fide neurological or psychiatric disorders. Rather, the performance patterns captured by these PVTs are typical of performances by non-injured persons simulating (feigning) brain impairment, or by persons identified as probable malingerers by failure of existing, validated PVTs in the presence of a significant external incentive. These atypical performances can manifest as impaired attention in the context of normal memory (Mittenberg, Azrin, Millsaps & Heilbronner, 1993), impaired gross motor but preserved fine motor skills (Greiffenstein, Baker, & Gola, 1996), or performances on tests of simple motor function that are worse than those seen in patients suffering Parkinson’s or Huntington’s disease (Greiffenstein, 2007).

Measures of PVT and SVT should be spaced throughout the examination, to provide continual sampling of the validity of a patient’s test results (Boone, 2009). Functional areas to be covered in a comprehensive neuropsychological evaluation include: language and verbal ability, spatial/perceptual functions, sensorimotor skills, orientation to time, attention, concentration, working memory, processing speed, verbal and visual learning and memory, intellectual and problem-solving skills, academic functions, personality testing, and pain scales if pain is a presenting complaint.

Interpretation of the test data integrates information from record review, interview, and direct examination. Larrabee (1990, 2012b) has previously proposed a consistency model that evaluates consistency of test performance within four different areas: within the test domain (e.g., Are more difficult tests performed less well than easier ones?); between the test domains (e.g., Does the patient show impaired attention but normal memory?); with actual behavior (e.g., Does the patient show excellent memory for post-accident history, but perform at Alzheimer levels on memory tests?); and with patterns associated with focal neurocognitive deficits or with known neurobehavioral disorders such as amnesia or dementia. If someone has multiple failed PVTs and SVTs in the context of the presence of compensation incentives, consistent with malingering, this does not automatically preclude test interpretation. What this does indicate is that, particularly in uncomplicated mTBI, which should not produce significant impairments, poor performances are more likely the result of intentional underperformance, while normal range scores themselves may be underestimates of actual level of function. This can
allow the presence of persisting impairment to be ruled out if someone performs normally on a sensitive verbal supraspan learning test such as the Auditory Verbal Learning Test and shows preserved processing speed on Trail Making B, despite showing evidence of invalid performance and symptom exaggeration by failing Reliable Digit Span, Finger Tapping, and producing an MMPI-2-RF Response Bias Scale T score of 100.

Examples of misinterpreted data abound. These include obtaining an impaired Controlled Oral Word Association (COWA) score in an illiterate man (who could pass animal naming, but who, understandably, could not say the alphabet, hence COWA should not have been administered), invalid MMPI and Personality Assessment Inventory in a man who read at the third grade level (reading was not assessed by the opposing expert), who left school in the eighth grade at age 16, or the case of an examinee who produced a Wechsler Memory Scale-Revised Attention/Concentration Index of 75 with a General Memory Index of 129, which was interpreted as showing brain damage (one would not be expected to have superior memory in association with impaired attention).

The differential diagnosis of mTBI includes non-neurologic influences on neuropsychological test data, such as PTSD, anxiety, and depression, as well as pre-existing developmental disorders. Malingering is a commonly occurring phenomenon, approximating 40% of mTBI in litigation (Larrabee, 2003b; Mittenberg, Patton, Canyock, & Condit, 2002).

Levin, Brown, Song, McCauley, Boake, Contant, & Kotrla (2001) found that a combined group of mild ($n=60$) and moderate ($n=9$) TBI patients did not differ in neuropsychological performance from a group of 52 general trauma (GT) patients at testing done three months post-trauma. When the TBI and GT patients were rearranged into groups showing presence or absence of major depressive disorder or groups showing presence or absence of PTSD, neuropsychological differences emerged as a function of type of psychiatric disorder. Depressed patients (TBI and GT) performed worse than non-depressed patients (TBI and GT) on processing speed, verbal and visual memory, and abstraction and set shifting skills. PTSD patients (TBI and GT) performed worse than TBI and GT patients without PTSD on abstraction and set shifting skills.

Figure 2 helps to illustrate the relevant differential diagnoses, as well as providing reference groups for more severely impaired neurological disorders, utilizing effect sizes. Effect sizes, again, are a useful heuristic for considering differential diagnosis, as they represent the distance, in SD units, between the target clinical group and a control group. The larger the effect size, the more impairment is displayed by the target group, and the larger the group separation. Effect sizes for moderate mental retardation, Alzheimer's disease, and schizophrenia are based on composite Wechsler Adult Intelligence Scale-III/Wechsler Adult Intelligence Scale-IV/Wechsler Memory Scale-III/Wechsler Memory Scale-IV index scores as computed from the respective Wechsler test manuals (as per Rohling et al., 2012). The substance abuse, PTSD, affective disorder, personality disorder, and neurosis effect sizes are based on data published by Weiser et al. (2004). The diagnosis threat effect size is derived from data published by Suhr and Gunstad (2002, 2005). Effect sizes for the varying severities of TBI, as a function of duration of LOC, are derived from Dikmen et al. (1995) as reanalyzed by Rohling et al. (2003). Pre-morbid mTBI differences (pre-mTBI Wechsler Test of Adult Reading, and pre-mTBI National Adult Reading Test, both tests of single-word reading) are computed from data published by Heitger et al. (2009) and Mathias and Coats (1999). Trauma control effect size is computed from data published by Dikmen et al. (1995) in comparison to expected demographics-adjusted normative data.
published by Heaton, Grant, and Matthews (1991) for the Halstead Impairment Index. Lastly, data for mTBI are from Rohling et al. (2011). As can be seen in Figure 2, the largest effect sizes are for moderate mental retardation, Alzheimer-type dementia, moderate to severe TBI, and schizophrenia. The smallest effect size is for uncomplicated mTBI (Rohling et al., 2011), which is about one-tenth the magnitude of the effects of substance abuse, PTSD, and major affective disorder. More importantly, the effect size for uncomplicated mTBI is seven times smaller than the neuropsychological differences seen in non-brain-injured orthopedic trauma controls or seen in association with attributing the reason for neuropsychological evaluation to history of mTBI, characterizing the effects of diagnosis threat.

For further contrast, intentional feigning or malingering produces neurocognitive test scores that fall far into the impaired range with an effect size of $-1.43$ SDs below their estimated true ability (Rohling, Allen, & Green, 2002). Certain tests, such as the forced-choice Digit Memory Test, show even larger effect sizes equal to or exceeding $2.00$ (Vickery, Berry, Inman, Harris, & Orey, 2001). Such effect sizes are of a very large magnitude, in the range obtained by severe TBI and Alzheimer’s disease, and are over 20 times greater than the non-significant effects averaging less than one-tenth of an SD that are expected for a person who has suffered an uncomplicated mTBI.
CONCLUSIONS

The typical outcome of uncomplicated mTBI is full and complete recovery. Persisting problems following such an injury, including persistent PCS, are often due to psychosocial factors, including diagnosis threat and expectancy effects. Many of these psychosocial factors are independent of the original physical trauma.

Complicated mTBI, characterized by the presence of day-of-injury CT abnormalities, despite otherwise meeting criteria for mTBI, can result in outcomes more similar to those experienced by persons suffering moderate TBI. Such persons may or may not make a full and complete recovery. Similarly, persons sustaining multiple mTBIs may or may not show the recovery associated with a single mTBI, and must be carefully analyzed as to whether acute and subacute factors suggest a more protracted neuropsychological outcome. What might appear to represent a cumulative effect of multiple mTBIs may actually reflect pre-morbid neuropsychological differences related to risk for experiencing multiple injuries, in general.

Three sources of data for forensic neuropsychological evaluation of mTBI are required, including medical records, direct interview of the claimant, and comprehensive neuropsychological and psychological testing. Data collected from testing are first subjected to analysis of performance validity and symptom validity, and then analyzed for consistency within test domain, between test domains, with actual behavior, and with patterns associated with focal or diffuse neurocognitive deficits. Given the strong meta-analytic evidence of full and complete recovery following uncomplicated mTBI, careful differential diagnosis is important in the individual forensic case, wherein apparent continuing complaints and neuropsychological test score abnormalities may be due to factors other than the original mTBI, including pre-existing psychiatric or developmental disorders, expectancy effects, “diagnosis threat,” and chronic pain. Malingering of deficits often accounts for continuing symptoms and demonstrated neuropsychological impairments in litigated mTBI.

ACKNOWLEDGMENTS

Doctors Larrabee and Rohling provide forensic consultation related to traumatic brain injury. Dr. Larrabee is a co-author of the Continuous Visual Memory Test and receives royalties from the sales of this test. No other potential for conflict of interest is present.

REFERENCES


Differential diagnosis of mTBI


