Objectives

- Upon completion of this course, attendants will be able to:
  - Describe disorders of consciousness including the Vegetative State, Minimally Conscious State, and Coma.
  - Understand the common neurologic and medical complications associated with Severe Traumatic Brain Injury.
  - Identify the components of a thorough Physical Therapy evaluation including Special Tests and the most commonly used Outcomes Measures including the CRS-R, GCS, and DRS.

Objectives (continued)

- Recognize the common physical, cognitive, and functional impairments seen as a result of severe traumatic brain injury.
- Identify appropriate Physical Therapy interventions along with the specialized equipment utilized and prescribed for this population.
- Write objective and functional therapeutic goals for this population.
- Identify commonly used medications and their impact on Physical Therapy.

Outline

- Incidence and etiology
- Neuromedical complications with severe TBI
- PT examination
- Examination of consciousness
- PT goal setting
- PT interventions for patients with severe TBI
- Commonly used medications and their impact on PT
- Outcome tools for patients with severe TBI

Incidence by Severity

- Mild TBI = 131 cases per 100,000 people
- Moderate = 15 cases per 100,000 people
- Severe = 14 cases per 100,000 people

TBI morbidity

- Mild head injury (80% of injuries)
  - 10% with disabilities
- Moderate head injury (10% of injuries)
  - 68% with disabilities
- Severe head injury (10% of injuries)
  - 100% with disabilities
- 1:20 receives proper rehabilitation (NHIF)
Outcomes

- N=140
- Studied patients in VS at one month
  - At one year:
    - 51% dead; 11% vegetative; 26% severe disability; 10% moderate or good recovery
    - 83% of patients who regained consciousness did so by 3 months
    - 93% at 6 months
  
  (Branden, 1986)

Prognostic Factors

- Age+
- GCS+
- Pupillary response and size+
- Presence of major intracranial injury+
- Medical complications
  - Elevated ICP+
  - Hyperthermia
  - Hypoxia
  
  (Jeng, 2002)

“Severe” TBI defined

- Referring to patients with disorders of consciousness (DOC) including:
  - Coma
  - Vegetative state (VS)
  - Minimally Conscious state (MCS)
  - Rancho Level I – III
    - Rancho Los Amigos Level of Cognitive Functioning Scale
  - GCS 3 – 8
    - Glasgow Coma Scale

Coma

- No evidence of arousal and awareness
- Eyes closed
- No sleep-wake cycle
- Rancho I
  - Rarely last longer than a few weeks
  - Sustained unconsciousness, eyes remain closed, can not be aroused
  - Not obeying commands, not uttering words, not opening eyes

Vegetative State

(VS)

- Spontaneous eye opening
- Sleep/wake cycle
- No awareness of environment or internal stimuli
- No purposeful movement
- No evidence of sustained, reproducible, purposeful or voluntary behavioral responses
- Capacity for spontaneous or stimulus induced arousal
- No cortical function
- Rancho II

(Prinsenberg and Giacino, 2011)

Vegetative State

(VS)

- Vegetative state
  - Persistent
    - One month or longer after injury
  - Permanent
    - 3 months or longer if anoxic injury
    - 12 months or longer if traumatic injury
  - Requires serial evaluation
  - Often misdiagnosed
Minimally Conscious State (MCS)

- Behavioral evidence of awareness of self or environment indicating cortical function
- Inconsistent but meaningful interaction with the environment
- Intentional communication
- Intelligible verbalization
- Localization to noxious stimulation
- Object manipulation
- Automatic motor response
- Consistent or reproducible movement to command
- Object recognition or localization (reaching)
- Visual pursuit or visual fixation
- Non-stereotypical movements
- Rancho III

[Link to source]

Minimally Conscious State (MCS)

- "Severely altered consciousness in which the patient does not meet the criteria for coma or the vegetative state because there is inconsistent but reproducible or sustained behavioral evidence of self or environmental awareness" (Aspen 1/FM 2001)

Common Complications in Severe TBI Population

- Elevated Intracranial Pressure (ICP)
- Hydrocephalus
- Sympathetic Storming
- Seizures
- Critical Illness Polyneuropathy (CIP)/CIPNM
- Fractures
- Heterotopic Ossification (HO)

Elevated Intracranial Pressure

- Definition: Pressure exerted by the cranium on brain tissue, CSF, and brain blood volume
- Can lead to decreased cerebral blood flow and brain ischemia
- Most frequent cause of death/disability following severe TBI
- Normal = 5-15 mmHg
- Incidence
  - >50% of patients with severe TBI and intracranial mass
  - 30-80% in patients without mass lesions
- Concern with elevated ICP is compromised cerebral perfusion pressure (CPP)
- CPP is an important determinant of cerebral blood flow
  - CPP = MAP - ICP
  - CPP will be decreased by:
    - Elevated ICP
    - Hypotension
Elevated Intracranial Pressure

- **Impact on treatment**
  - Monitoring
    - External ventricular drain (EVD) must be closed to mobilize
    - Both patients will remain on bed rest
  - Exercise and ICP
    - PROM showed trend to decrease ICP in pts w/ normal or higher ICP
    - Active exercise showed ICP and CPP unchanged
  - Isometric or increased ICP and CPP w/ normal ICP, unchanged in higher ICP
  - Use caution with casting in patients w/ elevated ICP (Parsons, 2004)

Elevated Intracranial Pressure

- **Prognosis**
  - Severity of elevated ICP is related to poorer outcomes post severe TBI
    - 77% of patients w/ ICP <15mmHg had favorable outcome vs. 43% of patients w/ ICP >15mmHg (Hayati, 2003)
    - Normal ICP compared to ICP which could not be decreased to 20mmHg (Bart, 1981)
      - Mortality increased 16% to 92%
      - Frequency of good outcomes decreased from 74 to 3%
  - May also result in secondary injury
    - Cerebral ischemia
    - Distortion and compression of brainstem

Hydrocephalus

- **Definition:** Excess CSF in the intracranial cavity which may be caused by:
  - An excess of CSF production
  - Obstruction of flow at any point in ventricles or subarachnoid space
  - A decrease in re-absorption
- **Incidence:** Post-traumatic hydrocephalus (PTH) varies from 0.75% to 10.7% in severe TBI (Mazzini, 2008)
  - 45% of patients developed PTH
  - 11% of patients required surgery
  - Developed within first 3 mos post injury
  - Ventriculomegaly developing slowly over period of 6 mos

Hydrocephalus

- **Impact on treatment**
  - Monitor patients for change in status or signs and symptoms of hydrocephalus and report to MD
  - Patients already treated with shunting should be observed for change in status as this may reflect shunt malfunction, obstruction, or overshunting

Hydrocephalus

- **Signs and symptoms**
  - Magnetic gait
  - Incontinence
  - Cognitive changes
  - Decreased level of consciousness
  - Headache
  - Nausea
  - Vomiting
  - Papilledema
  - Decreased vision
  - Sixth nerve palsies
  - (similar to those of elevated ICP)

Sympathetic Storming

- **Definition:** Autonomic instability following TBI
  - "Dysfunction of autonomic centers in the diencephalon or their connections to cortical, subcortical, and brainstem loci that mediate autonomic function."
  - Also known as
    - Paroxysmal sympathetic storms
    - Diencephalic seizures
    - Midbrain dysregulatory syndromes
    - Paroxysmal autonomic instability with dystonia (PAID)
  - May persist weeks to months in pts w/ low response state (Eckman, 2004)
Sympathetic Storming

- Incidence:
  - 15-33% of pts w/ severe TBI suffer storming (Lamba, 2007)

- Signs and Symptoms
  - Intermittent agitation
  - Diaphoresis
  - Hyperthermia
  - Hypertension
  - Tachycardia
  - Pupillary dilation

Sympathetic Storming

- Medical treatment
  - Medication management
  - Minimize complications

- Impact on treatment
  - Noxious stimuli may trigger storming in predisposed patients
  - Monitor VS response to treatment
  - Increased tone and posturing may result in skin breakdown or contractures

Seizures

- Definition: An episode of abnormally synchronized and high-frequency firing of neurons in the brain
  - Immediate: within 24 hours post injury
  - Early onset: between 1-7 days post injury
  - Late onset: longer than 7 days post injury

- Incidence: 5-11.9% (32-50% military) of pts with TBI experience new onset seizures

  Early Post-Traumatic seizures associated with depressed skull fracture and intracranial hematoma

Seizures

- Type of seizures
  - Partial (focal, local) seizures
    - Simple partial
    - Complex partial
  - Partial seizures evolving to secondary generalized seizures
  - Generalized seizures
    - Absence seizures
    - Myoclonic seizures
    - Clonic seizures
    - Tonic seizures
    - Tonic-clonic (grand mal) seizures
    - Atonic seizures
    - Unclassified epileptic seizures

Seizures

- Signs and Symptoms
  - Vary depending type and location of seizure
  - May include
    - Motor
      - Myoclonic jerks
      - Sustained contractions
    - Autonomic signs or symptoms
    - Somatosensory or special sensory symptoms

Seizures

- Impact on treatment
  - Increased fall risk
  - Medication side effects

  Post-ictal state
  - Paresis (Todd's paresis)
  - Lethargy
  - Confusion
  - Amnesia
  - Headache
Critical Illness Polyneuropathy (CIP)

- Definition: Axon-loss neuropathy affecting patients who are significantly medically compromised
  - Closely related myopathy also exists (CMM)
  - No clear consensus yet on subtypes, combination with myopathy
- Other related names include
  - Critical care neuropathy
  - ICU-acquired neuropathy
  - "Critical illness neuromuscular abnormality" (CIMA) (Rassen, 2000)
  - Critical Illness Polyneuropathy (CIPN)

- Incidence in this population not described:
  - 50% to 70% of patients with sepsis and multiple organ failure
  - Associated with long or complicated acute care ICU stays
  - Also correlated with time on vent, steroid use, neuromuscular blockade, hypoglycemia (Vennera, 2013)

Critical Illness Polyneuropathy (CIP)

- Signs and symptoms
  - Distal generally more affected vs. proximal
    - May affect limb, trunk, respiratory muscles
  - Usually motor and sensory
  - Usually symmetric
    - Impact of spasticity and CIP on each other not well described.
    - LMN vs. UMN signs
      - Diminished/absent reflexes
      - Increased muscle wasting
        - Most evident in tibialis anterior, quadriceps, suprascapular

Critical Illness Polyneuropathy (CIP)

- Impact on treatment
  - Expect longer course for recovery of strength
    - Peripheral nerve healing ~1-3 mm/day
  - Emerging literature supports use of EMS to prevent CIP and ICU-acquired weakness
    - Fan 2012, Route 2010
  - Use of e-stim or aggressive strengthening with diagnosed CIP is controversial
    - One study in rats suggested this may interfere with reinnervation of neuropathy (Cihai, 2003)
    - Cochrane review investigating exercises in neuropathy included three studies, concluded that evidence was limited. (Victor, 2004)

Critical Illness Polyneuropathy (CIP)

- Prognosis/outcomes
  - Mild to moderate cases with good outcomes
    - Severe cases with mixed outcomes (Mcllveen, 2000)
      - 18 patients with CIP and tetraplegia or tetraparesis
      - 2 died, 11 completely recovered; 4 with tetraplegia; 2 with tetraparesis

Fractures

- Fractures and peripheral nerve injuries
  - Present in 40-60% of head injured patients (Kushwa, 1998)
- Up to 11% of orthopedic injuries undiagnosed until rehab admission (Donahue, 1998)
  - Life saving measures more important than orthopedic concerns
  - Patients unable to complain or express concerns
  - Patients not moving
    - Symptoms may be confused for other medical issues, i.e. BIV
  - Lower extremity injuries more common than upper extremity
    - LE fractures: 50-75% (Kushwa, 1998)
    - Peripheral nerve injuries more common in LE (Kushwa, 1998)

Fractures

- Impact on treatment
  - Consider undiagnosed fractures
    - Pain
    - Swelling
    - Deformity
    - Bruising
  - Maintain Orthopedic precautions
    - Weight bearing
    - Range of motion
  - Intervention may be impacted by patients status
    - i.e. agitated patient attempting to remove splint, pulling at cast
  - Communication with ortho/trauma service regarding complications

PPTA SED CSM, Philadelphia, PA
April 20, 2013
Heterotopic Ossification

- Definition: Presence of bone in a location where bone does not normally exist
  - Myositis ossificans now generally regarded as a subtype of H.O.
- Incidence in this TBI
  - “Clinically relevant” H.O. varies between 8-22% in individuals with TBI (van Kampen, 2011)
  - Length of coma and ventilation, surgical fixation of fractures, autonomic dysregulation, spasticity strongly associated with increased H.O. risk. (van Kampen, 2011; Herkelrath, 2007)

Heterotopic Ossification

- Location: Most common location in TBI is hip, followed by shoulders, elbows, knees.
  - Develops in as little as 3 weeks, may onset months post
  - May not be discovered until months post
- Signs and symptoms
  - Stiffness, limited ROM, edema, erythema, pain
  - These signs can be difficult to discern in this population
  - Must be differentiated from DVT, local infection, local trauma/fracture

Heterotopic Ossification

- Impact on treatment
  - PT seen as an adjunctive role in prevention of H.O. formation
  - Relationship of ROM activities to H.O. very controversial
  - Gentle exercise within pain-free ROM is consensus guideline, not supported by literature or evidence
  - May need to premedicate for pain
  - Early rabbit studies indicated that aggressive ROM could worsen H.O., but not clinically proven (Hinkelbein, 2003)
  - CPM may increase ROM

Heterotopic Ossification

- Impact on Treatment (con’t)
  - Review by Cullen (2007) indicates that “there is limited evidence that forceful manipulation under general anesthesia increases ROM in patients with H.O. following brain injury”
  - Emerging evidence for pulse low intensity electromagnetic field therapy (ASHA, 2016)
  - May need medical assistance for spasticity management

Heterotopic Ossification

- Treatment: Limited literature both medical and PT management
  - Medication/Medical:
    - NSAIDs, Diphosphates, Cox-2 inhibitors may prevent and/or decrease severity
    - Diphosphates (disodium etidronate) - early phase
    - NSAIDs - early and intermediate phase
      - Methotrexate has shown efficacy in THA
    - Radiation
  - Further management dependent on impact on function or symptoms
    - Surgical resection with significant recurrence
      - Over 19.5% in recent review (Chadha, 2007)
      - Recurrence increased with increased coma duration
      - Also dependent on location, observation periods

EXAMINATION
PT Examination

• Goals of your exam
  - Describe movement dysfunction and how it impacts functional independence
  • Relevant to meaningful tasks
  - Identify impairments
  - Test hypotheses formulated from history and systems review
  - Develop prognosis

PT Examination

• Use neuroanatomy and pathophysiology to guide examination
  - Consider location of lesion/injury on imaging studies
  • Left frontal and parietal areas also important for language and motor function
  - Consider type of injury
  • Coup/contrecoup
  • Anoxic brain injury

Patient/Client History

• Demographics
  - Age, sex
• Social history
  - Activity pattern, interests, hobbies
• Employment (job/school/play)
  - Prior work and/or education level
• Living environment and options for home setup
  - Support available at home
  - Entrance to home or first floor setup

Patient/Client History

• Growth and development
  - Handedness
• General health status
  - Pre-morbid health conditions
  • Cardiopulmonary
  • Orthopedic
  • Musculoskeletal
  - Exercise pattern and history

Patient/Client History

• History of current condition
  - Time since injury
  - Course since injury
  - Complicating factors
  - Medical interventions
• Medications
  - Be aware of secondary or side effects of medications
  • I.e. lethargy, confusion, tachycardia
• Clinical tests
  - Blood tests (lab values)
  - Diagnostic imaging

Review of Systems

• Cardiopulmonary
  - Respiratory rate, HR, BP, edema
  • Cardiac status, HR, heart rhythm, BP
• Integumentary
  - Pressure sores, abrasions, post-surgical incisions, scars
• Musculoskeletal
  - Gross AP/ROM, strength, restrictions related to fractures, orthopedic precautions, height, weight
• Neuromuscular
  - Gross coordination of movements, motor function (motor control and learning)
• Communication, Affect, Cognition, Language and Learning Style
  - Consciousness
  • Verbal vs. non-verbal, tactile cues, demonstration
  - Ability to make needs known
Tests and Measures for Patients with Severe Brain Injury

- Standardized assessments
  - Often will not be able to be used in this population
  - Inability to follow commands, communicate
- General principles
  - Describe what is observed as objectively as possible
  - Consider both spontaneous and elicited behavior

Tests and Measures

- Observation is key to examination
  - What does the patient do at rest?
    - Positioning, movement, gaze, verbalization
    - What reactions do you see during Nursing care
  - Be aware of the different stimuli introduced and note responses
    - Auditory
    - Visual
    - Tactile
    - Combination
  - Be aware of patient’s care schedule
    - Nursing care sessions may result in overstimulation or fatigue

Tests and Measures

- Arousal
  - Arousal is actually an internal state of readiness that is unable to be directly measured
  - Very frequently impacted by severe TBI and secondary issues
  - Indirectly assess arousal through eye opening
  - Can be problematic with eye injuries, or subset of patients who tend to keep eyes closed even when aroused
  - Document spontaneous eye opening, or with stimulation

Tests and Measures

- Attention
  - Internal process that we are attempting to evaluate
  - Includes many different aspects
  - Attention is generally assessed with regard to engagement in a task or activity in other populations
  - Often unable to be performed in this population
  - Ability to attend to an object presented
  - If patient unable to physically interact, consider visual attention
    - Ability to sustain and/or track visually
    - Consider attention to both left and right

Tests and Measures

- Cognition
  - Unable to be evaluated formally
  - Describe any evidence of higher-order cognitive processing
    - Command following, communication
  - Differentiate reflexive behavior from behavior which requires processing
    - Reaching for objects
    - Purposeful object use
    - Non-reflexive responses to stimuli

Tests and Measures

- Ventilation, Respiration, and Circulation
  - HR, BP, SaO2, need for supplemental O2
  - Auscultation
  - Respiration
    - Rate
    - Pattern
    - Muscle use
    - Cough
  - Monitor response to interventions
### Tests and Measures

#### Cranial nerve exam:
- Lack of communication and command following prohibit many assessments
- Those that can be done
  - Pupillary responses - CN II, III
  - Visual threat – CN II
  - Extra-ocular movements – CN III, IV, VI
    - If unable to track, assess via doll’s eye maneuver
  - Corneal sensation – CN V, VII

#### Facial expression – CN VII
- Elicit grimacing if no spontaneous expression

#### Hearing – CN VIII
- Try to assess right and left
- If no response, assess auditory startle
- Gag reflex – CN IX, X
- Tongue protrusion – CN XII

### Tests and Measures

#### Muscle performance
- Description of observed movements
  - Quality/smoothness
  - Speed/timing
  - Isolated control vs. synergistic/patterned
  - Spontaneous and elicited
    - Type of stimulation to elicit
- May be observed during postural control challenges

#### Tone/spasticity assessment
- Modified Ashworth Scale
- Tardieu scale

### Tests and Measures

#### Range of Motion
- Assess and document key areas
  - Areas with current significant limitations
  - Areas most at risk for loss of ROM
    - Ankles: dorsiflexion, eversion
    - Hips: extension, internal rotation
    - Shoulders: flexion, abduction, external rotation
    - Pelvis: anterior tilt
    - Trunk: extension
    - Scapulae: upward rotation, general mobility
    - Cervical: throughout

### Tests and Measures

#### Peripheral Nerve Integrity
- DTR’s
- Sensation
  - Response or lack of response to tactile stimuli
  - Localizing vs withdrawal
- Muscle atrophy
  - EMG’s to supplement clinical findings
  - Consider Critical Illness Polyneuropathy (CIP)

#### Reflex integrity
- Can help identify LMN involvement
- Grasp reflex
  - May confound assessment if not recognized
- VOR (doll’s eye)
- DTR’s
- Spasticity

#### Neuromotor development and Sensory Integration
- Decorticate or decerebrate posturing
- Primitive reflexes
  - ATNR, STNR
Tests and Measures

- Pain
  - Can be difficult to assess
    - Facial expression/grunting may not be reliable
    - Heart rate and other physical signs may be confounded
  - Assess response to noxious stimuli: groaning/moaning, flexion withdrawal, localizing, facial expressions
- Sensory integrity
  - As in cranial nerve assessment
  - Evidence of sensation throughout
  - Reaction to deep pressure throughout

Tests and Measures

- Posture
  - Description of resting position
    - Include head/neck, eyes, trunk
    - May include supine or seated in wheelchair
  - Examine in supine, supported and unsupported sitting
    - Assess fixed vs flexible deformity
  - Postural control and righting reactions
    - Note righting and protective reactions to displacement

ROLE OF PT IN EVALUATING CONSCIOUSNESS

Evaluating Consciousness: The Challenge

- Patients can remain vegetative or minimally conscious for prolonged periods
- 20% of individuals with severe TBI are unresponsive at least 1 month
  - Re-emergence of consciousness if it occurs at all is likely to occur gradually (Rhode, 1995)
- Assessment of cognitive abilities depends on voluntary engagement of the patient and consistency of performance
- Variable behavior/ arousal is the hallmark of minimally conscious state and is present in vegetative patients

Evaluating Consciousness

The Assessment Challenge

- Observed behaviors may be volitional, spontaneous, reflexive
- Observation alone does not provide accurate information
- Clinical observations and conclusions are biased by “extremes”
- Errors in classification as VS vs MCS range from 15-43% (Tassini, 1991; Chess, 1993; Andrews, 1996)

Examination of Consciousness

- Standardized behavioral scales
  - Glasgow Coma Scale (GCS)
  - Full Outline of UnResponsiveness Scale (FOUR)
  - JFK-Coma Recovery Scale—Revised (CRS-R)
  - Rancho Los Amigos Level of Cognitive Functioning Scale (RLCFS)
- Patient specific measures
  - Individualized assessments can be used to identify evidence of command following vs. random movement (Rhode, 1995)
Glascow Coma Scale (GCS)

- Brief measure of brain injury severity
- Assesses the function of the cerebral cortex and the upper brainstem, the reticular activating system
  - eye-opening response - arousal mechanism of the brainstem
  - verbal response - integration of cerebral cortex and brainstem
  - motor response - integrity of cerebral cortex and spinal cord
- International use in ERs and trauma units
- Total score usually documented:
  - Mild = 13-15
  - Moderate = 9-12
  - Severe = 3-8
  - 3-4 = very severe


Glascow Coma Scale (GCS)

- Important instrument in clinical decision making
  - Surgery, follow up CT scanning, intubation, monitoring of ICP
- Limitations:
  - Brainstem reflexes and eye movements are not considered
  - Not sensitive to mild brain injury deficits
- Predicts recovery outcome in moderate to severe brain injury
- Strong predictor of:
  - hospital mortality, length of coma (LOC) and posttraumatic amnesia (PTA), Glasgow Outcome Score (GOS) at 6 months, long-term abilities after TBI


Rancho Los Amigos Level of Cognitive Functioning Scale

- Commonly used tool to describe a patient's level of cognitive function across the continuum of recovery after TBI
- Correlates with 24 hour GCS scores, length of coma, and duration of posttraumatic amnesia.
- Limited as a predictor of long term outcome or to monitor progress within levels
- Every patient does not go through all levels.
- Inter-rater and test-retest reliability (Zuiderwijk 1977)
- Includes 8 levels ranging from “No Response” to “Purposeful and Appropriate Responses”

www.blma.org/contbriefs/attrx.html

Rancho Los Amigos Level of Cognitive Functioning Scale

- Level I - No Response
  - Patient appears to be in a deep sleep and is completely unresponsive to any stimuli
  - No response to sounds, sights, touch, movement
  - Limiting factor: arousal
Rancho Los Amigos Level of Cognitive Functioning Scale

- Level II - Generalized Response
  - Generalized reflex response to painful stimuli
  - Responds to external stimuli with
    - physiological changes
    - generalized gross body movement
    - non-purposeful vocalization
  - Responses noted above may be same regardless of type and location of stimulation
  - Responses may be significantly delayed
  - Patient reacts inconsistently and non-purposefully to stimuli in a nonspecific manner
  - Limiting factor: awareness of environment

Rancho Los Amigos Level of Cognitive Functioning Scale

- Level III - Localized Response
  - Withdrawal or vocalization to painful stimuli
  - Turns toward or away from auditory stimuli
  - Blinks when strong light crosses visual field
  - Follows moving object passed within visual field
  - Responds to discomfort by pulling tubes or restraints
  - Responds inconsistently to simple commands
  - Responses directly related to type of stimulus
  - Reacts specifically and inconsistently to stimuli
  - Responses directly related to type of stimulus provided
  - May follow simple commands in an inconsistent, delayed manner
  - May respond to some persons (especially family and friends) but not to others.
  - Limiting factor: consistency of awareness

JFK Coma Recovery Scale – Revised (CRS-R)

- Original scale 1991 (Haxby et al.)
- Revised 2004 (Arias, Haxby & Teasdale)
- Developed to characterize and monitor patients at Rancho Levels I – IV
- Discriminate MCS from VS
- Used widely in clinical and research settings
- Reliable and Valid
  - Inter-rater reliability (0.84)
  - Test-retest reliability (0.94)
  - Concurrent validity (0.97) with the CRS
  - Concurrent validity (0.99) with the Disability Rating Scale (DRS)
- Differential diagnosis of DOC and tracks recovery
- Recommended to assess DOC with only minor reservations

JFK Coma Recovery Scale – Revised (CRS-R)

- 23 Items with 6 subscales
  - Auditory Function
  - Visual Function
  - Motor Function
  - Oromotor/Verbal Function
  - Communication
  - Arousal

- Hierarchical: lowest item is reflexive, highest item is cognitively-mediated

CRS-R Administration Overview

- Conduct 1 minute baseline observation
  - Determine level of arousal
  - Facilitate selection of appropriate commands
  - Differentiate volitional from random/residential movement
  - Resting position of extremities, eye opening status, spontaneous visual fixation/tracking, spontaneous movement
- Administer Arousal Facilitation Protocol (AFP)
  - May administer protocol any time
  - Purpose is to increase the length of time arousal is sustained
  - Deep pressure, vestibular

- Administer CRS-R items in sequence
  - Score related responses only
  - Do not score responses that occur after 10 seconds
  - Score best response within each subscale

(See Haxby et al., 2003; www.rbm.org/combics/CRS%20Protocol.pdf)
**CRS-R Auditory Function Scale**

- **Score 4 = Consistent Movement to Command**
  - Clearly discernible & accurate responses occur on all 4 trials
  - Functional significance:
    - Capable of sustained environmental interaction
    - Signals readiness for active rehabilitation
    - Able to tolerate more complex cognitive assessment
    - Denotes MCS

- **Score 3 = Reproducible Movement to Command**
  - 3 clearly discernible, accurate responses occur over the 4 trials
  - Functional significance:
    - Retains capacity for cortically based processing and cognitively mediated behavior
    - Cleaned indication of recovery of consciousness
    - Denotes MCS

**CRS-R Visual Function Scale**

- **Score 5 = Object Recognition**
  - 3 to 4 clearly discernible, accurate responses occur over 4 trials
  - Functional significance:
    - Retains capacity to follow commands and discriminate visual stimuli
    - Indicative of MCS

- **Score 4 = Object Localization: Reaching**
  - Limb must move toward object on 3 of 4 trials
  - Functional significance:
    - Retains capacity to detect, locate and apprehend stimuli in the immediate environment
    - Indicative of MCS

**CRS-R Motor Function Scale**

- **Score 6 = Functional Object Use**
  - Limb movement is generally compatible with specific function of each object across all 4 trials
  - Functional significance:
    - Retains basic capacity for instrumental ADL’s
    - Indicative of emergence from MCS

- **Score 5 = Automatic Motor Response**
  - 2 episodes of automatic motor behavior are observed, each episode can be differentiated from a reflexive response
  - Functional significance:
    - Maintains access to over-learned behavioral routines
    - Indicative of minimal conscious state (MCS)
**CRS-R Motor Function Scale**

- **Score = 4** = Object Manipulation
  - On at least 3 of 4 trials wrist must rotate, fingers must extend and object must be grasped and held for 3 seconds
  - Ball cannot be held by means of grasp reflex or flexor hypertonus
  - Functional significance:
    - Inability to perform exploratory motor movements
    - Indicates MCS
- **Score = 3** = Localization to Noxious Stimulation
  - Non-stimulated limb must localize and make contact with stimulated body part at the point of stimulation on at least 2 trials
  - Functional significance:
    - Selective awareness of body scheme
    - Capable of active, purposeful behavior
    - Denotes MCS

*(Giacino lecture, 2002; www.brms.org/combi/CRS%20Syllabus.pdf)*

**CRS-R Oromotor/Verbal Function Scale**

- **Score = 3** = Intelligible Verbalization
  - 2 different words, each consisting of at least consonant-vowel-consonant (CVC) not “Mia”
  - Intelligible, but not necessarily appropriate
  - Writing or alphabet board acceptable
  - Functional significance:
    - Interpretable use of language
    - Indicative of MCS
- **Score = 2** = Vocalization/Oral Movement
  - At least one episode of non-reflexive oral movement and/or vocalization occur spontaneously or in response to sensory stimulation
  - Functional significance:
    - Speech is not functional

*(Giacino lecture, 2003; www.brms.org/combi/CRS%20Syllabus.pdf)*

**CRS-R Communication Scale**

- **Score = 2** = Functional: Accurate
  - Accurate responses to all 6 questions situational orientation questions
  - Verbally communicate needs
  - Functional significance:
    - Language comprehension and expression reliable
    - Decides, engages in planning
  - **Score = 1** = Non-Functional: Intentional
    - Clearly discernible responses to at least 2 of the 6 questions
  - Functional significance:
    - Sugest loss of awareness of capacity for interactive communication
    - Indicative of MCS
- **Score = 0** = None
  - No discriminable auditory or non-verbal communicative responses occur at any time

*(Giacino lecture, 2003; www.brms.org/combi/CRS%20Syllabus.pdf)*

**CRS-R Arousal Scale**

- **Score = 3** = Attention
  - No more than 3 occasions across the length of evaluation where patient does not respond to a verbal prompt
  - Functional significance:
    - Retains basic capacity to direct attention and sustain attentional focus
- **Score = 2** = Eye Opening without Stimulation
  - Eyes remain open across the length of examination without the need for tactile, pressure, or noxious stimulation
  - Functional significance:
    - Sleep/wake cycle is re-established

*(Giacino lecture, 2003; www.brms.org/combi/CRS%20Syllabus.pdf)*
### CRS-R
**Arousal Scale**
- Score = 1 = Eye Opening with Stimulation
  - Tactile, pressure or noxious stimulation must be applied at least once during the examination in order for the patient to sustain eye opening
  - Length of time eyes remain open is not considered in scoring
- Score = 0 = Unarousable
  - No spontaneous or elicited eye opening at any time during the assessment
  - Functional significance:
    - Persistent disturbance of wakefulness
    - Sedation
    - Chemical paraplegia

(Chiarlitti & Liska, 2010; www.bmj.com/content/1971/suppl_1/suppl_2034/11537805.pdf)

### Full Outline of UnResponsiveness (FOUR)
- Evaluates visual functioning, command following, brainstem reflexes, breathing patterns, evidence of brain herniation
  - Developed to address limitations of GCS, but not widely used
  - Does not depend on verbal response
  - Able to identify locked-in syndrome
- Adequate reliability, validity
- Predicts recovery at 3 months
- The FOUR is not recommended at this time because of a lack of content validity, lack of standardization, and/or unproven reliability

(Steed et al., 2015)

### Coma/Near-Coma Scale
(CNC)
- Description: 11-item measure of sensory/perceptual functioning, primitive responses in patients with DOC
  - Sensitive to changes in severe TBI
  - Predicts recovery of consciousness one year after injury
- Five categories of Awareness/Responsivity
  - No Coma, Near Coma, Moderate Coma, Marked Coma, Extreme Coma
- The CNC may be used with major reservations

(Steed et al., 2010)

### Patient-Specific Measures
- Individualized quantitative behavioral assessment
- Purpose: To provide a valid and reliable means of assessing cognitive and/or behavioral capacities in patients with marked limitations in responsiveness
- Single subject experimental designs

(Uy'sle et al., 1999)

### Patient-Specific Measures
- Purpose: Evaluate clinically meaningful questions
  - Is the person under-aroused?
  - Can the person see?
  - Is the person demonstrating “purposeful behaviors”?
    - Tracking, pulling at tubes, reaching for caregiver, pushing away noxious stimuli
  - Can the person follow commands?
  - Is the person’s behavior changing over time or with medications?
Examples of Patient-Specific Measures

- Arousal
  - Time sampling of degree of eye-opening across therapy session
  - Therapists record level of eye opening every 5 min
    - 0 = closed
    - 0.5 = half-open
    - 1.0 = open
  - Average score reflects arousal
  - Average across days, time
  - Evaluates progress, medication effects

Arousal data

Examples of Patient-Specific Measures

- Command following
  - Identify spontaneously generated behaviors
  - Evaluate patient’s ability to perform behavior ‘to command’
  - Example: A patient is able to follow command for “thumbs up” and “thumbs down” with verbal and gestural command. His ability to follow a verbal command only is unclear.
  - Protocol will clarify command following and language comprehension.

Verbal command only, RR = 55%, Acc = 65%

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Verbal plus gesture, RR = 83%, Acc = 86%

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Changes in Command Following Over Time

Importance of Command Following

- “Whether or not a patient can follow commands is an extremely important issue for several reasons. It is one of the key factors that differentiates patients who are minimally conscious from those who are vegetative, and reliable and complex command-following also helps herald the transition from the minimally conscious state to higher levels of cognitive performance” (O’Muir et al, 2000)
Summary

- Correct diagnosis of level of consciousness is important for patient care and services
  - Misdiagnosis rate very high (15-43%)
- Use of standardized tools such as CRS-R and patient specific measures have been found to be best for diagnosing consciousness.

GOAL SETTING & INTERVENTIONS

Goal Setting and Interventions for patients with DOC

- Focus on prevention of secondary complications
  - contractures, skin breakdown, pulmonary
- Ongoing assessment of cognition
- Maximize functional ability/mobility
  - quality of life for patient and caregiver
- Family education and training
- Identification of appropriate level of care

- "Treatment interventions for patients with DOC should incorporate both preventive and restorative strategies" [Bromberg and Glueck, 2011]

Sample Goals for Low Level BI Patients

- Command follow:
  "Pt will kick leg >3/4 of the range of motion to verbal command in 4/6 trials."
- Head or trunk control:
  "Pt will maintain head in neutral after positioning, with visual and verbal cues for 30 seconds."
- Endurance:
  "Pt will tolerate tilt table for with VSS at 60 degrees x 20 minutes."
- ADLs:
  "Pt will assist in grooming with suction toothbrush by demonstrating intact grasp and mouth opening after presentation with verbal cues."
- Tracking:
  "Pt will track a picture of a family member when it is moved to the right and left of midline, 3 out of 5 times, in supported sitting."

Interventions for Patients with Severe TBI

- Ongoing assessment
  - Each session is an assessment of current abilities
    - Remember, inconsistency is the hallmark of these patients
    - Even small changes very important
      - Positive changes improve prognosis
      - Negative changes give concern for medical issues
    - Therapist consistency is crucial
      - Independent of setting

Body Structures and Function

- Arousal
- Range of Motion
- Strength and motor control
- Muscle tone/spasticity
- Postural control
- Endurance
Body Structures and Function:
Arousal
- Goals of interventions include
  - Increase arousal & attention
  - Increase reactive, adaptive, or meaningful responses
- Types of Sensory Stimulation
  - Vestibular
  - Proprioceptive/Kinesthetic
  - Auditory
  - Visual
  - Olfactory
  - Gustatory
  - Tactile

PT Interventions for Low Arousal:
Sensory Stimulation
- Vestibular
  - Stimulated using motion and gravity
  - Incorporate rocking, rolling, spinning into treatment
  - Tracking with and without head movement
  - Supine to/from sit
  - Elicit balance/righting reactions
  - Large ball
  - Large bolster
  - Rocker board

PT Interventions for Low Arousal:
Sensory Stimulation
- Auditory
  - Pleasant and unpleasant sounds
  - Familiar and unfamiliar sounds
  - Use normal tone of voice when addressing patient
  - Assume he/she understands what you say
  - Visualization
  - Familiar music
  - Modulate your voice for the activity
  - Orient patient frequently
  - Loud noise, music, or clapping to increase arousal

PT Interventions for Low Arousal:
Sensory Stimulation
- Visual
  - Present personal or familiar items, pictures
  - Mirror image
  - Assess awareness of surroundings using 'blink to threat'
  - Encourage families to bring in pictures of meaningful people and possessions
  - Facilitate tracking
  - Observe righting responses via eye gaze during therapy

PT Interventions for Low Arousal:
Sensory Stimulation
- Olfactory
  - Noxious or pleasant odors
  - Incorporate cologne or perfume into treatment sessions

- Gustatory
  - Stimulated using pleasant or sour tastes
  - Incorporate tooth brushing with suction toothbrush into ADL sessions
PT Interventions for Low Arousal: Sensory Stimulation

- Tactile
  - Incorporate ice or different textures into session
  - Sternal rub
  - Pressure to nail bed
  - Deep pressure using a therapy ball
  - Face, hands, feet, usually greatest response
  - Refer to arousal facilitation protocol of CRS-R

Evidence for Sensory Stimulation

- Systematic review by Lubben et al. (2008) found there is no reliable evidence to conclude whether or not sensory stimulation programs are effective for patients in comas or vegetative states.
- Article by Gerber, 2005 encouraged the implementation of structured sensory stimulation programs in long-term hospital units for the effective treatment of sensory deprivation.
- Sasekowskii and Wink, 1994 found that sensory stimulation programs improved the quality of life and productivity of patients in recovery from coma.
- A review by Meyer et al. (2010) concluded that sensory stimulation programs improve patients' cognitive, emotional, and physical functioning, even in patients with severe brain damage.
- Although the efficacy of sensory stimulation has not been confirmed, patients who are not conscious may benefit from sensory stimulation to increase arousal and provide a means for interaction (Kolachek and Cee 2002).

Evidence for Sensory Stimulation

- A study by Uribarri et al. (2009) indicated that sensory stimulation programs can improve the recovery of patients in comas or vegetative states, as measured by the MMSE and GCS scores.
- Dopamine with stimulation results in increased ability to process information, stimulation for creating a quiet environment, and providing selective input to improve response capabilities. (Wood 1991)
- The use of sensory stimuli in multimodal stimulation programs increases the greatest change. (Wendt et al. 1998)
- Altering the environment by providing meaningful yet novel sensory stimulation may enhance mobility and speed of reorganization of structures that support cognitive processes. (Wendt et al. 2000)
- When possible, observe patients and perform neurological assessments in the standing position. The results of the preliminary study suggested that positional changes may have an impact on behaviors demonstrated by patients in the SCI and NCS (Wendt et al. 2009).

Body Structures and Function: ROM

- Goal: to maintain or increase PROM
  - Allow for proper postural alignment, including:
    - Neutral alignment of head, trunk, pelvis, upper and lower extremities
    - Preparation for sitting, standing, gait, functional use of extremities
  - Passive stretching
    - Helps to prevent loss of ROM in acute setting
    - Appears to provide short-term decrease in spasticity (Dempsey 2001)
    - Recent review inconclusive as to effects of stretching on spasticity (Dempsey 2001)
    - ROM can be a skilled intervention in this compromised population, not maintenance

Body Structures and Function: ROM

- Positioning: bed and wheelchair
  - Focus on: ROM preservation, skin protection, tone inhibition
  - Pictures, training, positioning devices
  - Bed positioning recommendations
    - supine and sidelying
  - Customized wheelchairs
    - Tilt in space wheelchair, headrest, contoured back, contoured cushion, upper extremity support, legrests
    - Neutral alignment of head, trunk, pelvis, upper and lower extremities
Body Structures and Function: ROM

- Splinting/bracing/casting/bivalves
  - Serial casting is the only intervention with evidence suggesting that it can change spasticity over long term (Zafonte, 2004) (Helweg, S and Johannes, S, 2008)
  - Serial casting shown to increase ROM or prevent further loss of ROM (Helweg, S and Johannes, S, 2008)
    - Superior to positioning for elbow contractures in TBI patients (Nosey, 2000)
      - Reduced spasticity noted in serial casting
      - Effects on ROM and spasticity appeared short-lived

Body Structures and Function: Increased Muscle Tone/Spasticity

- Oral Medications (Read & T. 2013)
  - Baclofen
  - Tizanidine
  - Dantrolene
  - Dizapam
  - Gabapentin
- Intrathecal Baclofen Pump (Read & T. 2013)
- Rhizotomy (Read & T. 2013)
- Tendon Lengthening and Soft Tissue Release (Read & T. 2013)

Body Structures and Function: Strength/Motor Control

- Strength
  - Indirect strength training achieved through positioning
  - Maintain static positions
  - Therapeutic transitions
  - Address muscle activation, strength, coordination, motor planning
  - Provide opportunities for patient to practice purposeful movements

Body Structures and Function: Postural Control

- Postural Control
  - Sitting
    - Interaction w/ environment
    - Cardiopulmonary benefits
    - Considerations: ROM, Integumentary status, VS response
    - Facilitation of automatic postural reactions
    - Proprioceptive feedback may be provided through tactile cues to the
      - Trunk
      - Upper extremities
      - Lower extremities
  - Provide challenges
    - Rapid displacement of center of mass

Body Structures and Function: Endurance/Upright Tolerance

- Endurance/Cardiopulmonary
  - Upright tolerance
    - Gradually raise head of bed
    - Sitting
      - Wheelchair, unsupported edge of bed/mat, perched sitting
    - Standing
      - Tilt table, standing frame
      - Moveo™, Ergo®
      - Some ICU beds may reverse Trendelenburg and allow for standing/upright progression

Activity

- Transfers
  - Utilize lift devices as needed
  - Functional transfers including low pivot and sit to stand
    - Provide opportunity to stimulate and assess spontaneous muscle activation
- Gait training
  - LiteGait®
  - Lokomat®
  - Platform walker
  - Up n Go Walker®
- Strong evidence exists that intensive task-oriented rehabilitation programs lead to earlier and better functional abilities (Helweg, S and Johannes, S, 2008)
Learning Potential for Individuals with DOC

- A systematic literature review found individuals identified as being in a coma or vegetative state can learn specific behaviors with classical or operant conditioning (Marcus et al. 2013).
  - Positive or negative reinforcement was found to produce increased frequency of specific behaviors in individuals with severe brain injuries
    - Hand closure, eye blink, eye brow lifting, eye focus, lateral head movement, mouth opening, removal of a towel placed on face

Family Training and Education

- Course of rehabilitation
  - Plan of care
  - Behavioral and cognitive challenges
- PROM and sensory/environmental stimulation
  - Alternating time with TV or radio on/off
  - Soft voices if patient "storming" or showing agitation
- Positioning
  - WC and Bed
  - Integumentary Integrity
    - Weight shifts, skin checks, positioning

COMMONLY USED MEDICATIONS IN SEVERE BRAIN INJURY

Pharmacology in TBI – DOC and Arousal

- Amphetamines (Adderall) and methylphenidate (Ritalin)
  - Increase dopamine and norepinephrine availability
  - Few studies and no conclusive evidence support the use of neurostimulants to enhance emergence from states of impaired consciousness
- Amantadine (Symmetrel)
  - Anti-parkinsonian, antiviral agent
  - Increases pre- and postsynaptic dopamine availability, is also a weak NMDA receptor antagonist
  - Growing body of evidence supports its use in impaired consciousness due to TBI
- Zolpidem (Ambien)
  - address an approach to a subtype of GABA-A receptors
  - A number of case reports exist on its use as an “awakening” agent in patients in PVS or MCS
- Bromocriptine (Parlodol)
  - another dopamine-enhancing agent, postsynaptic D2 dopamine receptor agonist
  - has been examined less extensively
  - associated with a greater rate of transition from persistent VS (PVS) to MCS in a retrospective chart review
  (Chew & Zemek D, 2005)

Pharmacology in TBI – Amantadine

- More rapid recovery
- Affected functionally meaningful behaviors:
  - consistent responses to commands
  - intelligible speech
  - reliable yes-or-no communication
  - functional object use
- The benefits were consistent regardless of the interval since injury or whether patients were in a VS or MCS at enrollment
- Gains were generally well maintained but the rate of recovery attenuated after treatment
- Exposure did not increase the risk of adverse medical, neurologic, or behavioral events, including seizure
  (Graham J. et al. 2012)

Physical Therapy

OUTCOME MEASURES
Glasgow Outcome Scale (GOS)
- Commonly used before other scales were developed as a brief descriptive outcome scale
- Replaced by the DRS
- Still seen occasionally in the literature investigating early acute medical predictors of gross outcome.
- The five categories of the original scale are:
  - Dead
  - Vegetative = Unable to interact with environment; unresponsive
  - Severely disabled = Able to follow commands; unable to live independently
  - Moderately disabled = Able to live independently; unable to return to work or school
  - Good recovery = Able to return to work or school

The Disability Rating Scale (DRS)
- Developed and tested with individuals with moderate and severe TBI in an inpatient rehabilitation setting.
- The scale is intended to measure accurately general functional changes over the course of recovery.
- Addresses impairment, disability, and handicap.
  - The first three items of the DRS (Eye Opening, Communication Ability and Motor Response) are a modification of the GOS and reflect impairment ratings.
  - Cognitive ability for “Feeding,” “Toiletting” and “Grooming” reflect level of disability.
  - The Level of Functioning and Employability item reflects handicap.
- The maximum score is 29 (extreme vegetative state).
- Inter-rater and test-retest reliability.
- Limitations:
  - Relatively insensitive at the low end of the scale (mild TBI)
  - Inability to reflect more subtle but sometimes significant changes.

Evidence to Support Post Acute Rehabilitation
- Post acute care disposition frequently dictated by physical therapist.
  - Complete understanding of patients' current functioning and prognosis is essential to make proper recommendations.
- Strong evidence exists that more intensive rehabilitation programs lead to earlier functional abilities (Tye, M. S. and Johannes, S., 2003).
- Post-acute rehabilitation effective in improving functional outcome after TBI, including persons with stable neurologic recovery at 12 or more months post injury (Hugh WH et al, 2009).
  - Improvements
    - Improvement of overall disability
    - Independence
    - Home competency
    - Productivity
    - Gains were maintained at follow-up

Take Home Messages
- Formalized rehabilitation is an important part of the rehab process.
- Observation is key...as is documentation of these changes!
- Use of objective tools can support care and change.
- Medical and pharmacologic issues must be considered with this population.
- Prevention of secondary complications is important for future function.
- Recognize your part as an important part of the rehab team.
Physical Therapy Management for Patients with Disorders of Consciousness

Carolyn Tassini, PT, DPT, NCS
Natalie Sibley, PT, DPT, NCS

Case Presentation

- **HPI:** 30 y/o male restrained driver in an MVA. Sustained CHI w/ DAI, R frontal/parietal SAH, left posterior rib 6-7, right anterior pubic ramus (non-displaced), sacral fx, and left anterior column acetabular fx.
  - Later dx of L/CNS nerve root compression
- **Social:**
  - Married w/ 3 children (6 mos to 2.5 yrs)
  - PT: middle school social studies teacher
  - Enjoys singing
- **Admitted to MRH:** Responsiveness Program 3.5 weeks after the accident.
- **Precautions:**
  - NIV/ER: 6 wks

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- Anne Maattala, MOTR/L

- Our patients and families who have taught us so much about recovery and perseverance.

References

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