UNDERSTANDING THE BEHAVIORS OF CHILDREN WITH BRAIN INJURIES: DISCUSSIONS OF A DYNAMIC PROCESS

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LEARNER OBJECTIVES

- Walk away with an understanding of the research and basis for serial follow up care.
- Open the discussions for new policies.
- Share with you one of the biggest fallacies in TBI
- Learn about acute and long-term practical outcome
- Importance of comprehensive/neuropsychological assessments
- End with rehabilitation considerations – time permitting
INTRODUCTION
Brain Imaging and Behavioral Outcome – Cellular Level. Past research on TBI focused on shear/strain effects (Coup, Contra-Coup) these forces put strain on the brain and cells. Led to retrograde or anterograde degeneration of axon.
More current research looking at cellular metabolic factors
Excitatory neurotransmitters
Mechanical deformation of the cell
Break down in BBB
Axon cytoskeletal & microtubule structure
SECONDARY COMPLICATIONS

- Edema
- Brain or Meningeal hemorrhages
- Infection
- Presence of hemorrhages or hematomas
- Hypoxia or Anoxia
- Seizures
SECONDARY COMPLICATIONS

- During the minutes-hours following TBI, whether it be from a hypoxic event cells that are not irreversibly destroyed remain alive but in a vulnerable state.
- Reduced cerebral blood flow
- Increase in intracranial pressure.
- Metabolic depression
- Evidence show these events occur in all levels of TBI severity.
Like adults, children typically follow a predictable pattern of recovery, moving from coma to a period of agitation and disorientation, then to more purposeful and age-appropriate behaviors.

In the rehabilitation field we use measures called the Rancho Los Amigos or C.O.A.T.

Rate and extent dependent on severity & location

Unlike adults, recovery continues beyond 12 months because of the ongoing neural development still taking place until age 25.

This takes us into the saying “children following TBI grow into deficits”
CASE 1 INTRODUCTION – MEDICAL

- (KW) Karen is a 2 year, 8 month old Caucasian female
- Prior to injury normal development.
- No history of attention, behavioral or medical issues.
- Sustained a depressed skull fracture. LOC at the scene.
- Sedated in the emergency room
- Secondary complications: brain swelling, seizures, herniation, subarachnoid and subdural bleeds.
(LW) Lucy sustained a severe TBI at 3 ½ years old.

Prior development till age 3 was normal. No medical. Parents college educated.

At age 3 ½ she was a restrained passenger in a motor vehicle that struck a truck going 50 mph.

Severe injuries at the scene. GCS of 3 and improved to 9 in the ER.

Left sided brain contusions.

Went through rehabilitation for one year and discharged because met goals. Miraculous recovery!!

FAMILY CONCERNS FOLLOWING TBI

Recovery and Outcome
Theory of Recovery: A Dynamic System

- Kennard (1942) hypothesized that recovery from early TBI was associated with reorganization into new networks.
- Hebb (1947) postulated that the failure to recover was correlated with a failure of initial organization.
- Both have been proven correct.
Hebb (1942) theorized that brain injury was most likely to affect new skills and leave intact those that had already been acquired. In his 1942 study, 55% of the children injured between 4 and 8 years of age performed one year behind matched age peers on standardized academic tests. Thirty-three percent of the sample was two years behind. Children injured before 7 years of age, with prolonged unconsciousness, had a higher rate of reading disabilities than those injured at or about 8 years of age with similar etiologies and severity.

In support of Hebb's earlier research, subsequent studies consistently demonstrate reading delays and/or reading disabilities and written expression disabilities in children injured before 8 years of age (Ewing-Cobbs et al., 1986; Fay et al., 1994; Shaffer, Bijur, Chadwick, & Rutter, 1980).
Basis of Late Effects Following TBI – Why Children Grow into Deficits

1. Myelination process still ongoing. Normal maturation gives rise to day-to-day behaviors.

- Myelination is a orderly process. Although many areas of the brain are myelinated at birth many areas are not. Trauma affects the normal orderly progression.

2. Dendritic development and synapse formation lasts for several years after birth. Trauma affects this process.

- The density of synapses first increases toward peak levels at 5-8 years of life and then gradually decreases through adolescence
- Certain neurotransmitters are not complete (adult levels) until 10-12 years of age.
First, the developmental model recognizes that the young child’s brain is incompletely developed. In theory, when a head injury occurs early in life, the results can interrupt the developmental sequence and slow the rate of subsequent development or cause deficits in functional behaviors.

Evidence looking at academic and social development show increase in gaps among brain injured children compared to their age peers as they move through childhood (Ewing-Cobb, et.al. 2004; Catroppa and Anderson, 2007).

Second, from a cognitive perspective, young children possess fewer consolidated skills. The younger the age at insult, the fewer mature cognitive skills established by the child. Future acquisition of these skills can be compromised.

This theory has been supported by experimental and clinical research of long term problems multiple years out from the injury.
Research in the field of neuroscience has demonstrated that arborization of neurons progress in sprits between the ages of 6 to 8, 10 to 12 and 14 to 16 years, and correlates with accelerated cognitive growth (Spreen et al., 1995).

Additional research has identified specific neurons (Glogi type II) that have small cells and small axonal and dendritic expansions. Many of these cells form postnatal and play an integral part of higher cerebral functions (Spreen et al.).
In theory (Luria, 1973), any type of trauma that occurs during these growth periods, are expected to retard development of higher level functional behaviors dependent upon an organized, integrated, functional system.

Spurts in brain development all way though adolescents and adulthood (Casey, et.al. 2000; Giedd, et.al. 1999).

In essence, it can produce lasting effects and reduce brain growth if there is damage to the cerebral cells.

Research evidence to support this theory now – discussed later

Therefore, the final functional outcome of brain injured children depends not only on the recovery potential of the brain at the time of injury, but also the stage of neural development at the age of the insult.
MEMORY DEVELOPMENT GRAPH

Growth

# of Words

Age

Immediate
Delay
Recognition
Clinical Studies

- Cross-sectional and longitudinal studies investigating the intellectual, cognitive, academic, and behavioral outcome in children with TBI are consistent.
- Moderate-severe injury < 7 years old at the time of injury
- The research clearly shows that long-term deficits or delays in the acquisition of impairments are to be expected in children with moderate-severe TBI injured before 7 years of age
- In contrast, TBI in late childhood, regardless of severity, seems to have better overall prognosis and recovery
- Individual’s with single concussions expect full recovery baseline no late effects unless secondary gain present.
Clinical Studies

- The findings from several studies suggest that the deleterious effects of younger age at insult apply only within a restricted age range (critical developmental period for the skill measured) with new deficits emerging as the child matures.

- Age-related effects have been consistently demonstrated in children younger than 7 years of age (fundamental & more complex). Some studies have shown < 13 yrs. Long-term deficits (Anderson, et.al. 2012).

- The development of higher more complex abilities appear to be affected the younger the child is at the time of the brain insult.

- Younger children show slower rate of recovery.
There is little evidence that the sequelae resolve with age and time.

Cerebral damage in late childhood, regardless of site or severity, seems to show better overall progress in recovery years later when compared to matched children.

It appears that disruption or damage to critical areas still undergoing development and integration has an impact on the child's ability to acquire new higher level functions by impeding the normal processing of new information or neural development. Skills affected in the younger child may be basic to the later development of more complex behaviors.

**Clinical Studies**

In Summary: TBI and the Developmental Process

- Mild-Severe TBI disrupts the developmental process
- Concussions have not been shown to affect developmental progression
- Various factors may account for the vulnerability of the young child to significant and persistent neurobehavioral deficits following brain injury (e.g., family, experiences, etc.)
What we need to know now and later...

ACUTE AND LONG-TERM OUTCOME STUDIES
COMMON ACUTE COMPLAINTS – POST DISCHARGE/REENTRY

- Attention – divided, selective, sustained, shift
- Task shifting
- Inhibition
- Working Memory
- Explicit recall
- Planning, problem solving, decision making
- Speed of decision making
- Memory consolidation
- Trouble keeping up in school
Karen’s complaints post discharge from rehabilitation two months later

- Articulation problems
- Short term memory problems
- Easily frustrated
- Word finding problems.
- Otherwise parents report no developmental regression
Lucy’s Complaints 4 Years Post Injury

- Lucy is now 7 years old. It has been near 4 years since her injury.
- Remember at age 4 years her PT, OT and SP said she met her goals and discharged. Language and cognition were assessed as “average” for age.
- Kindergarten went well. No reported behavioral, social or learning issues.
- Lucy finished 1st grade. By year end she was behind par with peers in reading and comprehending new concepts.
- Low arousal by mid afternoon affecting attention/vigilance.
OUTCOME STUDIES

- Outcome studies look at abilities either acutely or long term.
- Both are important. Why?
- What we need to do now....
- What we need to prepare and watch for later....
OUTCOME STUDIES – GROUP DIVISIONS

- GCS 13-15 complete resolution (e.g. concussions)
- GCS 9-12 improve but don’t catch up with age controls
- GCS 3-8 not only show most deficits early on but don’t show expected developmental gains
MEDICAL PREDICTORS OF OUTCOME

- Parents ask what is my child’s prognosis?
- Days to an age-adjusted 75% performance on the COAT (Children’s Orientation and Amnesia Scale) (Ewing-Cobbs, et.al. 1990)
- Days to GCS score of 15
- Initial GCS
- LOC duration
- These four indices measure short- not long-term outcome in children
LONG-TERM PREDICTORS

- Pre-injury adaptive level
- Pre-injury developmental level
- Family functioning/resources
- Age at time of injury
- History of premorbid disruptive behaviors
- Level of family burden/stress
- Severity of injury (GCS 13-15 mild; GCS 9-12 moderate; GCS < or = to 8 severe)
- Location of injury
Need for unique perspective taking in the arena of assessments.
Lucy’s Neuropsychological Test Results

- Fine motor, sensory, balance, accuracy and modulation of movement normal. Writing, drawing, copying all normal.
- Verbal IQ = 75, Impaired range
- Performance IQ = 86, Low Average range
- Working Memory and Processing Speed- Average range
- Language Comprehension – Impaired range
- Expressive Communication – Low Average range
- Visual Memory immediate recall – Low Average
- Visual Memory delayed recall – Average (slow consolidation)
- Verbal Memory immediate and delayed recall – Average
- Sustained Attention, Response Times, Inhibition, Rapid discrimination – Impaired range
- Reading – vocabulary, fluency, and comprehension: well below grade level
Specific Domains

- Following slides cover short and long term brain-behavior function outcomes
There are no long-term deficits observed in strength, coordination, balance, or walking. However, substantial deficits have been observed in gross and fine motor skills in children with moderate-to-severe injuries three years post discharge compared to matched non-brain injured controls. The deficits are more pronounced in speed and fine motor dexterity such as copying or drawing (apraxia).

There is a high prevalence of deficits seen in timed motor tasks involving visual-motor integration and nonverbal reasoning. Children with injuries occurring before their gross and fine motor skills are fully developed (1-3 years of age), tend to far worse than those injured later in life. The incidence of persistent deficits in gross and fine motor abilities is higher for the younger age groups.
INTELLIGENCE

- Most studies controlling for premorbid intellectual and sociodemographic factors demonstrate persistent deficits in intelligence scores in severely brain-injured children. The deficits are more pronounced in Performance IQ where visual motor speed is important. Children 6 years or younger obtain poorer results, when compared to matched non-brain injured controls (Anderson et al., 1997; Koskiniemi, Kyykka, Naybo, & Jarho, 1995).

- Prospective and retrospective longitudinal studies have shown at 2 to 5 years post injury the deficits still remain and soon begin to interfere with new learning (Adelson & Kochanek, 1998; Capruso & Levin, 1992; Chadwick et al., 1981; Ewing-Cobbs et al., 1997; Fay et al., 1994; Jaffe et al., 1995; Koskiniemi et al., 1995).
MEMORY PROCESS – CRITICAL!

- Five levels of processing
  - Registration
  - Consolidation
  - Storage
  - Maintenance
  - Retrieval

- Mechanisms involved
  - Working memory
  - Executive function
Memory Types

- Episodic vs. Semantic
  - Episodic - specific events and autobiographical information; reliving the event; mental time travel; familiar but cannot remember context learned it.
  - Semantic - factual knowledge, concepts and vocabulary; highly linked to language

- Declarative vs. Nondeclarative
  - Declarative – conscious process forming, storing and recalling life events, semantic knowledge and facts
  - Nondeclarative – unconscious process of skill learning and access to procedural knowledge

- Explicit vs. Implicit
  - Explicit – conscious deliberate recollection
  - Implicit – non-deliberate learning, unintentional retrieval and indirect effects on memory like priming
Is Working Memory "Memory"?

- No!
- Represents “short term” or “mental scratch pad”
- Helps us learn and use what we know
- Helps us hold information for a short time, like a phone number
- Used with repetition of a few words or when asked to recall a few minutes later
- Also has a developmental trajectory
  - Preschoolers hold 3-4 words in WM
  - Children age 9 hold 5-6 words in WM
  - Adults hold about 7 items in WM
What Are Executive Skills?

- Social Judgment
- Apathy
- Affect regulation
- Attention
- Inhibition
- Reasoning – Abstract
- Organization
- Flexibility for Problem Solving
- Planning
- Fluency
- Retrieval
EXECUTIVE SKILLS

1. Older children's cognitive and executive skills appear to recover at a faster rate then younger children with similar acquired brain injuries

2. Older age groups with mild-to-moderate injuries show similar deficits in nonverbal memory as the younger age groups with similar severity, but recover at a more rapid pace from their deficits. The younger age groups still show persistent declines in nonverbal memory performance three years post discharge

3. Children injured before 12 years of age showed differences in retrieval and recognition of verbal and nonverbal memory tasks compared to matched adolescent patients three years post discharge

Speech/Language


- Dose-Response Relationship
- Linguistic skills that typically return rapidly after TBI include those that are rote, overlearned, and automatic
- Mild TBI several years post show normal language and reading performances
- Moderate TBI several years post show no language impairments but persisting academic problems. Once again we see same rate of development as normal’s but remain behind.
- Severe TBI several years post show ongoing delays in both. They have the most to gain (recover from) and loose by sheer nature of the tissue damage.
- Marchman, Miller, and Bates (1991) investigated language delays after traumatic brain injury in infancy. The authors observed delays in babbling and first-word acquisition, and language comprehension during their development for three years.
- Semantic, Syntax, & Pragmatics problems (not seen during testing but observed in more demanding contexts).
- The most significant deficits appear in verbal retrieval and object naming the more severe the injury. Children injured before 6 years of age had persistent delays in expressive and receptive language, whereas those subjects who were older up to adolescence had difficulty with comprehension or written expression.
- Lang. Comprehension lg. concern (Secondary to number of factors).
  - Decreased attention & speed of processing or abstraction.
ACADEMIC

- Remember deficits in attention, organization, and self-regulation can diminish a child’s academic progress
- Power tests not performance tests
- Well recognized relationship between intelligence and academic achievement early in grades but doesn’t hold same predictive power in later grades
- Memory and Executive become strongest predictors of academic success (Fulton, et. al. (2012). Neuropsychology)
**Behavior**

- Severely injured children with no premorbid histories of behavioral disturbance are at high risk for new psychiatric disorders following their injury (Ewing-Cobbs et al., 1986; Filley et al., 1987).

- There does not appear to be a homogeneous pattern or syndrome apparent in every case. However, most children with moderate to severe injuries tend to display socially uninhibited behaviors.

- Pragmatic deficits are more common following early insult and can lead to behavior problems in home and school. It can cause problems in adapting to demands of everyday living and in forming healthy relationships.

- Other investigators have observed higher incidences of impairments in verbal abstraction, understanding linguistic ambiguity, drawing inferences, and deciphering indirect meaning in adolescents and adults whom sustained a closed head injury in childhood compared to the general population (Fay et al., 1994).
FUNCTIONAL SKILLS

- The body of neurobehavioral outcome studies in pediatric head trauma is substantial. However, the results are limited to performances on standardized tests measuring a broad array of cognitive constructs. Although, this type of information is helpful and indirectly has an effect on functional skills, it falls short of describing how the child will function in everyday life.

- To date, only a handful of studies have evaluated the outcome of daily living skills after brain injury in children with measures that are developmentally appropriate (Greenspan, & MacKenzie, 1994; Max et al.,1998; Zafonte et al.,1997).

- The results suggest that children with moderate-to-severe injuries occurring early in life tend to far worse in terms of socialization (disinhibited behaviors & pragmatics), self-care, and communication than matched mildly injured children.
LONGITUDINAL STUDIES – SOME GOOD NEWS!

- Very Few (small handful)
- Ongoing impairment for 30 months especially in children <7 years of age at time of injury.
- Severe TBI children do not keep up with developmental expectations; however by 5 years post this pattern stabilizes, specifically survivors record gains consistent with developmental expectations that is while they continue to function at a lower level then age peers they do not “loose ground”
ANDERSON ET. AL. STUDY CONTINUED…

- 10 years post, regardless of the severity, group had low average to average performances on most cognitive tests except for processing speed and adaptive functioning.
- Small to medium size effects were seen in executive functioning and some aspects of IQ.
- Rates of impairment were higher than the general population expectations (16%) even among mild TBI
- IQ rate 25-32% in the entire group covering all severities
- Rate of impairment were twice that of the general population especially in social, executive and specific aspects of IQ
- Dose-Response relationship in general
Anderson Study Continued...

- What predicts 10 year outcomes?
- Not age, not length of coma, not white matter changes...than what?
- Level of pre-injury functions and family factors. The importance of family support, policy and education!
Karen’s Second Neuropsychological Evaluation

- 20 months post injury
- Karen is now 4 years 3 months old
- Did preschool last year and not retaining information
- Short term memory problems
- Seeing attention span is different than other’s her age
- Not able to trace and write/draw like others her age
Karen’s Test Outcome

- Verbal IQ = 101  Average (no change)
- Performance IQ = 88  Low average – decline (not acquiring certain higher level concepts)
- Working Memory = 94  Average (no previous assessment)
- Auditory Comprehension = 108  Average (no change)
- Expressive Communication = 105  Average (improvement)
- Fine Motor Coordination = <2%  (dramatic decline)
- Adaptive Skills = Communication (low average); Daily Living (average); Socialization (average); Motor (impaired) – Decline in motor and communication
- Tests assessing confrontational naming – impaired range
- Tests assessing visual memory – average for immediate, delayed and recognition
- Tests assessing verbal memory – impaired for immediate retrieval and low average for recognition
Does it Work?

REHABILITATION
Similar to parent reports of children with behavior disorders:
- Poor attention/concentration
- Distractibility
- Hyperactivity
- Irritability
- Poor motivation
- Apathy
- Poor anger control
- Aggression
- Social isolation
INTERVENTION

- Scant empirical data exist to support one method over another.
- 2005 review article: 3 on attention, 5 on memory, 3 on EF.
- Rely on strategies that have been empirically supported on children with behavior disorders.
- What type of cognitive deficits may affect behavioral problems?
- Behavioral Intervention
Rehabilitation Strategies

- Current cognitive rehabilitation programs are scaled down versions of adult programs.
- Some programs use methods learned from special educators.
COMMON APPROACHES

- Externally Focused Approach – does not attempt to change the child’s cognitive deficit, but alters aspects external to the child.
  - Modifying the environment
  - Alter expectations
  - Specialized teaching strategies
  - IEP’s
Internally Focused Intervention – restorative and compensatory approaches.

- Restorative strategies use computer-based programs. Positive results with attention problems but nothing else.
- Compensatory strategies
Remediation of Attention

- Developmental problems
- Most studies using computer-based programs & Biofeedback are with children with neurodevelopment disorders (ADHD)
- See improvements on measures but not in real world setting.
- Self-regulatory & Self-monitoring strategies have poor outcome in this population
REHABILITATION OF ATTENTION

- Research focus on 1 of 4 strategies
  - 1. Attention Process Training (ATP)
  - 2. Use of self-management techniques
  - 3. External aides
  - 4. Psychosocial supports

Only 3 documented studies. Relatively good results but poor designs.
Remediation of Memory
5 Studies to date – Older TBI

- Most studies have focused on nondisabled or children with developmental delays
- Mnemonic in either a visual elaboration or verbal rehearsal strategy has shown positive results in a population of children with reading disabilities.
- External memory devices –
- Direct Instructional Techniques – hold promise
REHABILITATION FOR EF
3 STUDIES TO DATE

- Multi-component package (self-instructional training, metacognitive, attribution and reinforcement training)
- Behaviorally based individually tailored approach.
- Direct instruction program (modeling, shaping and task analysis).
- All showed good outcome and generalization.
SUMMARY

- Pediatric TBI is very different from adult TBI
- Delayed deficits not readily apparent in the acute stage.
- TBI that occurs during critical stages of development are most vulnerable. Support given to increased vulnerability of emerging skills.
- Higher-order skills will be impacted down the line
- Most standardized measures for children do not include students with TBI in the norm. sample, which compromises validity of the tests unless use ones specific for TBI.
- Need for unique battery of tests that are sensitive and specific
- Overestimate real world performance / create a false impression.
- Unlike adults, expected competencies at the child’s developmental level.
- Good performance today does not ensure successful performance tomorrow.
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Questions