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While the diagnosis of TBI runs the spectrum from “mild” through “severe”, each individual patient’s injury along that spectrum can include characteristics which influence the prognosis and functional outcome. Even in mild TBI there can be features which affect functional capacity, be they cognitive deficits, emotional changes, behavioral dysfunction or physical disorders. It can be argued that *no one survives TBI unscathed,* and it is our collective responsibility as healthcare professionals to determine the nature and extent of disability that results from TBI while offering treatment and rehabilitation designed to maximize the individual’s overall functional outcome, including return to gainful employment and to a satisfying, productive life.

The loss of function due to TBI is not confined to physical and cognitive realms. TBI often changes *the person* in less overtly obvious ways which are often more difficult to measure. Emotional and behavioral changes are mostly what loved ones of those with TBI see as its lasting effects. Not uncommonly, the person who has sustained the TBI is less aware -- some are totally unaware -- of these changes in themselves and the associated problems which interfere with interpersonal relationships, employment and day-to-day life more broadly. After all, it is the human brain which allows us to “observe ourselves”, notice mistakes we make, edit what we think before we speak, take corrective action and reign in impulses. We must have the ability to plan the day’s events, organize our thoughts, select the proper word, and engage in complex multi-step activities simply to get to work, let alone function effectively in the workplace. Injury to the brain can render dysfunctional each of these, and many other, important human social functions. Herein lies the dilemma – how do we predict the disability in specific terms when we find it so difficult measure the very human characteristics which lead to disability of social and vocational skills.

Further complicating the picture is the knowledge that a person’s pre-injury function along all human dimensions plays a significant, if not dominant, role in the ultimate outcome attained. An individual who is prone to fret about the potential interference of the smallest of obstacles, or who obsesses over details to the point of near paralysis, will likely have difficulty adjusting to the new challenges of the deficits TBI brings. Those who live in the emotional state of chronic anxiety or depression before a TBI are more likely to experience problems adjusting emotionally to the often harsh realities they face in just getting through the day following TBI. It has been my observation that the

person after TBI is a caricature of the pre-injury person, with the most salient personality features even more evident. This does not bode well for the individual whose risk-taking behavior led to the injury in the first place, or whose interpersonal style was seen as disorganized or confrontational. There are several TBI factors which offer predictive information during the early states of care (emergency and intensive care) which will be expanded upon below. Those include, the initial Glasgow Coma Score (GCS), the presence and location of traumatic intracranial hemorrhage, and the presence and extent of intracranial hypertension (elevated intracranial pressure). Early complications such as anoxia (due to respiratory or cardiac arrest), stroke and infection (meningitis or encephalitis) carry poor prognosis.

The GCS is the most widely used acute injury severity scale ranging from 3 at the lowest to 15 at the highest. By convention the categories of severity are:

Mild TBI	GCS 13-15
Moderate TBI	GCS 9-12
Severe TBI	GCS 3-8

These categories roughly translate into intensity of medical intervention, length of hospitalization, need for medical rehabilitation, and functional outcome. Length of post-traumatic amnesia (PTA) has been shown to be a better predictor of outcome than GCS when measured daily by clinicians using an instrument called the Galveston Orientation and Amnesia Test (GOAT). That is, the longer the PTA the worse the outcome. One study showed that the presence of post-traumatic subarachnoid hemorrhage on CT scans was a stronger predictor of poor vocational outcome and neuropsychological function than either GCS or PTA.

Most research in TBI has relied upon the easily applied but rather insensitive Glasgow Outcome Scale (GOS) which is not particularly helpful when considering vocational status. The 5 item GOS scale is:

1. Death
2. Vegetative State
3. Sever Disability (conscious but dependent on others for activities of daily living or ADLs)
4. Moderate Disability (independent in ADLs and capable of participating in sheltered workshops or supported employment)
5. Good Recovery

As you can see, the range of outcomes internal to each of Levels 3, 4 and 5 is considerable. Only “Good Recovery” includes the possibility of return to competitive employment, but could also include those whom are unable to maintain gainful employment due to the neurobehavioral deficits mentioned above. More detailed outcome scales such as the Functional Independence

Measure (FIM) allow a more fine tuned method for assessing an individual's level of functioning, but these descriptive scales are limited by their own "snapshot" usefulness in depicting the level of function in the "here and now" while offering little or nothing in the prognosis of TBI in a given individual.

If we focus on severe TBI, we begin with standard diagnostic assessments used by paramedics at the scene and hospital personnel in the emergency care. The accepted diagnostic assessment is done by using the GCS which was designed to be used by physicians and non-physicians alike. It has high inter-rater reliability and it accurately grades the severity of the neurological dysfunction due to TBI. It is the most widely used clinical instrument internationally in the initial assessment of traumatic brain injury and is roughly correlated with outcome; that is, the lower the GCS the worse the outcome.

It is a truism that the diagnosis of TBI remains a clinical diagnosis made by the history and physical examination. However, the importance of the use of currently available neuroimaging technologies such as CT scans and MRI scans in the detection of intracranial pathology cannot be underestimated. For example, the presence of a sizable subdural hemorrhage which presses against the brain, thus compromising blood supply, represents a potential threat to like and function which requires neurosurgical evacuation and intensive neurological care. Traumatic contusions of the brain's cortex or deep within the substance of the brain indicate focal damage to anatomical structures superimposed on the widespread microscopic "common denominator" of diffuse axonal injury underlying TBI due to "closed head injury".

The length of coma, the length of post-traumatic amnesia, and the presence of deep brain lesions involving the thalamus or brainstem also factor into the ultimate outcome following TBI and affect vocational and academic status. Prognosis at the severe end of the brain injury spectrum is typically easier to determine. For instance, adults and children who emerge from coma into the unconscious condition called *vegetative state* are considered to be in "permanent vegetative state" one year after TBI or 3 months following anoxic brain injury. This means that fewer than 1% of those studied emerge from VS into a higher level of neurological function at those points in time. Even then those who do emerge from VS remain severely disabled. Experienced clinicians can offer reasonable prognoses on poor outcome from severe TBI if the following factors are present:

- Age over 60 years or under 2 years
- Duration of coma > 4 weeks
- PTA > 11 weeks
- Systolic BP < 90 during pre-hospital or emergency

Neuroimaging plays a central role in the diagnosis and prognosis of TBI, with CT scans most useful in the emergency and neurosurgical stages of acute injury,

and the more sensitive, time-consuming and costly MRI reserved for later stages of assessment. Both instruments are widely available in the United States and offer detailed anatomical localization and characterization of brain injury, adding a level of certainty upon which clinicians can then intervene. Surgical decisions are rarely made without information provided by these brain images. The management of intracranial pressure and many other nonsurgical treatments are guided by CT scans done routinely during intensive care. The detection of permanent anatomical injury responsible for functional deficits has been greatly improved by MRI scans performed days or weeks after the injury. Newer techniques such as diffusion tensor imaging and functional MRI show promise in visualizing injury to and dysfunction of complex neural networks engaged in mental as well as physical activity. Even so, it is often difficult to predict whether a given patient's injury will prohibit function many months in the future.

Offering a prognosis following mild TBI is much less certain. The injured individual's ability to cope with symptoms -- such as headache, dizziness, visual disturbance, and loss of cognitive power -- is a major determinant of successful return into pre-injury life. For high level athletes, airplane pilots, surgeons and others whose vocations require quick response times, accurate information processing and complex organizational skills, there are some common sense guidelines used by many clinicians. For me to medically clear an elite athlete to return to an activity which carries an inherent risk of mild TBI, these four criteria must be met:

1. The athlete must be symptom-free at rest and with exertion
2. The neurological examination must be entirely normal
3. An MRI Scan of the brain with gradient echo imaging must be normal
4. Neurocognitive assessment or neuropsychological evaluation must be normal

Allowing an athlete to return to a sport such as football or ice hockey with even one of these conditions unmet puts him/her a risk of additional injury or prolonged recovery from the original injury. Return to employed status must, first and foremost, take into account the well-being of the injured individual. While some high level occupations may not carry a significant risk of mild TBI, errors while performing routine job functions may cause significant risk to others, e.g., an airline pilot.

TBI in our military personnel while engaged in wartime activities carries a unique set of concerns. Readiness to return to military duty as the vocation implies being prepared to risk life and limb while engaged in military operations which themselves often involve the taking of lives. Quick decisions made under less than ideal conditions test the cognitive and emotional capacity of the fully intact and uninjured individual. Sleep deprivation, anxiety, hunger, thirst and excessive heat commonly exacerbate the problems. Anyone who sustains even a mild TBI under these conditions is more likely to experience concussive

symptoms and be adversely affected than those who sustain a mild TBI in civilian peacetime circumstances. Those returning from deployment in war zones require and deserve special consideration as to the emotional toll of their experiences, as well as the determination of lingering effects of blows to the head or from blast injury. Research is underway to examine the effects of deployed status on the ability to safely return to duty, but long-term outcome studies will be required to ascertain the true and potentially lingering affects of wartime experience.

Neurological disability comes in many forms, but is largely the product of who we are as individuals and what has happened to our brains. Efforts have been made to predict disability at an early stage following traumatic brain injury (TBI) with limited success. There is simply no injury severity scale, diagnostic scan of the brain or disability rating system which can accurately and reliably predict outcome for the vast majority of acute TBI cases. Further research is needed to follow those who sustain TBI for years, even decades. We must create a formula which can evolve as it takes into account the latest advances in pharmacologic neuroprotection, neuroimaging techniques, treatment protocols, regenerative medicine and rehabilitation science.

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