A Brief Review of Traumatic Brain Injury Rehabilitation

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Abstract

Introduction: This article aims to provide an overview of the epidemiology, medical and rehabilitation issues, current evidence for traumatic brain injury (TBI) rehabilitation, recent advances and emerging practices. Special TBI population groups will also be addressed. Materials and Methods: We included publications indexed in Medline and the Cochrane Database of Systemic Reviews from 1974 to 2006, relevant chapters in major rehabilitation texts and Physical Medicine and Rehabilitation Clinics of North America and accessed Internet publications. Results: TBI has been implicated by the World Health Organisation to be a 21st century epidemic similar to malaria and HIV/AIDS, not restricted to the developed world. One third of patients may suffer severe TBI with long-term cognitive and behavioural disabilities. Injuries to the brain do not only damage the cerebrum but may give rise to a multisystem disorder due to associated injuries in 20% of cases, which can include complex neurological impairments, neuroendocrine and neuromedical complications. There is promising evidence of improved outcome and functional benefits with early induction into a transdisciplinary brain injury rehabilitation programme. However, TBI research is fraught with difficulties because of an intrinsically heterogeneous population due to age, injury severity and type, functional outcome measures and small samples. Recent advances in TBI rehabilitation include task-specific training of cognitive deficits, computer-aided cognitive remediation and visual-spatial and visual scanning techniques and body weight-supported treadmill training for motor deficits. In addition, special rehabilitation issues for mild TBI, TBI-related vegetative states, elderly and young TBI, ethical issues and local data will also be discussed.

Ann Acad Med Singapore 2007;36:31-42

Key words: Disability, Head injury, Impairment, Neurorehabilitation, Vegetative state

Introduction

In 2005, accidents accounted for 4.9% (795) of deaths and were the fifth most common cause of death locally. Traumatic brain injury (TBI) is the most common cause of death and chronic disability in the under-35-year-old age group.[1] Accidents were the most common cause for hospitalisation locally, accounting for 404.7 per 100 000 admissions in 2005.[1] In modern America, injury is the leading cause of mortality for under-45-year-olds and TBI is responsible for the majority of these deaths.[2,3] Each year in the United States (US), around 50,000 people die after a TBI. This accounts for 1/3 of all injury deaths. In addition, 80,000 to 90,000 people experience lifelong disability associated with a TBI.[4,5] TBI is also often associated with polytrauma, fractures, spinal cord injuries, peripheral nerve injuries and limb amputations. Hence, the consequences of TBI are vast and encompass physical impairments, cognitive, psychological, behavioural and emotional deficits, with the latter 4 often bearing a heavy, hidden psychosocial and economic burden on this predominantly young population.

Epidemiology of TBI

In the US, the estimated annual incidence of hospitalised TBI is 200 per 100,000 persons. Severe and moderate head injuries account for 14 per 100,000 and 15 per 100,000 people respectively. The incidence of mild head injury (MHI) has been reported to be 131 per 100,000 people.

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These figures are largely underestimated due to classification and diagnostic errors as well as under-reporting of mild TBI, where patients may have been treated and discharged from primary healthcare facilities.[2] Approximately 52,000 US deaths per year occur as a result of TBI. In a Traumatic Coma Bank (TCB) data study, the mortality rate for severe brain injury was around 33%, and 2.5% for moderate brain injury. Approximately 5.3 million Americans or 2% of the population currently live with disabilities resulting from TBI.[6,7] The overall number of TBI cases has declined over the years following legislation as well as public education about preventive measures such as the use of helmets, the enforcement of passenger and child restraints, speed limits and tough drink driving penalties. Coupled with improvements in emergency medical evacuation, neurosurgical and intensive care, these changes have meant that more patients are surviving injuries that would have previously been fatal.[8,9]

The most frequent cause associated with both fatal and non-fatal brain injury is transport-related. It involves motor vehicles, bicycles, motorcycles and pedestrian-automobile accidents and accounts for around 50% of all accidents.[6,8] The second most significant cause of TBI is falls, which accounts for 20% to 30% of all injuries, especially among the very young and the elderly. In many parts of the world, assault is fast becoming one of the leading causes of brain trauma, particularly in the lower socio-economic groups and war-torn countries. Other significant causes include the use of firearms (around 12%) and sports or recreational-related activities.[10]

The risk of TBI is highest in the 15- to 24-year-old age group and decreases in the midlife years, but rises again after 70 years.[6] A second peak occurs in the elderly due to falls.[6] Younger persons, especially those under 5 years of age, are at moderate risk. This pattern reflects an increased exposure for young adults to motor vehicle accidents and increasing frailty in the elderly. Males are approximately 3 to 4 times as likely as females to sustain a TBI. This ratio narrows in the elderly. This is likely due to differences in risk exposure and lifestyles. Mortality rates are also higher in males, indicating a likelihood that men may sustain more severe injuries than women.[10] There is limited epidemiological or registry data on the prevalence of TBI and resultant neuro-disabilities in Singapore. Two local institution-based studies published 7 years apart display demographic profiles similar to those in the West.[11,12]

Acute TBI Management, Neurological Impairments and Associated Injuries

Adequate cardiopulmonary resuscitation is the first and most important priority in the initial care of the brain injured patient. Further management is governed by the need to control intracranial pressure (ICP) with the aim of maintaining an adequate cerebral perfusion pressure (CPP) and oxygen flow to the brain. Head elevation reduces ICP and improves CPP. Intravenous mannitol is useful in lowering ICP although adequate fluid replacement needs to be maintained during therapy.[13] Hyperventilation in the first 24 hours after severe brain injury is not recommended as it causes cerebral vasoconstriction and reduces CPP.[14] The routine use of steroids in acute TBI management is not recommended.[15,16] Mass lesions, such as haemorrhages causing increased ICP, may need urgent surgical evacuation. A recent meta-analysis did not support the routine use of hypothermia in acute TBI management.[17] Treatment with anticonvulsants, such as phenytoin and carbamazepine, reduces the incidence of early post-injury seizures but not late-onset epilepsy; hence, long-term prophylactic treatment is currently not recommended.[14,18]

Initial trauma to the brain sets off a cascade of chemical changes such as the release of excitatory amino acids, increased arachidonic acid metabolism and production of free radicals leading to "secondary impact" injury. Magnesium had initially shown promise in the treatment of acute brain injury in preclinical trials.[19] However, this initial success has been attenuated by the unfavourable results of a clinical trial involving its use in acute stroke patients.[20] Further research into putative drugs to reverse or minimise this neurochemical cascade and useful cerebral neuroprotectants continues.[21]

Primary injury processes to the brain, such as cerebral contusions, lacerations and diffuse axonal injury, make up the bulk of the neurological and functional deficits in TBI patients. Depending on the underlying mechanism of trauma, 70% of patients may also present with various associated injuries such as fractures, cardiopulmonary or visceral injuries, spinal cord injuries, peripheral nerve injuries and limb amputations. These may have a significant impact on the acute management of TBI patients and compound TBI-related neurodisability. In view of the similarities in aetiologic factors for TBI, it is important to realise that concomitant spinal cord injuries may occur in 40% to 50% of patients with TBI.[22]

Radiculopathies may result from root avulsion or compression and plexopathies or peripheral nerve injuries may result from traction injury, compression or bony injuries of the upper extremities. Skull fractures and head trauma may also damage cranial nerves exiting the brain. Olfactory and visual deficits resulting from olfactory and optic nerve damage may not be readily appreciated especially in the acute treatment phase.[16] Patients may present with visual field deficits, diplopia or scotomata. Eye movement disorders may also result from injury to cranial nerves, brainstem nuclei and the conjugate gaze centres. Auditory deficits and facial paralysis may result from trauma to the auditory and facial nerves, respectively.[16]

Medical Complications After TBI

Urinary tract infections, pulmonary complications and derangement in electrolytes and liver function are common in 60% to 70% of acute TBI cases and may prolong acute hospital stay. Seizures may be reported in 20% of those with a severe TBI.[13] Patients may develop hydrocephalus and can present with failure to improve or with deterioration of function. Extrapyramidal symptoms, dystonia and spasticity have been observed in TBI patients. In addition, a wide range of motor and sensory dysfunctions, such as slowed motor responses, balance, coordination and sensory perception issues, may occur. Bowel and bladder incontinence have been observed, especially with lesions involving the frontal lobes. Fractures and soft tissue injuries may be missed in 15% of patients in the rehabilitation phase and a higher index of suspicion may be required as cognitive abilities to report pain may be reduced in patients with low levels of awareness.

Another known complication of young and severe TBI, heterotopic ossification refers to the formation of lamellar bone in soft tissue or peri-articular tissue.[23] Neuroendocrine disorders resulting from trauma to the pituitary stalk and hypothalamus have been well-described including pituitary dysfunction in 60% of patients with severe TBI.[24] Common neuroendocrine disorders include growth hormone deficiency, syndrome of inappropriate secretion of antidiuretic hormone, diabetes insipidus, secondary amenorrhoea, galactorrhoea and gynaecomastia. Autonomic dysfunction may also occur following TBI and includes TBI-related hypertension and central dysautonomia, which needs to be differentiated from SCI-related autonomic dysreflexia, diencephalic seizures or the neuroleptic malignant syndrome.[16]

Prognosticating Outcome after TBI

This forms an integral part of TBI rehabilitation and can be used to aid functional goal-setting and estimate rehabilitation length of stay (LOS). It can also provide valuable information for caregivers with regard to potential disabilities and future care planning. However, there is no single set of indicators which has been demonstrated to be uniformly accurate in predicting outcome. Common acute injury predictors include the depth and length of coma immediately after injury. A coma duration of more than 6 hours denotes a severe injury.

Severity of brain injury may also be classified according to the level of consciousness. This is the most common and reliable clinical parameter used to measure TBI severity.[25,26] The Glasgow Coma Scale (GCS) defines severity of TBI within 48 hours of injury. A score of GCS 13 to 15 is considered mild injury, a score of 9 to12 denotes moderate injury and a score of 3 to 8 denotes severe injury. Specifically, the motor component of the GCS correlates well with global outcome at discharge.[27]

What is more important during rehabilitation is the use of the post-traumatic amnesia (PTA) duration as an acute predictor of TBI outcome. PTA is defined as "an interval during which the patient is confused, amnesic for ongoing events and likely to evidence behavioural disturbances".[28] A PTA duration of more than 24 hours is deemed as severe TBI, and PTA duration of more than 4 weeks is indicative of a very severe brain injury.[29] PTA has been found to correlate well with long-term outcome measures such as the Glasgow Outcome Score (GOS) at 6 and 12 months post-TBI. It is also predictive of the presence of chronic cognitive deficits at 6 to 12 months post-injury, the development of psychiatric disorders and the ability to return to work.[30] Generally, patients with more than 3 weeks of PTA may be expected to have residual cognitive deficits at 1 year post-injury.[31]

Pre-injury factors such as extremes of age have been linked to increased mortality and poorer outcome, and a history of previous head injury, alcohol abuse, lower socio-economic and educational status have been associated with worse outcome after TBI.[32]

Rehabilitation of TBI

Rehabilitation is broadly defined as "a problem solving educational process aimed at reducing disability and handicap experienced as a result of disease or injury".[33] The goal is to help the person achieve the maximum degree of return to their previous level of functioning within limits imposed by their residual physical, functional and cognitive impairments. After TBI, return of function is not restricted to physical reintegration but also includes reintegration in the social, emotional, community and vocational domains. The latter is especially important to TBI patients who may suffer in isolation, cognitive and behavioural deficits without congruent physical impairment.[33,34]

Engaging TBI patients with moderate and severe injuries actively in the rehabilitation process understandably poses definite challenges as it requires the participation of the multiply-challenged TBI patient in various aspects of multidisciplinary rehabilitation. Hence, there is a need for a specialised interdisciplinary team of rehabilitation professionals, led by a rehabilitation physician (Table 1). Central to this is the patient and his family or primary caregivers.

Unique features of TBI rehabilitation include the presence of a brain injury rehabilitation specialist and a trained clinical psychologist who guides the neurobehavioral

Table 1. The Multi-disciplinary Rehabilitation Team

The brain injury rehabilitation team
Patient and patients' family or caregivers
Rehabilitation physician or physiatrist
Rehabilitation nurse, rehabilitation technicians
Primary neurosurgeon
Allied health professionals: physiotherapist, occupational therapist, speech and language pathologist, clinical psychologist, neuropsychologist, social worker and counsellor.
Paramedical health professionals: dietician, orthotist, and rehabilitation engineer.
Other medical specialists: ophthalmologist, otorhinolaryngologist, orthopaedic surgeon, gastroenterologist and neurologist for electrophysiological studies.
Vocational rehabilitation services and counsellors
Volunteers from support or spiritual groups

Table 2. Specific Programmes for TBI

Specific programmes offered during brain injury rehabilitation
Post-traumatic amnesia assessment
Management of post-traumatic agitation
Neuropharmacological management
Cognitive rehabilitation therapy
Coma emergence and rehabilitation of minimally responsive states
Spasticity management including motor point/nerve blocks and Botulinum toxin therapy
Casting, splinting, orthotics, contracture management
Pain management services for cervicogenic headaches, trigger point injections
Balance and vestibular assessment and rehabilitation
Cognitive and behavioural assessment and remediation
Comprehensive dysphagia and speech therapy services
Assistive technology using augmentative and alternative communication
Rehabilitation nursing education
Intrathecal Baclofen pump therapy
Brain injury discharge advice and family education
Social support: discharge planning, caregiver training

assessment, management and monitoring during the inpatient stay within a transdisciplinary model of rehabilitation, where there is a crossing of boundaries involving 2 or more different therapeutic specialties in treating patients and family to achieve a common functional goal.[35]

Specialised brain injury units have evolved over the past 20 years in recognition of the unique needs of TBI patients with specific models of care to provide a continuum of rehabilitation services for each stage of recovery from TBI. These range from sensory regulation for coma-emergent and minimally responsive patients to environmental modifications such as secured units, safe "floor or low beds" for agitated patients, to post-acute vocational and social integration programmes.

TBI rehabilitation often consists of 2 phases: the *inpatient phase* which may last from 1 to 3 months, including the acute neurosurgical and early rehabilitation phase prior to transfer to a specialised brain injury unit and the *outpatient or community* rehabilitation phase, which may continue for 1 to 2 years depending on the age of the patient, injury severity and residual disability.[33]

(1) Inpatient management is required for those with a moderate-to-severe degree of physical, cognitive and/or behavioural deficits. The rehabilitation team's focus is on a comprehensive assessment for TBI-related neurological and functional impairments and the development of an individualised programme based on specific functional goals and serial monitoring of outcome (Table 2).

(2) Community rehabilitation follows discharge from an inpatient rehabilitation stay. Patients may benefit from further training in household independence and community reintegration through an outpatient programme or through a transitional living unit where patients are largely self-managing under health professional supervision. Helping a person with TBI return to maximal independence is a challenging task and requires the dedicated involvement of the patient, treatment team and family. Cost, variability of access and availability of such specialised services may limit a patient's ability to benefit from such services. Vocational assessment and rehabilitation, driving retraining, virtual reality training for remediation of visual-spatial deficits and computer-aided cognitive rehabilitation may be required to address the needs of high-functioning TBI survivors. Pain management clinics may be needed for those with chronic post-traumatic headaches, cervicogenic headaches or orthopaedic or peripheral nerve injuries.[33] Issues of caregiver coping and long-term psychological or peer support for caregivers or spouses of patients who are unable to return to independent living may be provided by caregiver support or volunteer groups.

The Role of the Rehabilitation Physician in TBI

The rehabilitation physician plays a central role in leading, coordinating and providing a continuum of care and services over the course of the patient's recovery. Therefore, early involvement of the rehabilitation physician as part of the acute managing team is imperative and this can be initiated either by a referral or during combined staff rounds.[34,36]

Some of the rehabilitation physician's specific roles include:

1) Identification of specific rehabilitation needs and physical impairments, which may be directly related to

the brain injury or secondary to concomitant orthopaedic or spinal cord injury.

2) Assessment of injury severity and initial functional prognostication based on acute injury variables.
3) Acute management of neuromedical complications and active prevention of immobility and other related complications, as well as multidisciplinary management of bladder, bowel and skin issues, including prolonged fevers, venous thromboembolism, anti-epileptic drug management, spasticity, heterotopic ossification, post-traumatic amnesia management and related agitated behaviour.
4) Coordination of early rehabilitation therapies, timing of transfer of patients to intensive brain injury rehabilitation units, as well as commencement of discharge planning processes.
5) Coordination of inpatient brain injury rehabilitation programmes and post-discharge rehabilitation therapies for social, educational and vocational reintegration, determining readiness for driving rehabilitation and prevention of second TBI.
6) Independent medical examinations for assessment of permanent disability, legal and workers' compensation or litigation, end of life and legal-ethical issues for those in a permanent vegetative state.

TBI Rehabilitation in Singapore

From the 1970s to the 1990s, local TBI patients undergoing inpatient rehabilitation were located together with patients with spinal cord injury, orthopaedic injuries and stroke.[37] Rehabilitation physician-led brain injury rehabilitation programmes first started in Tan Tock Seng Hospital (TTSH) rehabilitation centre in the mid to late-1990s. Since the year 2000, the number of acute hospital-based rehabilitation units has increased exponentially, due to the strategic development of secondary rehabilitation services within acute hospitals and the aggressive recruitment of trained rehabilitation physicians along with the training of younger specialists. Currently, all restructured hospitals have acute rehabilitation units with a 20- to 40-bed capacity each, with more severe TBI patients being transferred to the TTSH rehabilitation centre.

In TTSH, an average of 100 patients with severe brain injuries were admitted for inpatient brain injury rehabilitation each year, with brain trauma comprising more than 80% of all cases. These represent less than 10% of all TBI cases locally, albeit the most severe. Their average rehabilitation LOS was 30 days and more than 90% of patients were discharged home.[12] The inpatient programme is modelled on similar TBI rehabilitation units in America and Australia. Comprehensive outpatient and community-based services are also available, including driving rehabilitation and vocational assessment.[38,39]

Current Evidence for TBI Rehabilitation

To date there exists a limited body of evidence to study patient outcomes after TBI rehabilitation. Indeed, randomisation and comparison of group differences are not employed in the great majority of published studies on TBI rehabilitation. Due to the intrinsic heterogeneity of TBI patients, pathologies, impairments, rehabilitation services and differences in recovery even among similar injury severities and demographic classes, some clinicians assert that this renders inappropriate the use of a randomised controlled trial (RCT) to study treatment efficacy.[40] There are, in fact, a number of challenges when using a RCT methodology to study TBI.

These include:

1) Small patient numbers with marked heterogeneity with respect to patient group, intervention and setting, as well as to outcomes.
2) The expanding body of evidence for the effectiveness of multidisciplinary rehabilitation on other conditions such as stroke makes it increasingly difficult, both ethically and practically, to randomise patients into "standard care" or "no treatment" groups.
3) Patients with TBI often lack the mental capacity to give fully informed consent for participation in clinical trials and may have problems with treatment compliance in drug trials unless they have a reliable caregiver.
4) The resources required to assign systems of care to different groups are far greater than those required to deliver specific medications or procedures.
5) Outcome measures after TBI are also similarly varied and can be categorised into:
    i) Residual impairment and disability e.g., post-traumatic amnesia or post-concussion symptoms.
    ii) General outcome measures such as rehabilitation LOS, discharge outcome, need for caregiving, medical complications and rehabilitation morbidity, readmission rates and return to work.
    iii) Functional independence, including mobility, cognitive functioning and ability to perform basic activities of daily living [Barthel index, Functional Independence Measure (FIM) or Functional Assessment Measure (FAM)] and the Glasgow Outcome Scale (GOS).[41]
    iv) Outcome measures that focus on handicap, psychosocial adjustment or quality of life (Social reintegration, community reintegration, health-related quality of life for patient and caregiver, patient and caregiver mood and caregiver burden).

There is an even more pronounced scarcity of data pertaining to relevant trials for the paediatric brain injury population, compared to data for the adult TBI population, in determining the effectiveness of early intensive rehabilitation or social support services to families of children or adolescents with TBI aged between 2 and 18 years old.[42]

An early paper published by Chestnut and supported by the Agency for Health Care Policy and Research in the US found limited evidence that an earlier transfer of severe TBI patients (GCS scores of 3 to 8) to a formalised, multidisciplinary, rehabilitation physician-driven TBI rehabilitation programme, decreases acute and rehabilitation LOS, shows some positive measures of short-term non-cognitive outcomes, and a higher proportion of patients being discharged home rather than moved to institutional care.[33,36,43] In addition, acute LOS and discharge FIM scores were strongly associated with rehabilitation LOS and long-term outcome.[43-45] However, there was no evidence of comparative studies for or against early rehabilitation in patients with mild or moderate TBI severity. The extent of functional recovery or final functional level of the patient at 6 to12 months post-injury may be unaffected as these were more likely to be determined by the initial severity of brain injury.

In this early review, there were no RCTs that assessed the effect of different levels of intensity of acute rehabilitation on outcomes from TBI. The question of how much of which interventions optimise recovery in a given type of patient remains inadequately studied. Thus, the evidence does not support mandating a minimum number of hours of rehabilitation therapy for all TBI patients.[33,43]

A more up-to-date systemic review by Turner-Stokes et al,[46] included further questions into the effectiveness of intensities, types of programmes, different settings, specific outcomes and cost-benefits of multi-disciplinary rehabilitation for adults aged 16 to 65 years with all types of traumatic and acquired brain injuries. From an initial 15 trials covering a range of differing severities and which fulfilled methodological criteria, 10 trials of good and 4 of lower quality were selected for closer review. In the mild injury group (admission GCS 13 to 15, post-traumatic amnesia duration >1 hour), there was strong evidence to suggest that:

1) The majority of patients with mild TBI make a good recovery;
2) Patients with post-traumatic amnesia of >1 hour are usually not admitted to hospital and do not require any specific intervention;
3) Patients with post-traumatic amnesia of 1 hour or more do benefit from routine follow-up contact providing information and advice;
4) There is a subgroup of patients with moderate-to-severe injury, who may benefit from a higher level of intervention, and who may not present themselves unless routine follow-up is provided.[46]

Regarding the intensity of rehabilitation for moderate-to-severe brain injury inpatients in a transdisciplinary setting, there is strong evidence that more intensive rehabilitation programmes are associated with earlier and more rapid functional gains as shown on the FIM and FAM, and possibly shorter rehabilitation LOS, once patients are fit to engage.[41] The additional hours of therapy consisted of similar content repeated in the later session of the day. There was no evidence of a ceiling effect in therapeutic intensity in any of these studies. There was also moderate evidence that more intensive rehabilitation (a 30% increase in the number of therapy hours) led to a significantly reduced LOS without a reduction in discharge functional outcome.[47] However, in order for intensive intervention to be cost-effective, it is necessary to demonstrate that it is associated with potential cost savings down the line (e.g., reduction in LOS or long-term dependency), which might offset the additional costs of providing the initial programme. However, a direct analysis of cost-effectiveness was not undertaken and the balance between cost-effectiveness and intensity has yet to be determined. It must also not be forgotten that rehabilitation LOS can often be confounded by external factors such as lack of a designated discharge destination or lack of community support.[48-50]

There is limited evidence that multi-disciplinary community-based rehabilitation for TBI patients can improve the functional outcome for severely injured patients at the level of activity (disability) especially targeted towards specific goals and social functioning, but evidence for caregiver benefits has yet to be demonstrated.[46,51] Patients who are discharged from inpatient rehabilitation settings, should have access to follow-up community-based services that are appropriate to their needs.

RCTs also provided no direct evidence about the efficacy of supported employment either in the form of “a low cost of job coaches using trained supervisors with employees of TBI” or using a revised concept of a revised work setting designed to fit the abilities and deficits of survivors of TBI.[46,51]

Regarding specific rehabilitation interventions, there is limited evidence for pragmatic aides such as notebooks with alarm wristwatches for remediation of everyday memory failures and computer-aided cognitive rehabilitation to improve immediate recall on tests. However, the reviewers also recognised the need to identify the laboratory tests which are the strongest and most reliable in their ability to measure cognitive function in the relevant context.[46]

Special Populations in TBI

Mild Traumatic Brain Injury

Mild traumatic brain injury (MTBI) is defined, by most authorities on the subject, to be a head injury that results in a loss of consciousness lasting <30 minutes, if it occurs at all. Other generally agreed upon criteria for MTBI are that the GCS score does not fall below 13, there is no focal neurological deficit and neuroimaging is negative. Some authors further grade the severity of MTBI according to the presence of post-traumatic amnesia or changes in mental state.[52-55] Diffuse axonal injury is the primary pathology in MTBI, and its severity is suggested by the duration of loss of consciousness.[56,57] The incidence of mild TBI is increasing, and is estimated to account for about 75% of all TBI cases, although many do go unreported.[57] However, data on the incidence and prevalence of MTBI in Singapore is scarce.

In sports medicine, MTBI is used synonymously with concussion, and the constellations of symptoms that may arise thereafter are termed the *post-concussion syndrome.* Post-concussion symptoms can be somatic, such as headache, dizziness, fatigue and sensory impairments. In addition, affective symptoms such as irritability and depression may be present.[58,59] Neuro-cognitive impairment is common and may be unmasked upon detailed neuropsychological testing in areas such as attention, concentration and memory.[58] Many of these impairments persist and cause chronic disability. The potential hazards of premature return to play or work include an increased risk of experiencing post-concussion symptoms, death from the second-impact syndrome and permanent neurological deficit from cumulative trauma.[60,61] Many of the post-concussion symptoms are responsive to vocational counselling and patient education, cognitive rehabilitation, therapeutic exercise and judicious use of medications.[62]

States of Severely Altered Consciousness (The Vegetative State)

Perhaps the most striking subset of TBI patients are those in a vegetative state (VS). This term refers to patients who were awake but unaware of their environment, whose eyes open spontaneously and they have preserved sleep and wake cycles.[63,64] However, they do not exhibit intentional movement, do not follow commands and voice-recognisable words and do not sustain a visual pursuit movement.[63-65] The term *persistent* vegetative state (PVS) is used when it lasts for more than 3 months.[63,64]

The minimally responsive state (MRS) refers to a state where a meaningful behavioural response has occurred indicating awareness or interaction with the environment whilst these patients remain severely disabled.[65] The MRS and PVS may be collectively termed states of severely altered consciousness (SSAC).[56] The prevalence of PVS is approximately 4 per million persons, but our local prevalence is as yet unknown.[39,64] Assessment of awareness and low-level functioning is challenging and best done using specialised disability scales such as the Disability Rating Scale (DRS) and various coma recovery scales sensitive to small changes in such profoundly disabled patients.[66]

Misdiagnosis of VS, however, is common and it is must be extremely distressing for these patients to be aware but unable to interact with their families or caregivers.[67] A multidisciplinary approach involving a rehabilitation physician-led team is typically used by rehabilitation centres in managing such patients (Table 1). A comprehensive rehabilitation programme for TBI in SSAC comprises medical management which includes the provision of optimal nutrition, bladder and bowel function and prevention of secondary complications, wheelchair seating prescriptions, management of spastic hypertonia and contractures, coma stimulation and social management. Coma or sensory stimulation is a technique whereby the senses (vision, hearing, touch, taste, smell) are assessed in response to stimuli, and subsequently facilitated and trained if there is a consistent and meaningful response. It is offered by an increasing number of specialised TBI rehabilitation centres, but the clinical effectiveness has been equivocal and ongoing trials are still being conducted.[68]

Traumatic Brain Injury in the Elderly

The incidence of patients with TBI in the over 65-year-old age group is expected to increase with any greying population. The elderly form the second peak in prevalence for TBI and account for 20% of all local TBI patients. Elderly patients, with their medical co-morbidities and frailty, are at significant risk for sustaining a TBI and they have almost double the mortality rate compared to younger patients under 65 years of age, and have poorer functional outcome even with a seemingly less severe TBI.[69-71] The elderly with moderate-to-severe TBI tend to have a higher incidence of traumatic intracranial and subarachnoid haemorrhage, which is associated with a poorer outcome and reduced chances of survival.

Long-term outcome is closely related to behavioural status, which is reportedly worse with advanced age. Rehabilitation outcomes in the elderly include a more prolonged duration of PTA, poorer FIM and GOS outcome, poorer ability to return to independent living, longer rehabilitation LOS compared to younger patients and higher medical complication rates. The elderly require more time at all levels of rehabilitation.[71] Age has been cited to be a significant risk factor for poorer outcome, and some authors have suggested a worsening prognosis over 55 to 60 years of age related to poorer neuronal reserve and quality in the elderly due to cerebrovascular disease and dementia.[33,72]

A comprehensive rehabilitation programme for elderly patients with TBI includes:

1) Prevention of common medical complications related to prolonged immobility and meticulous day-to-day medical management.
2) Medication review including reduction of cognition-impairing medications such as anti-epileptic drugs, anti-psychotic drugs, H2 blockers and anti-spasticity drugs to allow for optimal participation in rehabilitation.
3) Recognition of co-morbidities such as cardio-pulmonary disease, which may affect activity tolerance and the intensity of rehabilitation.
4) Setting of rehabilitation goals appropriate to the patient's premorbid and current medical, neurologic and cognitive status. Rehabilitation management includes issues such as disrupted sleep-wake cycles, elderly agitation and apathy, risk of falls in the busy rehabilitation ward, communication and cultural issues. Aphasic, hearing-or-visually challenged individuals may be difficult to rehabilitate and may therefore make even slower progress.
5) Social issues are more pertinent in the elderly TBI patient than in the younger TBI patient and prolonged support through community rehabilitation post-discharge may be needed in order to maintain function.

TBI in Adolescents and the Young

In the US, TBI is the leading cause of death in children under 16 years of age, accounting for 100,000 hospital admissions yearly and an incidence of 200 per 100,000.[73] The mortality is highest in under-2-year-olds (6.2%) with a steady decline throughout childhood till age 12 (0.9%), and then a rise throughout adolescence and adulthood where causes of injuries parallel those for adults. There have been few large outcome studies on paediatric TBI. In general, infants under 1 year of age have worse outcomes than older children due to increased incidence of subdural haematomas, soft consistency of the partially myelinated brain, delayed diagnosis, repetitive injury in child abuse and a small pre-trauma knowledge base. Typical prognostic indicators are similar to those for adults: lower GCS or children's coma scale scores, prolonged coma and a PTA duration of more than 2 weeks predict long-term cognitive deficits.

The diagnosis and assessment of paediatric injuries is similar to that of adult TBI. Children's norms, with regard to measurements of Children's Coma Score, used in under 3-year-olds, and the Children's Westmead PTA scales applicable to those more than 7-year-olds, are used in paediatric hospitals.[74] Other frequently used scales include the paediatric version of the Rancho Los Amigos level of consciousness, a categorical scale which tracks neuro-behavioural progress, and paediatric functional outcome measures which includes the WeeFIM or Paediatric Evaluation of Disability Inventory (PEDI).[75,76]

Medical and rehabilitation issues for children with TBI are similar to those for the adult population, with particular attention being paid to the detection of post-injury hearing, vision or visual field impairment, prevention of contractures and early spasticity treatment, treatment of agitation and behavioural issues and management of heterotopic ossification.

The rehabilitation goals for children and adolescents with TBI are similar to those for adults: to promote as much age-appropriate functional independence as possible in all areas within the framework of the child and family, with special attention being paid to developmental needs, using an integration of the therapist with the family and using play as the main mode of therapy for younger children. The play therapist and paediatric rehabilitation nurse are particularly important members of the rehabilitation team managing a young child with TBI. In the sub-acute phase, family therapy and social intervention may be required to help families cope with disrupted routines, finances, relationships as well as mourning for a child who was previously normal.[73]

In the chronic phase, deficits in attention, concentration, communication, memory, initiation and fatigue are common problems together with behavioural issues such as anxiety, reduced self-esteem and depression. Skills and speed of recovery may be uneven and affect smooth integration back to school. As far as possible, early educational integration to a structured learning environment either in a mainstream school, small group teaching or special education services should be encouraged. Age-appropriate socialisation skills, computer-aided cognitive rehabilitation, higher mobility skills, social integration and a return to sporting activities must also be taught.

Recent Advances in TBI Rehabilitation

Rapid advances have been made in the remediation of cognitive disorders after TBI. New scales have been developed to accurately measure arousal and attentional deficits.[77] Targeted therapies specific to sustained, selective, and divided attention have shown promise.[78] Task-specific training of working attention appears to be practical and beneficial.[79] Similarly, memory retraining has recently begun to focus on rehabilitating prospective memory (remembering what to do in the future) rather than retrospective memory (remembering past events), as TBI affects the former to a greater extent than the latter. This draws on facilitating implicit or procedural learning, which tends to be spared in

TBI, as opposed to training explicit or factual learning.[80] Errorless learning, a training method based on implicit memory models, has been widely explored in TBI with good results.[81]

Visual scanning techniques have been found to be the most useful in treating visuospatial deficits, compared to visual training equipment such as prisms and eye patches.[82] Computer programs, such as the useful field of view (UFOV) test, are increasingly used in the assessment and training of visual deficits in TBI and these are undergoing trials to assess their correlation to return to driving.[83] Newly-developed automated systems such as virtual reality and Internet-based systems are being developed to train various cognitive and motor impairments after TBI in order to improve visual impairments and higher executive function deficits.[84] Advantages include the possibility of continual home-based rehabilitation and telerehabilitation with remote monitoring.[85]

The use of robotic devices to improve the diffuse motor impairments in TBI may promote motor recovery through new developmental insights in neuroplasticity and reduce the amount of one-to-one therapeutic effort required during rehabilitation.[86] Examples of such devices include the MIT-Manus and Mirror-Image Motion Enabler Robot for the upper limbs, and the Lokomat for body weight-supported treadmill training for the lower limbs.[86]

Current research suggests that fatigue plays an important role in diminishing recovery from various cognitive and motor deficits, beyond that of mood disorders.[87] Neuropharmacological interventions have also been widely used to aid recovery from the plethora of attentional, memory, processing and behavioural impairments including agitation and aggression after TBI. However, currently the research has not firmly established their efficacy, hence further evaluations of drugs are required to determine their definitive roles.[46]

Prevention of TBI

Prevention of head trauma involves reducing the risk factors through education programmes, enforcement and legislation. The use of helmets and seatbelts reduces the incidence and severity of TBI in the young.[88,89] Education programmes and legislation to strongly discourage driving under the influence of alcohol exist and should be enforced.[88,90] In the elderly, a multidisciplinary approach to the prevention of falls is required and may include addressing behavioural problems, environmental modifications, and the incorporation of exercise programmes targeting balance training.[91,92] Locally, the Workplace Safety and Health Act has been recently revised to further increase safety requirements at worksites for fall-related industrial accidents and enforce stiffer penalties for errant employers.[93]

Ethical and Medico-legal Issues in TBI

A number of important ethical and medico legal issues can arise for TBI survivors. Cognitive impairment can range from the subtle to profound, and may disrupt autonomy of clinical decision-making, obtaining informed consent for surgical and rehabilitation interventions, privacy rights and participation in TBI-related research.[94] Decisional competency assessment can be complex and highly specialised.[95] There is no single test that determines competency, and neuropsychological testing in TBI itself has been intently scrutinised about its sensitivity, validity, self-reported versus objective testing, appropriate time of testing from injury onset and specificity of the target TBI cohort. This is highlighted in the assessment of MTBI or post-concussion syndrome.[96] In addition, subtle cognitive deficits uncovered during a competency assessment such as complex problem-solving deficits may be confounded by factors such as depression and secondary gain.[95]

Medical litigation for sustained injuries may be a prolonged, costly and painful process for patients and their families. The Singapore Workmen's Compensation guide provides objective assessments of physical impairment correlating to the quantum of disability and compensation, but acknowledges that cognitive, behavioural and pain-related impairments are more subjective and hence difficult to quantify.[97] This is highly pertinent for the young TBI survivor, as cognitive impairments including memory, language and post-traumatic stress disorder may be very disabling and impair societal and vocational reintegration.[98] Only general guidelines pertaining to medical diseases exist locally regarding fitness to drive and specific guidelines will need to be developed for TBI.[99] There are laudable efforts in Singapore to provide vocational rehabilitation and sheltered employment. These tasks have been taken up by local voluntary welfare organisations to provide opportunities for TBI survivors to return to work.

Decisions regarding withdrawal of life-supporting tube feeding, nutrition, and medical care in SSAC continue to be vociferously debated in medical, legal, religious and political circles, with the media and public opinion further clouding issues.[100] Quality of life is difficult to measure in these patients and their decisional competencies are difficult to assess in the light of complex neurodisability and communication difficulties. No consensus exists on measuring recovery or on what constitutes a reasonable recovery. The advanced medical directive (AMD) is a step forward in addressing these issues.[101] However, the awareness and response rate has been low, and this may be due to cultural and social differences in attitudes towards death and end-of-life issues.[102] In addition, the content of AMDs vary widely and tend to address withdrawal of life-sustaining measures including mechanical ventilation, rather than life-supporting measures more relevant to vegetative and MRS states. The knowledge, attitudes and perceptions of TBI also differ considerably in cross-cultural and social settings. Families may cope differently, and may delay decisions regarding end-of-life issues because of a belief that the individual may eventually recover.[103]

Conclusion

In summary, TBI rehabilitation is a recognised subspecialty of neurorehabilitation and there is increasing awareness of its important role in early management for all severities of injury. While evidence for its effectiveness and specific interventions is limited, emerging therapies, both at a cellular and therapeutic level, continue to be subjected to rigorous research. The families of TBI survivors, particularly the severely injured, young TBI and those in VS bear most of the social and societal burden of long-term care. It must be remembered that prevention of TBI is vital as there remains no cure for the sequelae of moderate-to-severe TBI.

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