ADVANCES IN TRAUMATIC BRAIN INJURY NEUROREHABILITATION

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Predictive Determinants of Outcome

- Type and severity of neurological injury
- Type and severity of bodily injuries
- Pre-injury characteristics (biological, social)
- Psychosocial co-morbidities
- Supports, treatment paradigms, environment

Neuropathology of Head Injuries
Gennarelli and Graham: 1998

TBI is a Process not an Event

Physiological Disruption → Structural Integrity
RECOVERY PATTERNS
- Not Random
- CHI-more specific
- Neurological and semi-predictable
- Correlates with clinical and diagnostics

Specific Types of Injuries
- Diffuse Injury
- Diffuse Axonal Injury
- Focal
- Multi-Focal/ Mixed
- Hypoxia--Ischemia

INJURY SEVERITY RELATES TO AXONAL FUNCTION
Physiologic ↔ ↔ ↔ Anatomic Disruption
SPECTRUM OF DIFFUSE BRAIN INJURY

- Mild Concussion
- Classical Cerebral Concussion
- Diffuse Injury
- Diffuse White Matter Shearing

Diffuse Axonal Injury (DAI)

Clinical Indicators
- Depth of unconsciousness (LOC)
- Duration of disturbed consciousness (PTA)

Spectrum of Injury Severity
(Surrogate Clinical Tools)

- Glasgow Coma Scale (GCS) depth of unconsciousness
- Time to Follow Commands (TFC) duration of unconsciousness
- Post-traumatic amnesia (GOAT)
- Neuroimaging and other diagnostics
- Clinical exam
GLASGOW COMA SCALE

<table>
<thead>
<tr>
<th>Eye Opening</th>
<th>Verbal Response</th>
<th>Motor Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 = Spontaneously</td>
<td>5 = Oriented</td>
<td>6 = Follows Commands</td>
</tr>
<tr>
<td>3 = To Voice</td>
<td>4 = Confused</td>
<td>5 = Localizes to Pain</td>
</tr>
<tr>
<td>2 = To Pain</td>
<td>3 = Inappropriate Words</td>
<td>4 = Withdrawal to Pain</td>
</tr>
<tr>
<td>1 = None</td>
<td>2 = Incomprehensible Sounds</td>
<td>3 = Abnormal Flexion</td>
</tr>
<tr>
<td></td>
<td>1 = None</td>
<td>2 = Abnormal Extension</td>
</tr>
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Head-injury severity was assessed by the Glasgow Coma Scale (GCS) obtained in the emergency department and by time to follow commands. The GCS evaluates depth of coma by responsiveness in eye opening, motor and verbal modalities.

-Dikmen 1999

One year psychosocial outcome in head injury

Dikmen, 1999

Cumulative Percent of Head-Injured Subjects Who Return to Work

% Returned to Work

<table>
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<th>Characteristics</th>
<th>12 months</th>
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<td>Demographics</td>
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<tr>
<td>Neurological Severity</td>
<td></td>
</tr>
<tr>
<td>GCS</td>
<td></td>
</tr>
<tr>
<td>≤8</td>
<td>26</td>
</tr>
<tr>
<td>9-12</td>
<td>56</td>
</tr>
<tr>
<td>≥13-15</td>
<td>80</td>
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<tr>
<td>TFC</td>
<td></td>
</tr>
<tr>
<td>&lt;5 h</td>
<td>82</td>
</tr>
<tr>
<td>6-24 h</td>
<td>67</td>
</tr>
<tr>
<td>25 H-6 d</td>
<td>67</td>
</tr>
<tr>
<td>7-13 d</td>
<td>46</td>
</tr>
<tr>
<td>14-28 d</td>
<td>21</td>
</tr>
<tr>
<td>&gt;29 d</td>
<td>6</td>
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*Time to follow commands was used as a measure to length of coma and was operationally defined as the duration of time between the injury and the patients’ regaining the ability to respond consistently to verbal commands as defined by the motor component of the GCS.* -Dikmen 1999

Acute Signs of Traumatic Brain Injury

Normal
Consciousness

Loss of Consciousness

Injury

Retrograde Amnesia

Posttraumatic Confusion-Amnesia

PTA Duration and One Year Outcome

Outcome probability at one year post injury in a group of patients admitted to inpatient rehabilitation with moderate to severe traumatic brain injury classified by duration of posttraumatic amnesia (PTA).

Outcomes are categorized by the by Glasgow Outcome Scale (veg., vegetative state; sev. Severe disability’s mod. Moderate disability; good, good recovery).

-Levin et al, dikmen et al, Katz alexander
SPECTRUM OF DIFFUSE BRAIN INJURY

- Mild Concussion
- Classical Cerebral Concussion
- Diffuse Injury
- Diffuse White Matter Shearing

Increasing Disruption of Axonal Fibers

DIFFUSE INJURY (concussion)
Disrupted Brain Stem Mediated Reticulo-Activating and Neocortical Efficiency

DIMINISHED (↓) CATECHOLAMINES
Leading to Impairments in:
- Arousal
- Attention
- Speed of Information Processing
MILD TBI

Predictors of Outcome – Risk Factors
- Medical
- Psychological Processes
- Environmental

DIFFUSE INJURY

LOC > 24 Hours
Generalized Damage to Axonal Structure
or
Brain White Matter

EIGHT STAGES OF COGNITIVE RECOVERY FOR HEAD TRAUMA
- Level I - Coma
- Level II - Generalized Response
- Level III - Localized Response
- Level IV - Confused/Agitated
- Level V - Confused/Inappropriate/Non-agitated
- Level VI - Confused/Appropriate
- Level VII - Automatic/Appropriate
- Level VIII - Purposeful/Appropriate
Case 1

DAI
GCS 4
TFC 4 weeks
PTA 3 months?

Severe DAI Syndromes
( Differential )

- Vegetative State (disconnection bs, wm, th, cts)
- Minimal Responsive State (white matter)
- Akinetic Mutism (supplemental motor area)
- Locked-Out Syndrome (thalamic)
- Locked-In and Locked In Plus (brainstem)
Hypoxic and/or Ischemic Patterns
- Hippocampal cells (amnestic)
- Purkinge cerebellar cells (dystaxic)
- Basal Ganglia (parkinsonian spectrum)
- Watershed or “Borderzones” (dyspraxia, visual perceptual, motor planning, tactile auditory and visual defensiveness)
- Mixed Pattern (movement disorders, myoclonus)

THE NEUROBIOLOGY OF INJURY
- Neurodiagnostic advances
- Development of novel and innovative therapies

NEUROIMAGING ADVANCES
Expanded Understanding of Injury Relationships
- Anatomy - CT
  - MRI
  - MRA
HEMATOMAS

- Extradural
- Subdural
- Intracerebral

NEUROIMAGING ADVANCES
Expanded Understanding of Injury Relationships

- Anatomy - CT
  - MRI
  - MRA
- Physiology – Advanced MRI techniques
  - SPECT
  - PET
  - EEG
  - Brain Mapping techniques

MRI in 2001+: Evaluating brain physiology

- Goal: Improve diagnostic sensitivity / specificity.
- Tests:
  - Diffusion imaging: evaluates water motion.
  - Spectroscopy: studies tissue metabolism.
  - Functional MR: evaluates brain function.
MR diffusion imaging
Normal  Abnormal

Tensor & fMRI - Fusion

Combined fMRI Expressive Speech Map with MR Tractography from Diffusion Tensor Imaging
fMRI
Gradient-echo epIRT
26 cm FOV, 128x128
TE/TR=50/4000ms, 90°
65 phases
Diffusion Tensor Imaging
Six direction encoding, \( b = 1576 \) s/mm²
SE-EPI, 24 cm FOV, 128x128

TRACTOGRAPHY
NEUROIMAGING ADVANCES
Expanded Understanding of Injury Relationships

- Anatomy
  - CT
  - MRI
  - MRA

- Physiology – Advanced MRI techniques
  - SPECT
  - PET
  - EEG
  - Brain Mapping techniques

- Functional
  - QMRI
  - FMRI

PREDICTOR RESEARCH

- Advanced Neuro-imaging
- Gender
- Biologic markers – APOE4
DIFFUSE VS. FOCAL INJURIES (emerging or isolated)

Focal
- Neuroanatomically specific
- Cortical Contusions
- Frequently Frontal and/or Temporal
- GCS,TFC (brief) and disproportionate to PTA
- Physical, Cognitive and Neurobehavioral characteristics
Case 2

Fall
Orbitofrontal
Bi temporal
CAUSE OF DISABILITY

- MENTAL > PHYSICAL

MR spectroscopy in trauma

Metabolic map
MR spectroscopy in trauma

NAA decreased
Cho increased
Lactate present
Common Neuro-Medical Sequelae

- Hydrocephalus
- Seizures
- Spasticity/dystonia
- Posttraumatic Movement Disorders
- Heterotopic Ossification
- Communicative, cognitive and behavioral disturbances

Acute TBI Neuro-Medical Issues

- Thrombotic risks ie... DVT ppx, filters etc..
- Cardio-pulmonary ie.. Dysautonomic
- Metabolic-Electrolytes ie.. SIADH, DI, etc..
- GI issues eg.. infection, motility, tubes

Ventricular Shunting

- Hydrocephalus vs. Atrophy
- Risk Benefit Ratio (complications/outcome)
- Timing
- Type of Shunt Valve (programmable)
- Rehabilitation Synergy (therapy/medications)
- Long term management
SEIZURES

- Risk/benefit considerations
- Provide “functional” control without side-effects.

NEW ANTI-EPILEPTIC DRUGS

- Levaracitam
- Lamotrigine
- Felbamate
- Tiagabine
- Topiramate
- Vigabatrin
- Others…….

REFRACTIVE CONSIDERATIONS

- Electrophysiologic and Imaging Workup
- Surgical Options
- Vagus Nerve Stimulators
- Genetic Research – “Inherited Epilepsies”
TYPES OF SURGERY

- Temporal lobectomy
- Extratemporal resections
- Corpus callosotomy
- Stereotaxic procedures
- Hemispherectomy
SPASTICITY

- Dantrolene Sodium
- Lioresal
- Diazepam
- Tizanidine
- Clonidine
- Klonopin

SPASTICITY – ADJUNCTIVE PROCEDURES

- Local and Regional Anesthetic Blocks *
- Phenol Neurolysis *
- Botox Type A Injection Therapy *

* Coupled with Rehabilitative Techniques
SPASTICITY – ADJUNCTIVE PROCEDURES

- Intrathecal Lioresal Pump
- Central Neurosurgical Intervention
- Functional Orthopedic Interventions

POSTTRAUMATIC MOVEMENT DISORDERS

- Akinetic or Hypokinetic – Parkinsonian
- Hyperkinetic
  - Tremors
  - Ataxia
  - Myoclonus
  - Dyskinesias
  - Dystonias
NEUROPHYSIOLOGIC CORRELATES OF MOVEMENT DICTATE “RATIONAL” TREATMENT

- AEDs
- Anti-Anxiety
- Parkinsonian Meds

POSTTRAUMATIC MOVEMENT DISORDERS

- Parkinson’s research
- Essential Tremor Research

Deep Brain Thalamic Stimulator

HETEROTOPIC OSSIFICATION

- Non-Steroidal Anti-Inflammatory
- Diphosphonates (Didronel)
- Radiation Therapy
- Surgical Excision
COGNITIVE-BEHAVIORAL DISTURBANCES

- Minimal Responsive
- Agitated – Aggressive
- Initiation and Communication
- Memory and Cognition
- Mood

NEUROTRANSMITTER IMBALANCES

- Acute
- Subacute
- Chronic

MEMORY AND COGNITIVE DISORDERS

- Acetylcholine Enhancers (Alzheimer's Meds)
- Vitamins (Lecithin, Phosphatidylcholine)
- Nootropes (Piracetam, Pramiracetam)
MOOD DISORDERS

- Tricyclic Antidepressants
- Novel Antidepressants
- Mood Stabilizers – AEDs (VPA, CBZ)
- Lithium
- Anxiolytics
- Neuroleptics

NEUROFUNCTIONAL FUTURE CONSIDERATIONS

- HBO – acute vs. chronic
- Neural transplantation research
- Gene therapy
HYPERBARIC OXYGEN THERAPY (HBO)

- Carbon Monoxide
- Hypoxic – ischemic encephalopathy
- Traumatic focal and/or diffuse axonal injury

NEURAL TRANSPLANTATION

- Parkinson’s and Huntington’s research
- Embryonic neural tissue grafting
  - replacement of damaged nerve cells
  - re-establishment of neural pathways
  - release of specific neurotransmitters
  - production of factors which promote neural growth

GENE THERAPY

- Goal: Transfer biologically relevant genetic material into cells to promote survival of neurons and even growth.

HOLISTIC APPROACHES

Evidence Based Guidelines?

HOLISTIC APPROACHES

- Herbs
- Vitamins
- Diet
- Sport Supplements
- Procedures, i.e., acupuncture, therapeutic touch techniques, CST, etc.

Pharmacological Modulation of Plasticity in the Human Motor Cortex

Neurorehab and Neural Repair
20(2)/2006
AGING CONSIDERATIONS

- Normal Aging
- Dementia – Alzheimer’s
- Psychosocial dilemmas

Effect of Estrogen on Brain Activation Patterns in Postmenopausal Women During Working Memory Tasks

Shaywitz, MD, et al.
JAMA, April 7, 1999
DETERMINANTS OF OUTCOME

- Pre-injury Personality Characteristics
- Type and Severity Neurologic Injury
- Support System Available

“It is not only the kind of injury that matters, but also the kind of head.”

Sir Charles Symonds, 1937

LIFE ADAPTATION

Quality of Life and Outcome Considerations
**WIT MODEL**

*Whatever It Takes: A Model for Community-Based Services*

*Willer, B., Corrigan, J.D., Brain Injury 8:7 1994, 647-659*

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“To be all within one’s abilities”
- Relationships
- Productivity
- Socialization

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Pathways and Planning Outcome Oriented Treatment.

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“I Skate to where the puck will be”
-Wayne Gretsky
AWARENESS AND ACCESS

- Surveillance research
- TBI Model Systems 5——17 centers
- TBI Act 1995
  - Federal Initiatives
  - State Demonstration Grants
  - NIH Guidelines
- Information and dissemination
  - World Wide Web - Internet