

Recovery After Traumatic Brain Injury from a Fall: A Multifaceted Analysis of the Possibility of 'Perfect Recovery'

Introduction: The Concept of 'Perfect Recovery' in Traumatic Brain Injury

After a traumatic brain injury (TBI) from a fall, the most pressing question for patients and their families is, "Can I recover completely, just as I was before?" To answer this, we must first medically define the concept of 'perfect recovery.' Once the brain is damaged and neurons die, these cells do not physically regenerate.¹ Therefore, a 'complete anatomical recovery,' where brain tissue is restored to its 100% pre-accident state, is impossible with modern medicine.

However, the recovery process after a brain injury is not solely determined by the regeneration of damaged tissue. The core principle of recovery lies in 'neuroplasticity.'² Neuroplasticity is the brain's remarkable ability to reorganize its structure and function, forming new neural connections so that healthy areas can take over the functions of damaged parts.¹ The entire rehabilitation process focuses on maximizing this neuroplasticity to regain as much lost function as possible.

Thus, the realistic goal of TBI recovery is not 'perfect recovery' but 'maximal functional recovery.' This means enabling the patient to lead as independent and meaningful a life as possible, despite any remaining physical, cognitive, and emotional sequelae. Compared to stroke patients, TBI patients often have some surviving neural tissue in the damaged area, suggesting greater neuroplasticity and a higher potential for functional recovery.²

This report aims to assess the possibility of 'perfect recovery' after a head impact from a fall by conducting an in-depth analysis of 10 key clinical factors that determine the prognosis for recovery. From the anatomical location and type of injury to the initial state of consciousness, the recovery process of motor and cognitive functions, the role of rehabilitation, the patient's age, and emotional issues, we will comprehensively examine the impact of each factor on the

overall recovery process to provide a deep understanding of the complex and multidimensional reality of TBI recovery.

Section 1: How the Location of Injury Determines the Pattern of Sequelae

The type and severity of sequelae following a traumatic brain injury are critically dependent on the anatomical location of the damaged brain area. Each region of the brain is responsible for unique functions, so identifying which part was impacted is the most fundamental starting point for predicting the patient's prognosis and establishing a rehabilitation plan.

The Brain's Functional Map and Injury-Related Sequelae

- **Frontal Lobe:** Located at the very front of the brain, the frontal lobe is often called the 'CEO of the brain' or the 'command center.' It is responsible for higher-level cognitive functions known as 'executive functions,' such as planning, problem-solving, judgment, impulse control, social behavior, and personality expression.⁵ Frontal lobe damage often causes sequelae like personality changes, poor judgment, impulsive and risky behavior, and inappropriate language, rather than visible disabilities like paralysis.⁵ Patients may experience severe mood swings (emotional lability) or fall into a state of apathy, showing no motivation for anything.⁵ They may also struggle significantly with multitasking or systematically planning tasks, making it difficult to complete even routine activities like preparing a meal or organizing laundry.⁶
- **Temporal Lobe:** Located near the ears on both sides of the brain, the temporal lobe plays a key role in memory, language comprehension, auditory information processing, and emotional regulation. Specifically, the hippocampus in the medial temporal lobe is essential for learning new information and converting it into long-term memory, while the amygdala processes emotions like fear and anxiety.¹⁰ Damage to the temporal lobe can lead to severe memory impairment, particularly 'anterograde amnesia,' the inability to form new memories.¹² It can also cause 'Wernicke's aphasia,' a difficulty in understanding others' speech, and increase the likelihood of experiencing emotional problems such as anxiety or panic attacks.¹⁰
- **Parietal Lobe:** Situated at the top center of the brain, the parietal lobe integrates sensory information like touch, pain, and temperature, and is involved in spatial awareness, calculation, reading, and writing. Damage to this area can make it difficult to

distinguish objects by shape or weight through touch, cause confusion between left and right, and lead to trouble finding familiar routes. In severe cases, 'hemispatial neglect,' a condition where the patient is unaware of one side of their body, may occur.

- **Occipital Lobe:** Located at the back of the brain, the occipital lobe is the center for processing visual information. Occipital lobe damage can result in a visual field defect (a blind spot), visual agnosia (the inability to recognize objects or faces), and in severe cases, complete blindness.
- **Cerebellum:** Located below the cerebrum at the back of the brain, the cerebellum is responsible for fine motor control, balance, and posture. Damage to the cerebellum can lead to decreased muscle tone, an unstable gait, and clumsy, shaky goal-oriented movements, a condition known as 'ataxia.'¹⁴
- **Brainstem:** Connecting to the spinal cord at the base of the brain, the brainstem controls involuntary functions essential for life, such as breathing, heart rate, blood pressure, body temperature, swallowing, and consciousness.¹⁴ Brainstem damage is often fatal, and survivors frequently have severe and widespread disabilities.

The Complex Nature of Recovery Based on Injury Location

A crucial point in the brain injury recovery process is that damage to a specific area does not result in a single, isolated problem but can trigger a chain of difficulties. For example, memory loss from temporal lobe damage¹⁰ directly hinders the ability to learn new motor skills or compensatory strategies during rehabilitation.¹² Loss of balance due to cerebellar damage¹⁵ can cause a fear of falling, making the patient hesitant to participate in physical therapy and thus slowing physical recovery. This reduction in physical activity can lead to social isolation, which in turn can worsen depression.⁹ As such, the sequelae of brain injury are intricately interconnected, and the recovery process involves managing these linked issues comprehensively.

Cognitive and personality changes resulting from frontal or temporal lobe damage, often called an 'invisible injury,' cause great distress for patients and their families. The patient may look physically fine but act like a completely different person, getting easily angered over trivial matters or repeatedly forgetting important appointments.⁵ People around them may not understand that these changes are symptoms of the brain injury and may misinterpret them as issues of willpower or personality, leading to serious relationship conflicts. Therefore, successful recovery extends beyond regaining physical function and must include a deep understanding of these 'invisible injuries' by family and society, along with professional psychosocial support.

Brain Region	Primary Functions	Common Sequelae After Traumatic Brain Injury
Frontal Lobe	Executive functions (planning, judgment, problem-solving), impulse control, personality, emotional regulation	Personality changes, poor judgment, impulsive behavior, social deficits, apathy, attention deficits, emotional lability ⁵
Temporal Lobe	Memory formation and storage (hippocampus), language comprehension (Wernicke's area), hearing, emotion processing (amygdala)	Amnesia (especially forming new memories), impaired language comprehension, auditory processing issues, anxiety and panic disorders ¹⁰
Parietal Lobe	Sensory information integration (touch, pain), spatial perception, calculation, reading/writing	Sensory deficits, hemispatial neglect, disorientation, acalculia, alexia/agraphia
Occipital Lobe	Visual information processing	Visual field defects, visual agnosia (inability to recognize objects/faces), cortical blindness
Cerebellum	Motor control, balance, posture	Ataxia (staggering gait, clumsy movements), hypotonia, tremor ¹⁴
Brainstem	Life-sustaining functions (breathing, heart rate, blood pressure), consciousness, swallowing	Coma, respiratory distress, dysphagia, severe motor dysfunction, death ¹⁴

Section 2: Prognostic Differences Between Focal Injury and Diffuse Axonal Injury (DAI)

Brain injuries can be broadly classified into 'focal injury' and 'diffuse injury' based on the scope and pattern of the damage, and their prognoses differ starkly.¹⁶

Definitions of Focal Injury and Diffuse Axonal Injury

- **Focal Brain Injury:** A focal injury is damage confined to a specific area of the brain. Examples include a cerebral contusion (bruising of the brain) from a direct impact when the head hits the ground during a fall, or an intracranial hematoma (a collection of blood) that compresses the brain.¹⁴ The resulting symptoms are directly related to the function of the specific brain region damaged, as described in Section 1. For instance, a focal contusion in the frontal lobe would primarily manifest as executive dysfunction.
- **Diffuse Axonal Injury (DAI):** DAI refers to microscopic damage that occurs extensively throughout the brain. It can happen even without a direct blow to the head, caused by sudden acceleration-deceleration or rotational forces, such as in a fall or car accident.¹⁴ These forces cause the brain to shake or twist within the skull, tearing or damaging the long, slender nerve fibers called 'axons' that connect different brain regions.¹⁴ DAI is not a problem in a specific part but damage to the brain's overall information transmission system—the neural network itself.

Critical Differences in Prognosis

Generally, diffuse axonal injury results in much more severe sequelae and has a poorer prognosis than a focal injury of similar size. If a focal injury is like a specific 'part' of the brain breaking down, DAI is comparable to the 'wires' connecting all those parts being damaged system-wide.

The most characteristic clinical feature of DAI is an immediate and prolonged loss of consciousness (coma) right after the accident.¹⁷ This indicates widespread damage to the brain's arousal and consciousness systems. Even if the patient regains consciousness, they often exhibit a significant slowing of overall information processing speed and severe deficits in multiple cognitive domains, such as attention, memory, and multitasking.¹⁰ This is due to a 'disconnection syndrome,' where individual functional areas of the brain may be relatively intact, but the smooth exchange of information between them is disrupted. It is like the brain's 'internet' speed has become extremely slow or the connection is lost.

Differences also appear in the recovery process. Recovery from a focal injury tends to follow a more predictable path through neuroplasticity in the areas surrounding the damage. In contrast, recovery from DAI is often much slower and more incomplete.¹⁸

Diagnostic challenges also affect the prognosis. A focal hematoma or a large contusion can be easily detected on a computed tomography (CT) scan in the emergency room. However, because DAI involves microscopic axonal damage, initial CT scans may appear normal or show only minor changes. This can lead families to underestimate the patient's condition based on early imaging, while the patient exhibits severe cognitive impairments. An accurate diagnosis of DAI requires more detailed imaging like magnetic resonance imaging (MRI), and clinical findings such as the duration of initial loss of consciousness and post-traumatic amnesia play a crucial role in the diagnosis.

Characteristic	Focal Injury	Diffuse Axonal Injury (DAI)
Mechanism of Injury	Direct impact (brain colliding with the skull)	Acceleration-deceleration, rotational forces (brain shaking and twisting)
Primary Form of Damage	Cerebral contusion, laceration, intracranial hematoma	Widespread shearing and damage of nerve axons
Initial Imaging (CT)	Clear lesions like hematomas or contusions are often visible	May appear normal or show only minor changes
Primary Clinical Manifestation	Specific functional deficits related to the damaged brain area (e.g., aphasia, hemiplegia)	Immediate and prolonged loss of consciousness (coma), global cognitive deficits (processing speed, attention, memory)
General Prognosis	Varies with severity, but recovery tends to be faster and the prognosis better than DAI	Recovery is slower and often incomplete, with a high likelihood of long-term cognitive and behavioral impairments ¹⁸

Section 3: The Correlation Between Initial State of Consciousness and Long-Term Prognosis

The patient's state of consciousness immediately after the accident is one of the most critical early indicators for assessing the severity of a traumatic brain injury and predicting the long-term prognosis. The deeper the level of consciousness impairment and the longer its duration, the more extensive and severe the brain damage is likely to be.

Glasgow Coma Scale (GCS)

Medical professionals use a standardized tool called the Glasgow Coma Scale (GCS) to objectively assess a patient's level of consciousness at the scene of the accident or in the emergency room.¹⁹ The GCS scores three types of responses:

1. **Eye Opening (E):** 4 points (spontaneous) to 1 point (no response)
2. **Verbal Response (V):** 5 points (oriented and conversing) to 1 point (no sound)
3. **Motor Response (M):** 6 points (obeys commands) to 1 point (no movement)

The scores from these three categories are summed, with a total score ranging from a minimum of 3 to a maximum of 15. Based on the GCS score, the severity of a traumatic brain injury is classified as follows ¹⁴:

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

A GCS score of 8 or less defines a state of 'coma,' where the patient does not open their eyes spontaneously and cannot follow commands.²¹

The Link Between GCS Score and Prognosis

The initial GCS score is very closely related to the patient's chances of survival and their long-term level of functional recovery. The lower the GCS score, the exponentially higher the

mortality rate, and for survivors, the greater the probability of having severe disabilities.²¹

Particularly, patients with a 'critical' severe brain injury, with a GCS score of 3-5, have a very poor prognosis, with high rates of mortality and long-term disability.²³ One study reported that only about 20% of patients with a reliable initial GCS score of 3-5 survive, and of those survivors, less than half achieve a 'good outcome' (moderate disability or good recovery).²¹

The duration of the coma is also a significant prognostic factor. If a coma lasts for several weeks, the subsequent period of post-traumatic amnesia can extend for months, and overall recovery may take months to years.¹⁸ If it takes more than a month for a patient to progress beyond responding to painful stimuli to following simple commands like "lift your hand," the long-term prognosis is likely to be poor.²¹

Caveats and Limitations of GCS Interpretation

While the GCS is a very useful tool, a patient's fate should not be determined by the score alone. The GCS is just a 'snapshot' at a particular moment and does not reveal the full extent of a patient's recovery potential. Especially in young patients, there are cases of remarkable recovery even with very low initial GCS scores.²³ Although a GCS score of 3-4 in elderly patients over 65 suggests a very poor prognosis, a study showing that about 9% of them achieved a functionally good recovery demonstrates that the GCS provides probabilities, not an absolute, 100% certain prediction of an individual's outcome.²⁴

Furthermore, it is important to consider that the GCS score can be artificially lowered by factors other than the brain injury itself.¹⁹ For example, if a patient is intubated to secure an airway, their verbal response (V) cannot be assessed, inevitably resulting in a lower score (in this case, a 'T' is added, e.g., GCS 3T). Also, the administration of sedatives or anesthetics, alcohol or drug intoxication, or shock (hypotension) from other severe physical injuries can lower the GCS score irrespective of the actual degree of brain damage.¹⁹ Therefore, the trend of GCS scores measured repeatedly after the patient's blood pressure has stabilized in the hospital is more important for prognosis than the initial GCS score measured at the scene.

Severity	GCS Score (after stabilization)	Typical Duration of LOC	Typical Duration of PTA	General Long-Term Prognosis
Mild	13-15	< 30 minutes	< 24 hours	Most recover

				well, but sequelae like headaches, fatigue, and concentration difficulties may persist. ¹⁴
Moderate	9-12	30 minutes - 24 hours	1 - 7 days	May leave some permanent physical and cognitive disabilities; rehabilitation is essential for returning to society. ¹⁸
Severe	3-8	> 24 hours	> 7 days	High mortality rate; survivors often have severe physical, cognitive, and behavioral disabilities. Long-term care may be necessary. ¹⁸

Section 4: Reconstructing Memory: Post-Traumatic Amnesia and Recovery

Amnesia after a brain injury is one of the most confusing symptoms for patients and their families. There are two main types of amnesia, and the length of the period during which new memories cannot be formed after the accident is a crucial indicator for predicting long-term cognitive recovery.

Retrograde Amnesia and Post-Traumatic Amnesia (PTA)

- **Retrograde Amnesia:** This is the inability to recall events that occurred *before* the accident.²⁵ The period of memory loss can range from a few minutes just before the accident to several days or months. Fortunately, during recovery, memories from the distant past tend to return first, while memory for the short period immediately preceding the accident is often permanently lost.²⁶
- **Post-Traumatic Amnesia (PTA):** This refers to the state of being unable to consistently form and store new memories *after* the accident has occurred.²⁵ After waking from a coma, the patient may appear confused, not knowing who they are, where they are, or what time it is.²⁷ During this period, the patient may forget a conversation they just had or a person they just met within minutes, as daily experiences are not stored as continuous memories.²⁷ The duration of PTA is considered a more sensitive indicator of the severity of the brain injury and long-term prognosis than the duration of the loss of consciousness.²⁵

The severity of brain injury based on the duration of PTA is generally classified as follows:

- **Mild TBI:** PTA < 24 hours¹⁸
- **Moderate TBI:** PTA 1-7 days¹⁸
- **Severe TBI:** PTA > 7 days¹⁸

If the PTA period exceeds one week, it can be predicted that there is a very high probability of persistent cognitive impairment.¹⁸

The Clinical Significance of the PTA Period

The PTA period is not simply a 'blank' state of no memory. During this time, the patient is in a state of extreme confusion, disorientation, and attention deficit, and may sometimes exhibit unexplained agitation, anxiety, or aggressive behavior.² This is a temporary state of dysfunction as the brain recovers from the injury, and patients themselves usually have no memory of their confused behavior during this time.²⁷ Therefore, it is crucial for caregivers to understand that this behavior is not intentional or a personality issue but a symptom of the brain's recovery process, and to provide a calm and stable environment.

Another characteristic of memory recovery after brain injury is the 'imbalance between old memories and the ability to form new ones.' Many patients can recall old memories from

before the accident, such as childhood memories or school experiences, relatively well. However, they struggle greatly to remember recent events, like what they had for breakfast this morning or who visited them in the hospital yesterday.¹² This is because old memories are already stored and 'encoded' in the brain, whereas the 'machinery' for taking in and storing new information (primarily handled by the hippocampus in the temporal lobe) is damaged.¹⁰ This phenomenon can be very frustrating for patients and families, so it is necessary to understand the specific nature of post-TBI memory impairment and to have realistic expectations.

Section 5: The Recovery of Movement: The Spectrum and Possibilities of Hemiplegia

A brain injury from a fall can damage the brain areas or neural pathways that control movement, causing paralysis in parts or all of the body. 'Hemiplegia,' paralysis on one side of the body due to damage to the opposite brain hemisphere, is a common sequela. Hemiplegia is classified into 'hemiplegia' (complete paralysis) and 'hemiparesis' (partial weakness), which is an important criterion for assessing recovery potential.

Hemiplegia and Hemiparesis

- **Hemiplegia:** This refers to a state where one side of the body is completely or almost completely paralyzed.³⁰ The patient cannot move their arm or leg on that side at will. This indicates very severe damage to the motor command pathways from the brain to the muscles.
- **Hemiparesis:** This refers to a state of weakness on one side of the body.³¹ It is not complete paralysis, so some movement is possible, but muscle strength is reduced, making it difficult to perform normal activities. For example, lifting an arm or gripping an object may feel strenuous.

Differences in Recovery Potential

Clinically, hemiparesis has a much better prognosis for recovery than hemiplegia. The

presence of even slight voluntary movement is evidence that some of the neural pathways connecting the brain and muscles are still intact. These remaining connections can be strengthened through rehabilitation, and based on the principle of neuroplasticity, the surrounding neural networks can be trained to take over the function.¹

On the other hand, recovery from complete paralysis (hemiplegia) can be slower and more difficult. However, it is not without hope. A study on stroke patients (whose recovery mechanisms are similar to TBI) reported that 74% of patients who were unable to walk at 3 months post-stroke could walk without assistance after two years of long-term rehabilitation.³³ This suggests that functional recovery through neuroplasticity can occur over a long period.

A study on arm paralysis recovery after TBI reported that most recovery occurs intensively within the first 2 months after the accident, but for patients with diffuse brain injury, slow recovery can continue even after 3 months.³⁴ The degree of recovery is most influenced by the initial severity of the paralysis and the overall severity of the brain injury.³⁴

'Use It or Lose It': Overcoming Learned Non-use

One of the most important concepts in hemiplegia recovery is preventing 'learned non-use.'³⁰ Using a paralyzed limb after a brain injury is a very difficult and frustrating experience. Therefore, patients naturally tend to use only their healthy limbs. When this behavior is repeated, the brain gradually 'forgets' how to use the paralyzed side. In other words, even potential neural functions that could be recovered are allowed to degenerate through disuse.

Therefore, it is crucial to start rehabilitation as early as possible to repeatedly stimulate the paralyzed body parts. This is not just about strengthening muscles; it is a process of continuously sending signals to the brain that "this body part still exists and should be used," thereby promoting neuroplasticity and breaking the vicious cycle of 'learned non-use.'

Section 6: The Quality of Functional Recovery: Is 100% Possible?

A major goal of rehabilitation after a traumatic brain injury is to restore motor function so that the patient can live independently as before. Many patients regain a significant portion of their ability to perform basic physical activities like walking, eating, and dressing. However, the

answer to the question, "Have they recovered 100% to be exactly the same as before the accident?" is much more complex.

The Recovery Gap Between Gross and Fine Motor Skills

Traumatic brain injury patients often recover to a point where their physical functions do not significantly hinder their daily lives.⁴ That is, gross motor skills like walking or climbing stairs can be substantially restored. However, the complete recovery of fine motor skills that require precision, such as buttoning a shirt or writing, is a more challenging task.

Even if they appear to walk normally on the outside, many patients live with subtle sequelae. These residual symptoms greatly affect the 'quality of recovery.'

- **Movement Disorders:** A kinetic tremor that worsens when reaching for a target, or spasticity (muscle stiffness), may remain and interfere with movement.³⁵
- **Impaired Balance and Coordination:** Subtle balance deficits or ataxia may persist, causing instability when walking fast, changing direction, or walking on uneven surfaces.²
- **Chronic Fatigue:** One of the most common and distressing sequelae after TBI is extreme fatigue.⁹ Even a small amount of physical or mental activity can be exhausting, and it takes a long time to recover. This makes it very difficult to maintain a job or social activities.³⁶
- **Slowness:** All physical and cognitive response times tend to be slower than before.

The 'Cognitive Load' of Movement and Subjective Recovery Experience

One of the fundamental reasons why complete recovery is difficult is the increased 'cognitive load' of movement. Actions that were unconscious and automatic before the accident, such as walking and balancing, require considerable conscious effort after a brain injury. The patient must consciously focus on their foot placement and body's center of gravity with every step to avoid falling.

This situation, where once-automated motor programs are damaged and every movement must be consciously controlled, places an enormous burden on the brain. This is precisely why many patients feel completely exhausted after walking even a short distance. The fatigue is not just a physical phenomenon but the result of expending excessive mental energy for

basic movements.

Therefore, the 'quality of recovery' cannot be measured by objective functional assessments alone. Clinically, a patient may be assessed as 'able to walk independently,' but the patient themselves may be walking with immense effort and fatigue. This is why the goal of rehabilitation shifts from 'cure' to 'compensation and adaptation.' While 100% perfect recovery of motor function is very rare, learning to manage the remaining subtle discomforts and using energy-efficient strategies to successfully adapt to a new way of life is an entirely achievable goal.

Section 7: The Role and Efficacy of Cognitive Rehabilitation

After a traumatic brain injury, the biggest obstacle for a patient's return to home and society is often not physical disability but a decline in cognitive functions such as memory, attention, and problem-solving skills.⁴ Therefore, professional cognitive rehabilitation therapy is an essential component of the TBI recovery process, and it is a clear fact that receiving systematic rehabilitation leads to much better outcomes than not.³⁸

The Necessity and Proven Effects of Cognitive Rehabilitation

After a brain injury, patients experience various cognitive difficulties. Memory and concentration impairments are particularly prominent, and problems with executive functions, such as planning and executing tasks, also arise.³⁸ This decline in cognitive function affects all areas of life, including learning, work performance, and interpersonal relationships.

Cognitive rehabilitation is a therapeutic approach that provides systematic training to improve these problems. Numerous studies have proven that cognitive rehabilitation programs significantly enhance the cognitive functions of TBI patients. In particular, programs focusing on improving attention have been reported to improve scores on neuropsychological tests for attention and memory.³⁹

Methods of Cognitive Rehabilitation: The Rise of Computer-Assisted

Cognitive Rehabilitation (CACR)

While traditional cognitive rehabilitation was conducted through one-on-one training with a therapist, recently, Computer-Assisted Cognitive Rehabilitation (CACR) programs have been widely used.⁴¹ CACR has several advantages:

- **Objectivity and Immediate Feedback:** The patient's performance is accurately recorded, and immediate feedback on correctness or time taken is provided, enhancing learning effects and motivation.³⁹
- **Repetitive Training:** Patients can use the program on their own for sufficient repetitive training.
- **Personalized Adaptation:** The difficulty of tasks can be adjusted according to the patient's cognitive level.

Research suggests that computerized cognitive rehabilitation programs may be more effective than traditional cognitive therapy in improving the cognitive function and daily living activities of TBI patients.⁴² Korean-style computerized cognitive rehabilitation programs have also been confirmed as useful intervention tools for improving the frontal-executive functions of TBI patients.⁴³

The Essence of Rehabilitation: Restoration of Function and Learning of Compensatory Strategies

Cognitive rehabilitation does not revive damaged brain cells. The core principles of cognitive rehabilitation are twofold. The first is 'restoration,' which strengthens weakened cognitive functions through repetitive training. The second is 'compensation,' which involves learning new ways to overcome permanent deficits.

A successful outcome of cognitive rehabilitation does not necessarily mean returning to pre-injury cognitive abilities. Rather, it is more important to acquire effective 'compensatory strategies' to supplement one's cognitive weaknesses and successfully apply them in daily life. For example, a patient with memory problems learns to use smartphone alarms or notepads to remember appointments or tasks, rather than trying to restore their memory to 100%.¹² A patient who finds it difficult to perform complex tasks is trained to break the task down into several small steps and handle them sequentially.

However, one of the biggest challenges in cognitive rehabilitation is the 'generalization' of skills learned in the therapy room to real-life environments. Getting a high score in a computer

game does not automatically improve problem-solving skills in real life.⁴⁴ Therefore, the most effective cognitive rehabilitation requires a personalized approach that closely links training in the therapy room with real-life tasks, considering the patient's actual living environment and occupational demands.

Section 8: The Variable of Age: Neuroplasticity, Cognitive Reserve, and Recovery Potential

The patient's age is one of the most powerful and consistent factors in determining the prognosis of a traumatic brain injury. Generally, the younger the age, the greater the brain's potential for recovery, and the older the age, the slower and more incomplete the recovery.¹⁴ This is due to age-related differences in neuroplasticity and 'cognitive reserve.'

Age-Dependent Neuroplasticity

Neuroplasticity, the brain's ability to adapt and reorganize itself in response to injury, occurs throughout life, but its extent varies significantly with age.⁴⁶ Infancy and childhood, in particular, are periods of explosive brain development and change, corresponding to a 'critical period' or 'sensitive period' of peak neuroplasticity.⁴⁶ During this time, even if a brain injury occurs, the ability of other brain regions to take over the functions of the damaged area is so outstanding that functional recovery is often much more dramatic than in adults.⁴⁷ For example, pediatric brain injury patients show very good recovery of language functions, with infants under one year of age showing even more remarkable resilience.⁴⁸

In contrast, as the brain matures into adulthood and ages, the speed and scope of neuroplasticity gradually decrease.⁴⁶ An older brain has a reduced capacity to form new neural connections compared to a younger brain, so even with the same degree of injury, functional recovery is more limited.¹⁴

The 'Cognitive Reserve' Hypothesis

Another important concept that explains age-related differences in prognosis is 'cognitive

reserve.' Cognitive reserve refers to the brain's ability to resist damage and buffer its effects—in other words, the brain's 'spare capacity.' A high level of education, a complex occupation, and active intellectual pursuits are known to build rich neural networks, thereby increasing cognitive reserve.

A young, healthy brain has a high reserve, so even if some areas are damaged, it can utilize other neural circuits to maintain or compensate for function. However, an aging brain has already undergone natural neuron loss or microvascular changes, resulting in a diminished reserve.⁴⁵ In this state, when it receives the additional blow of a traumatic brain injury, it lacks the capacity to buffer the impact of the damage, leading to much more severe functional decline. Furthermore, research indicates that moderate to severe brain injury can accelerate brain aging and increase the long-term risk of dementia.⁵⁰

Brain Injury at a Young Age: A Double-Edged Sword

While the superior neuroplasticity of a young age is clearly an advantage for recovery, it does not always lead to positive outcomes. A brain injury at a very early age can be a 'double-edged sword.' When the brain is still developing, an injury might allow for a remarkable recovery of immediate, basic functions. However, the injury can derail the brain's normal developmental trajectory.

Specifically, the development of higher-order executive functions (planning, abstract thinking, social judgment), which mature during late adolescence and early adulthood, can be impaired. As a result, problems that were not apparent in childhood may only manifest later in adulthood when academic demands become more complex and independent social life is required. In other words, while the initial recovery may seem good, it can result in a lower 'ceiling' for the functional level that can be achieved in adulthood. Therefore, pediatric brain injury patients require continuous monitoring over many years and appropriate educational and therapeutic support tailored to their developmental stage.⁴⁸

Section 9: The Invisible Wound: The Impact of Emotional Sequelae on Rehabilitation

The recovery process after a traumatic brain injury is not just a battle to regain physical and cognitive functions. Many patients must also fight against serious emotional problems, the

'invisible wounds,' such as depression, anxiety disorders, and post-traumatic stress disorder (PTSD). These emotional sequelae are not only distressing in themselves but also act as serious obstacles that sap the motivation for rehabilitation and hinder the recovery process.

High Prevalence and Complex Causes

Emotional and behavioral changes are very common after a traumatic brain injury. Studies show that about 25% to 60% of TBI survivors experience depression, a rate significantly higher than in the general population.⁹ Anxiety disorders, PTSD, irritability over minor issues, and severe mood swings (emotional lability) are also frequently observed.⁹

The causes of these emotional problems are twofold:

1. **Neurobiological Causes:** The brain injury itself alters the brain's structure and chemical balance. Damage to the frontal lobe or limbic system, which are responsible for emotional regulation, and disruption of neurotransmitter systems involved in mood regulation (e.g., serotonin) can be direct causes.⁹
2. **Psychosocial Causes:** These are psychological reactions to the life-altering experience of the brain injury. Suddenly losing physical and cognitive abilities, losing one's job and social roles, and having to depend on others can cause immense stress and a sense of loss. It is a natural process for this frustration and helplessness to lead to depression and anxiety.¹⁵

How Emotional Problems Hinder Rehabilitation

Emotional sequelae are not mere side effects; they are key factors that can determine the success or failure of rehabilitation. Depression depletes a patient's motivation and energy, taking away the drive to actively participate in the difficult and painful rehabilitation process.⁹ Patients with accompanying apathy tend to have a poor response to treatment and lower compliance, leading to a poor prognosis.⁹ Anxiety disorders can cause patients to avoid new challenges or social situations, obstructing functional recovery and social reintegration.

In particular, cognitive and emotional problems form a 'vicious cycle' that exacerbates each other. Cognitive difficulties caused by the brain injury, such as decreased attention or slowed information processing, constantly frustrate the patient, which in turn amplifies feelings of depression or anxiety.⁵⁵ Conversely, depression and anxiety are known to further impair cognitive functions like attention, memory, and problem-solving.⁵² To break this vicious cycle,

active treatment for emotional problems must be combined with physical and cognitive rehabilitation.

Symptom Overlap and Diagnostic Challenges

Diagnostic difficulties also exist. The main symptoms of depression—fatigue, lethargy, poor concentration, sleep disturbances—are very similar to and overlap with the symptoms of the traumatic brain injury itself.⁵³ This can make it difficult to distinguish whether a patient's lethargy is due to treatable depression or an irreversible symptom of the brain injury. If it is dismissed as an unavoidable consequence of the brain injury, the patient may miss the opportunity to receive effective treatment (e.g., antidepressant medication, cognitive-behavioral therapy).⁵² Therefore, it is crucial to conduct regular and proactive depression screening for all TBI patients, carefully differentiate the cause of the symptoms, and establish an integrated treatment plan.

Section 10: Redefining Intelligence: Changes in Cognitive Structure After Brain Injury

To discuss the impact of a traumatic brain injury on 'intelligence,' one must first understand that 'intelligence' is not a single ability but a complex of various cognitive functions. Generally, TBI does not significantly affect 'crystallized intelligence,' such as stored knowledge or vocabulary, but it severely impairs 'fluid intelligence,' the ability to efficiently process new information and solve problems.

Key Cognitive Domains Impaired by TBI

After a brain injury, patients experience a marked decline in the following specific cognitive areas, which is perceived as a general decline in 'intelligence.'

- **Information Processing Speed:** One of the most common and persistent sequelae after a brain injury is a slowing of the speed of thought.¹³ The overall efficiency of the brain decreases, requiring more time to understand conversations, read texts, and react to surrounding situations. Since this is a decline in the fundamental speed that underlies all

other cognitive activities, it affects every aspect of life.

- **Memory and Learning:** As previously discussed, the ability to take in (encode), store, and retrieve new information when needed is one of the most vulnerable areas after a brain injury.² This leads to great difficulty in learning new skills or adapting to new environments.
- **Attention and Concentration:** The ability to maintain focus on a specific task, selectively attend to important information among multiple stimuli, and ignore irrelevant stimuli is impaired.² Patients become easily distracted and find it hard to follow the flow of conversation in situations where multiple people are talking at once.
- **Executive Functions:** A decline in executive functions, closely related to frontal lobe damage, has a devastating impact on problem-solving abilities. The entire process of setting a goal, creating a plan to achieve it, executing the plan in the correct sequence, and flexibly responding to unexpected problems becomes difficult.⁴

The 'Smart but Scattered' Phenomenon

This change in cognitive structure gives rise to a paradoxical phenomenon described as 'smart but scattered.' Brain injury survivors often retain a significant portion of their pre-accident vocabulary, knowledge, and basic reasoning skills. Therefore, in short, structured conversations, they may appear intellectually unimpaired. They might be able to discuss politics or history fluently, yet fail to perform complex real-life tasks like preparing a simple meal, which requires gathering ingredients, planning the cooking sequence, and managing multiple tasks simultaneously.

This is not because the patient's 'intelligence' has decreased, but because their ability to efficiently organize and apply their existing knowledge in real-world situations is impaired. This discrepancy between apparent intellectual ability and actual functional performance can be a source of great confusion and frustration for both the patient and those around them. This is a particularly important consideration in vocational rehabilitation. The reason a patient may find it difficult to return to a previous complex and fast-paced work environment is not because they have become 'less smart,' but because their brain's cognitive structure can no longer handle the demands of speed, flexibility, and organization.

Cognitive Fatigue: 'Thinking' as a Costly Energy Expenditure

After a brain injury, 'thinking' itself becomes an activity that consumes an enormous amount of

energy. Many cognitive processes that were automatic before the accident now require conscious effort. Focusing on a conversation, deciding what to wear, planning the day's schedule—all mental activities place a greater burden on the brain.

This is the fundamental cause of the extreme 'cognitive fatigue' that many patients report.¹⁵ The brain's 'processing power' has decreased, yet more energy must be expended for each task, causing the brain's 'battery' to drain much faster. Therefore, to successfully adapt to life after a brain injury, learning to manage one's cognitive energy is just as important as training specific cognitive skills. Prioritizing activities, taking sufficient breaks, and reducing unnecessary stimuli to prevent brain overload become key strategies for a new life.

Summary and Conclusion: Redefining 'Perfect Recovery' and Setting Realistic Goals

This report has conducted an in-depth review of 10 key factors that determine the prognosis of recovery to analyze the possibility of 'perfect recovery' after a traumatic brain injury from a fall. From the location and type of injury, initial state of consciousness, the recovery process of motor and cognitive functions, the role of rehabilitation, the influence of age, and emotional issues, all evidence points to one consistent conclusion.

Medical Judgment on 'Perfect Recovery'

In conclusion, after a moderate to severe traumatic brain injury, a 'perfect recovery'—returning to a state that is 100% identical physically, cognitively, and emotionally to before the accident—is clinically almost impossible and extremely rare. Once destroyed, neural tissue is permanently lost¹, leaving subtle but permanent changes in the brain's structure and function. Even if motor function appears to be fully restored, the patient may need to exert more cognitive effort for movement and suffer from chronic fatigue. Cognitively, while old knowledge may be retained, the speed and efficiency of learning and processing new information may be permanently reduced. Furthermore, a brain injury can leave subtle or dramatic changes in personality and emotional regulation, making the patient and those around them feel that they are 'a different person.'

Redefining Success: Towards Maximal Functional Recovery

However, the fact that 'perfect recovery' is impossible does not mean despair. The success of TBI rehabilitation should be redefined not as returning to one's former self, but as the process of creating a 'new self' that can lead the most independent, productive, and satisfying life possible under the given circumstances. At the core of this is the brain's remarkable ability of 'neuroplasticity,' and the goal of rehabilitation is to achieve 'maximal functional recovery' by drawing out this potential to the fullest.

A 'good prognosis' or 'successful recovery' can be characterized by the following elements:

- **Functional Independence:** Regaining the ability to perform basic activities of daily living, such as eating, dressing, and moving, with minimal assistance from others.
- **Acquisition of Compensatory Strategies:** Successfully integrating effective compensatory strategies into daily life, such as notepads, alarms, and systematic routines, to overcome permanent cognitive weaknesses like memory loss and attention deficits.
- **Emotional Stability:** Recognizing emotional problems like depression or anxiety and actively managing them through medication, counseling, or support groups to maintain a stable psychological state.
- **Building a Social Support Network:** Receiving emotional support through positive relationships with family, friends, and therapists, and re-engaging in social activities.
- **Discovering New Meaning in Life:** Accepting the reality of the 'new normal' and finding new goals and a sense of purpose within it to enhance the quality of life.

Final Conclusion

Recovery from a traumatic brain injury is a long and arduous journey, fraught with numerous challenges. However, the brain's potential for change and adaptation is truly immense. Intensive and comprehensive rehabilitation started early, combined with consistent effort throughout life, can continuously expand the boundaries of recovery. Recovery is not a sprint but a marathon, and functional improvement can continue for years, even decades, after the accident.²⁸ Therefore, rather than being bound by the unrealistic ideal of 'perfection,' it is most important to place hope in adaptation, compensation, and the remarkable resilience of the human spirit against neurological damage, and to cherish the small progress made each day.

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