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Over the past three decades, there has been a significant growth of interest in the study of individuals with traumatic brain injury (TBI). Although physical disabilities are associated with TBI, the more prominent and common impairments are psychological in nature and involve deficits in attention, memory and executive functions, communication difficulties, and behaviour and personality changes. Psychology has contributed much to understanding the mechanisms of injury and recovery following TBI, the nature of the cognitive, behavioural and emotional sequelae of TBI and predictors of psychosocial outcome, and effective models of rehabilitation and management. These contributions, and the central role of psychologists in assisting with the complex and challenging problems of TBI for its survivors, their relatives and clinicians, are highlighted in this article.

Incidence of TBI

Improvements in the acute management of TBI have resulted in a reduction in mortality rates. This, together with the relative youth of those who sustain TBI, has led to a growth in the number of survivors of TBI in the community. The Australian Institute of Health and Welfare has reported a rate of 107 TBIs per 100,000 population in Australia. Most studies suggest that approximately 20 per cent of TBI patients admitted to hospital have sustained moderate or severe head injuries, with the other 80 per cent having mild injuries.

The majority of moderate to severe TBIs result from motor vehicle accidents. Other injury causes include falls, bicycle accidents, assault and sports injuries, with the latter causing a higher proportion of mild TBIs. With the ageing of the population there has been an increasing number of elderly people injured as a result of falls. In recent years the use of explosive devices in armed conflict has added a new mechanism of injury – blast injury, the effects of which are the focus of considerable current research interest, particularly in the USA . A major issue is the differentiation of mild TBI from PTSD occurring in the context of blast injury. This represents a significant challenge for psychologists working with the armed forces.

TBI occurs predominantly in young adults, most commonly males. Many of these accidents occur in the context of substance abuse and risk taking behaviour and may be associated with a history of psychiatric disorder, limited educational attainment and an unstable work history. These young people may still be in the process of becoming independent of parental support, completing their education or developing vocational skills, and establishing a social network and lasting personal relationships. The effects of TBI frequently disrupt the ability to attain these important life goals, resulting in negative changes in self-concept, lowered self-esteem, depression and anxiety. Those injured will be confronting their disabilities for decades in a society which most commonly associates disability with the elderly or those with congenital intellectual disabilities.

Mechanisms of injury

Neuropathological evidence suggests that there are several mechanisms of brain injury, some operating at the moment of impact and others as a consequence of secondary complications. This results in significant heterogeneity of injury across individuals. Acceleration or deceleration forces may cause laceration of the scalp, skull fracture and/or shifting of the intracranial contents, with resultant focal and diffuse changes. Focal changes include haematoma formation as a result of tearing of blood vessels, and contusion or bruising, most commonly on the basal and polar portions of the frontal and temporal lobes. Diffuse changes include axonal injury and microvascular damage, as well as widespread neural excitation and metabolic changes. Complications, including brain swelling, infection, raised intracranial pressure and respiratory arrest, may cause secondary brain injury. Results of clinical trials examining the efficacy of drugs that block various processes contributing to secondary injury have unfortunately been disappointing.

Limitations in the sensitivity of various imaging techniques make delineating the precise nature and extent of injury in an individual difficult. Scans generally show decreasing brain volume over time. It is nevertheless apparent from the neuropathological evidence available that diffuse injury is common, and that damage occurs most frequently in the frontal and temporal lobes, corpus callosum, basal ganglia, hypothalamus, superior cerebellar peduncles, fornices and the hippocampus.

Recovery from TBI

TBI usually results in immediate loss or impairment of consciousness, followed by a period of confusion, known as post-traumatic amnesia (PTA). The depth or length of coma, measured using the Glasgow Coma Scale (GCS), and the duration of PTA may be used as measures of severity of TBI.

Following the return of orientation, most of those who sustain TBI exhibit a range of ongoing sensorimotor, cognitive and behavioural sequelae, which vary widely in their nature and severity. Mechanisms of recovery are poorly understood, and there is considerable variability in patterns of recovery. Recovery from moderate or severe TBI tends to follow a negatively accelerating curve, which is most rapid in the first 3-6 months, but may continue for several years. In the case of mild TBI, recovery takes place within weeks or months, although some individuals have symptoms which persist beyond this period.

The mechanisms underlying recovery of function are, as yet, poorly understood. Much of the early spontaneous recovery after TBI is explained by the resolution of temporary physiological changes. In addition there are regenerative neuronal changes that have been associated with behavioural improvement. However, particularly in the case of severe injuries, the potential for regenerative growth is limited. It is thought that most recovery beyond this occurs through the substitution or reorganisation of neural structures and/or functions. There is a growing body of evidence to suggest that environmental stimulation and specifically behavioural therapies can alter brain function and organisation after injury, termed plasticity. This may occur by the reorganisation of neural circuits within or associated with the damaged area or via the reorganisation of remaining circuits. The capacity for reorganisation decreases as the size of the damaged area increases, because presence of intact tissue appears to be important to allow this reorganisation of function to occur. It also varies

according to genetic differences, pre-injury experience and age. Whilst there is some evidence that sensory or motor stimulation results in reorganisation of sensori-motor functions, the evidence in relation to cognitive functions is much more limited. It appears that general, non-specific stimulation results in better outcomes, although there is as yet limited evidence indicating what type of therapy is most effective.

Psychological sequelae of TBI

In the majority of cases it is the cognitive, behavioural and emotional changes which are most disruptive and disabling to the long-term functioning of individuals who have sustained a TBI. Because of the limitations of imaging technologies in elucidating the effects of TBI, clinical neuropsychologists play a vital role in delineating the cognitive and behavioural effects of TBI, as well as the residual strengths which may be used to overcome difficulties.

Mild TBI

Following mild TBI the person may experience symptoms, including headache, dizziness, fatigue, blurred or double vision, sensitivity to noise and/or bright lights, tinnitus, restlessness, insomnia, reduced speed of thinking, concentration and memory problems, irritability, anxiety and depression, and poor balance. In many cases these so-called post-concussional symptoms subside over a period of days or weeks. Neuropsychological studies have confirmed the presence of impaired speed of information processing, attention and/or memory in the early days after injury. Recovery from symptoms and cognitive impairments appears to take place within two weeks following sports-related concussion. In other aetiological groups the timeframe of recovery is more variable, but in the majority of cases symptoms have resolved within three months.

However in 15-25 per cent of cases these difficulties persist and sometimes result in significant ongoing disability and adjustment problems. The cause of such ongoing problems, termed the persistent post-concussive syndrome, remains a subject of much debate. Injury severity measures (i.e., GCS and PTA) and cognitive function do not show a significant association with outcome following mild TBI (Ponsford et al., 2011). In a recent study (Ponsford et al., in press), although it was clear that mild TBI caused more symptoms after injury than other forms of trauma, the factors most strongly associated with continuing symptoms following mild TBI were found to be pre-injury physical and psychiatric problems. A number of other authors have drawn attention to the overlap of post-concussional symptoms with symptoms associated with pain resulting from other injuries, medication effects, posttraumatic stress, anxiety, depression, pre-accident psychological adjustment issues, individual coping styles, the presence of other stressors and/or litigation/compensation. It would appear that although mild TBI is usually associated with significant injury-related post-concussional symptomatology, these other issues may interact with these effects to exacerbate symptoms and distress and contribute to longer term problems. Psychologists have a significant role to play in disentangling these issues in order to provide effective management.

Moderate to severe TBI

The most common cognitive impairments following moderate to severe TBI include fatigue, deficits of attention and speed of information processing (affecting the ability to focus and divide attention), difficulties with new learning and memory, word-finding problems, and executive difficulties (including impaired planning and problem-solving, goal-directed behaviour, abstract thinking and mental flexibility). Behavioural and emotional changes reflect reduced control and regulation of behaviour, thought processes and emotions. They may include impulsivity, lowered frustration tolerance, irritability, aggression, reduced initiative or apathy, verbosity, egocentricity, reduced emotion perception, mood swings, excessive emotions or a flattening of affect. These changes are also commonly associated with reduced self-awareness, whereby the person with TBI lacks insight into the changes others perceive. These problems, which occur in differing combinations and in varying degrees of severity, have been shown to have a significant impact on the capacity of the individual with TBI to participate in and benefit from rehabilitation, and to resume previous activities and relationships.

The majority of individuals with TBI make a fairly good physical recovery, although balance and co-ordination difficulties may impede some activities. On the other hand, more than 60 per cent of people with moderate to severe TBI report persisting cognitive and behavioural changes up to 10 years post-injury. Up to one third require some supervision in activities of daily living, most commonly shopping and financial management. More than half are unable to return to employment or to resume previous leisure activities. Difficulty in forming or sustaining relationships is also common, with a growing sense of social isolation and increasing dependency on family for support. Such disabilities occurring in young people in their prime can have a catastrophic impact not only on their lives, but also on those of their relatives on whom there may be long-term dependency.

Psychosocial outcomes

Psychological studies, including many conducted by Australian psychologists, have contributed much to understanding the nature and predictors of psychosocial outcome following TBI. Factors associated with poorer long-term outcome include older age at injury, longer PTA duration, lower education, greater cognitive impairment, and genetic status, specifically possession of the ApoE e4 gene. Other influences on outcome include cultural background, premorbid employment status, premorbid psychiatric history and non-productive coping style.

Recent studies have highlighted the high frequency of psychiatric disorders following TBI. There is a growing body of evidence demonstrating the effectiveness of psychological therapy for anxiety and depression following TBI, which Australian psychologists are contributing to (see page 14). Australian psychologists have also led the way in using CBT to successfully enhance adaptive coping in people with TBI (Anson & Ponsford, 2006), and manage anger control problems (Medd & Tate, 2000).

Family members of people with TBI also show elevated rates of anxiety and depression, which persist over many years after injury, as well as experiencing social isolation. They report that cognitive and behavioural changes represent the greatest source of stress, particularly for those in a direct caregiving role.

Rehabilitation following TBI

Over the past two decades there have been some changes in models of post-acute rehabilitation services following brain injury. Most Australians are treated either in government-funded programs, or in private programs funded by the no-fault accident insurance schemes which exist in some States. However, there are wide variations in the quality and availability of programs.

Historically rehabilitation services have been provided in traditional inpatient and outpatient settings. The emphasis of these programs is multidisciplinary, i.e., different team members evaluate different components of the injured person's physical and cognitive impairments, and ameliorate these directly. Cognitive impairments are identified via neuropsychological assessment. If cognitive rehabilitation is administered it tends to involve repeated practice on computerised or pen-and-paper tasks exercising different components of the deficit, with the aim being to restore impaired functions. Although the training tasks bear little resemblance to tasks encountered in everyday life, it is argued that re-training the cognitive processes underlying functional activities will result in most lasting and generalisable gains. A number of studies have evaluated the effectiveness of such cognitive retraining programs. Although there has been some evidence of improvement on tasks practised, and some other neuropsychological measures tapping similar functions, there has been no clear evidence that this form of training has an impact upon the everyday functioning of the person with TBI.

Community-based TBI

There has been a growing awareness in Australia that many people with TBI, particularly those with associated executive problems, have difficulty in generalising what they learn in one situation to another. Follow-up studies have identified a significant number of individuals who continue to experience difficulties in their daily lives after they leave the rehabilitation setting. This has led some programs to alter their focus towards working with the person with TBI within the context of their daily life, rather than within the rehabilitation centre.

These programs differ from the traditional centre-based model in several ways. Firstly, the emphasis has shifted from ameliorating impairments and disabilities towards re-establishing life roles, and thereby increasing participation. The process of assessment no longer involves just the standardised administration of neuropsychological or vocational tests, or scales of activities of daily living. In addition to these things, it involves identifying the roles and skills which are important for the individual with TBI within the community context, as assessed from the perspective of that individual, close others, employers and educators. Individuals with TBI and close others are thereby actively involved in the process of goal setting and empowered to play a key role in their rehabilitation. Assessment and therapy occur, as far as possible, in the context in which a given role is normally performed. Education of the injured person's network of contacts, including family, friends, employers or teachers, is another key aspect of this model, since the use and adaptation of strategies will continue through the person's lifetime, far beyond the availability of therapeutic input.

Psychological support is required to assist the person with TBI and close others in coming to terms with lasting personality and lifestyle changes and forming a new post-injury identity.

Ideally, follow-up contact is maintained over an extended period to provide support in dealing with new problems as they arise with changing circumstances.

Where the person with TBI is not able to return home from hospital, this therapeutic input may be provided within a residential 'Transitional Living Program'. Staff provide therapy to enhance independent living skills and interpersonal skills, and eventually support the move to independent living, with continuing attendant care or other supports as necessary.

A more common model of service provision is that of a 'community-based team'. This generally comprises occupational therapy, speech pathology, clinical and/or neuropsychology, physical therapy and/or social work services, vocational counselling and educational assessment as needed. Generic services in the local community may be utilised. Assessment, goal-setting and interventions are carried out within the relevant settings in the community. Intervention may involve repeated practice to establish routines, development of compensatory strategies, or modification of the task or environment to maximise successful task performance. Attendant care assistance may be employed. The psychologist would be involved in cognitive and behavioural assessment to identify strengths and weaknesses as a basis for decisions regarding management strategies (e.g., use of a diary), in providing therapy for behavioural or interpersonal difficulties, problem-solving skills, and in facilitating psychological adjustment to disability and lifestyle changes, ideally in a community-based context. The team harnesses community resources and natural supports to assist the individual with TBI to attain self-determined goals. The establishment of a support network of family, friends and others is also facilitated. The long-term aim of intervention is to have the person with TBI and family supported within their local community, although a case manager or specific team members typically have follow-up contact to ensure that the network is maintained and to deal with any difficulties arising. A similar approach is applied to the processes of return to work or school (Ponsford, Sloan, & Snow, 2012).

Family support

TBI has a significant impact on caregivers, and on the family as a whole. Family members provide most ongoing support of a practical, social and emotional nature to the TBI individual, and family interactions are an important determinant of the injured person's psychosocial adjustment. Therefore it is vital that the family unit be involved in the rehabilitation process, and have access to supportive counselling and assistance in finding and dealing with service agencies and managing financial and legal issues. The adjustment process for families is likely to be lengthy. Multifamily group interventions may provide opportunities to share experiences and enhance family functioning and social integration for caregivers. Access to family therapy services should be available to assist families who have difficulty in grieving, or in adjusting roles and expectations of the injured individual within the family following injury. All forms of family support should be available over the lifespan of the person with TBI.

Provision of support in managing behavioural problems following TBI is of paramount importance. Family caregivers report this to be the greatest source of stress in caring for their injured relatives. Psychologists with specialist expertise in this domain are highly sought-after. A community-based support team for individuals with severe behaviour problems exists

in Victoria. This team of clinical and neuropsychologists offers education, secondary and tertiary consultation to institutions (e.g. nursing homes, schools) or carers, as well as direct intervention in relevant community settings.

TBI in children

The impact of TBI is somewhat different in children from that in adults. The causes of TBI differ, with high rates of child abuse in infants, and a higher proportion of falls and injuries involving a bat and ball and a lower proportion of motor vehicle accidents, although this rises in adolescents. Whilst children appear to have a lower mortality and show a better motor-sensory recovery, there is clear evidence of lasting impairment in the domains of memory, attention, speed of performance, abstract thinking and executive function, as in adults (Babikian & Asarnow, 2009). These impairments have long-term effects on academic attainment. As in adults, children with TBI experience social interaction difficulties. Behaviour problems are also common following severe TBI, but they follow a less predictable pattern, being associated with premorbid behavioural patterns and family functioning, as well as the injury and emotional factors.

Evidence from numerous outcome studies suggests that the manifestations of TBI in children, both cognitively and behaviourally, depend on three factors. The first is the severity of injury, those with most severe injuries being at greatest risk of long-term sequelae (Anderson et al., 2009). The second is the age at injury, with children injured in the pre-school years being more vulnerable to long-term impairments than children injured at older ages (Anderson et al., 2005). The third influence is the child's pre-injury cognitive behavioural and psychosocial functioning, including the socioeconomic and family environment. There is a need for skilled and careful assessment in all these areas, including a comprehensive assessment of the child's physical, linguistic, cognitive, academic and behavioural functioning prior to injury, as well as social and family functioning.

Rehabilitation facilities need to cater specifically to children, and have the flexibility to work in the community. Attention should be paid to the child's social and emotional adjustment throughout the rehabilitation process. Return to school must be carefully planned, with follow-up support available over many years as the demands on the child change. Given the impact of family functioning on outcome following paediatric TBI, ongoing family support is also vital.

Future directions and conclusions

TBI creates complex and challenging problems for those injured and their families. Australian psychologists have been at the forefront of developing an understanding, of these problems, raising community awareness and identifying effective models of care. Psychologists have many roles to play in diagnosing cognitive, behavioural and emotional difficulties, devising appropriate management strategies in collaboration with other allied health professionals, providing psychological interventions to those injured and their families, and evaluating their efficacy. The delivery of psychological therapy to people with TBI is challenging. It requires an understanding of cognitive and behavioural limitations, as well as the individual's personality style, pre-injury history and surrounding social factors, and needs

to be adapted accordingly. Unfortunately there are relatively few psychologists employed in rehabilitation settings, which limits access to specialised psychological care.

As well as increased numbers of psychologists, there is a significant need for cross-disciplinary training between clinical neuropsychologists, clinical psychologists and educational psychologists, working together with other disciplines in order to provide the right skill set to achieve effective interventions in adults and children. Much further evaluative research is required to establish the evidence base for psychological interventions for individuals with TBI. With the relatively rich funding systems for rehabilitation and large number of well trained clinical neuropsychologists, Australian psychologists will continue to lead the world in building this evidence base and contributing to improved quality of life for individuals with TBI and their families.

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