

# Windows To The Brain: Neuropsychiatry of TBI

Presented by

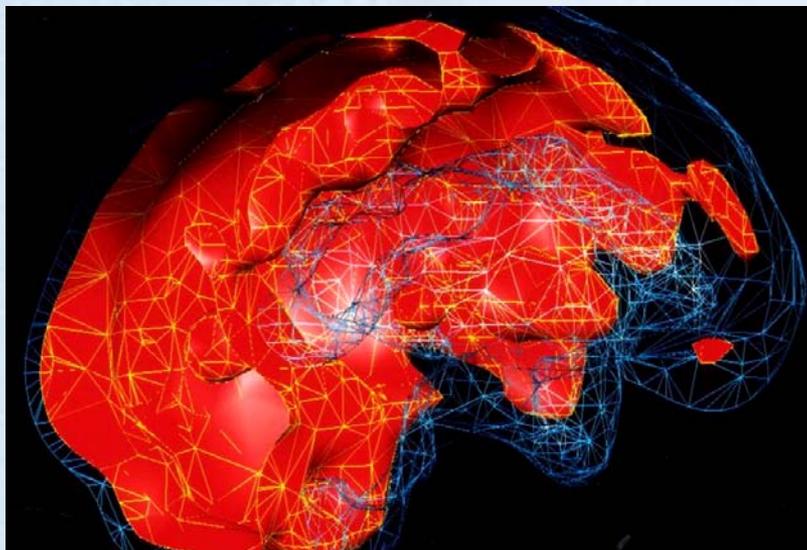
National Center for PTSD

U.S. Department of Veterans Affairs

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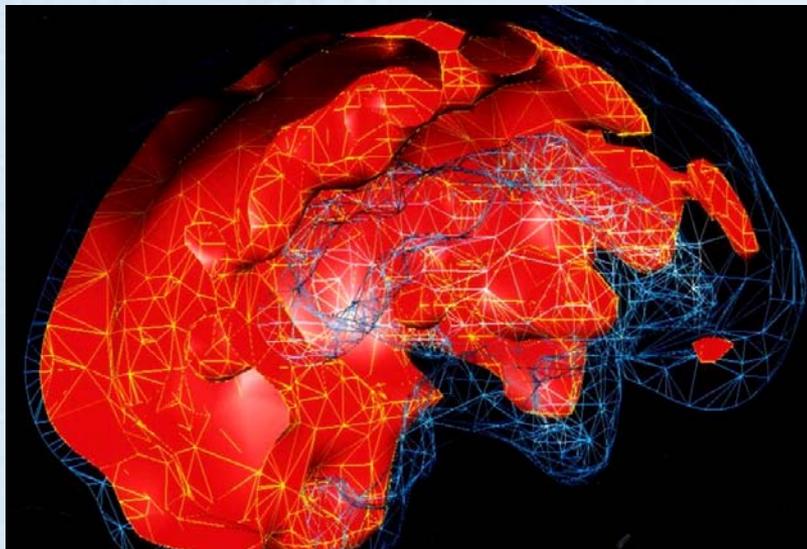
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National  
Center for  
**PTSD**  
Posttraumatic  
Stress Disorder

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**Acknowledgement to: Katherine H. Taber, Ph.D., FANPA**

# Disclaimer

The views expressed in this session are strictly those of the presenters (RAH & KHT). They do NOT represent those of the Veteran's Health Administration, the Department of Defense, or the United States Government.

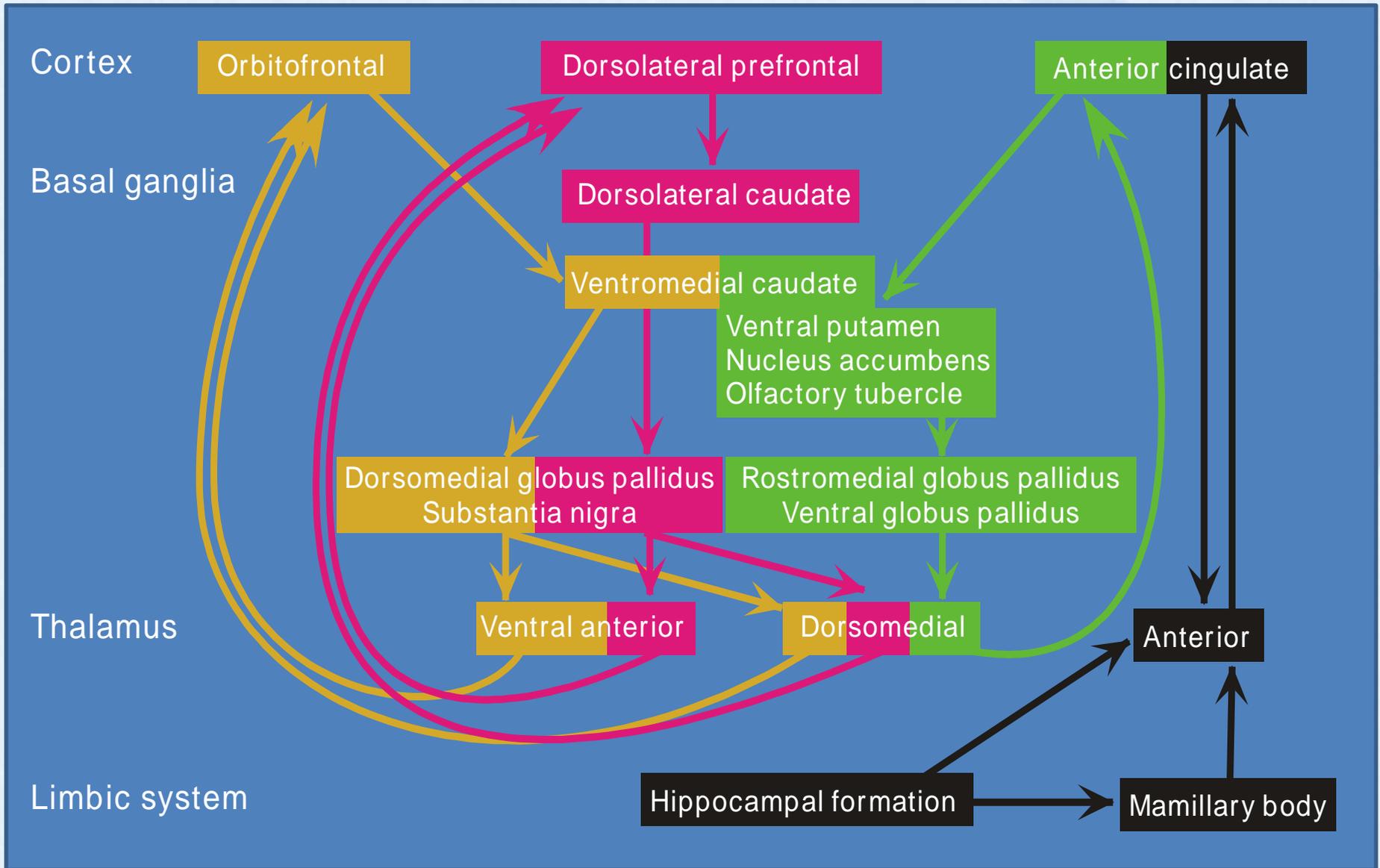
# Learning Objectives

## Neuropsychiatry of TBI: current understanding and future challenges



1. Functional Anatomy of emotion, memory, and behavior circuits
2. Functional deficits in civilian brain injury
3. Current assessment and treatment advice
4. Suggestions for future research initiatives

# Frontal Lobe Circuits

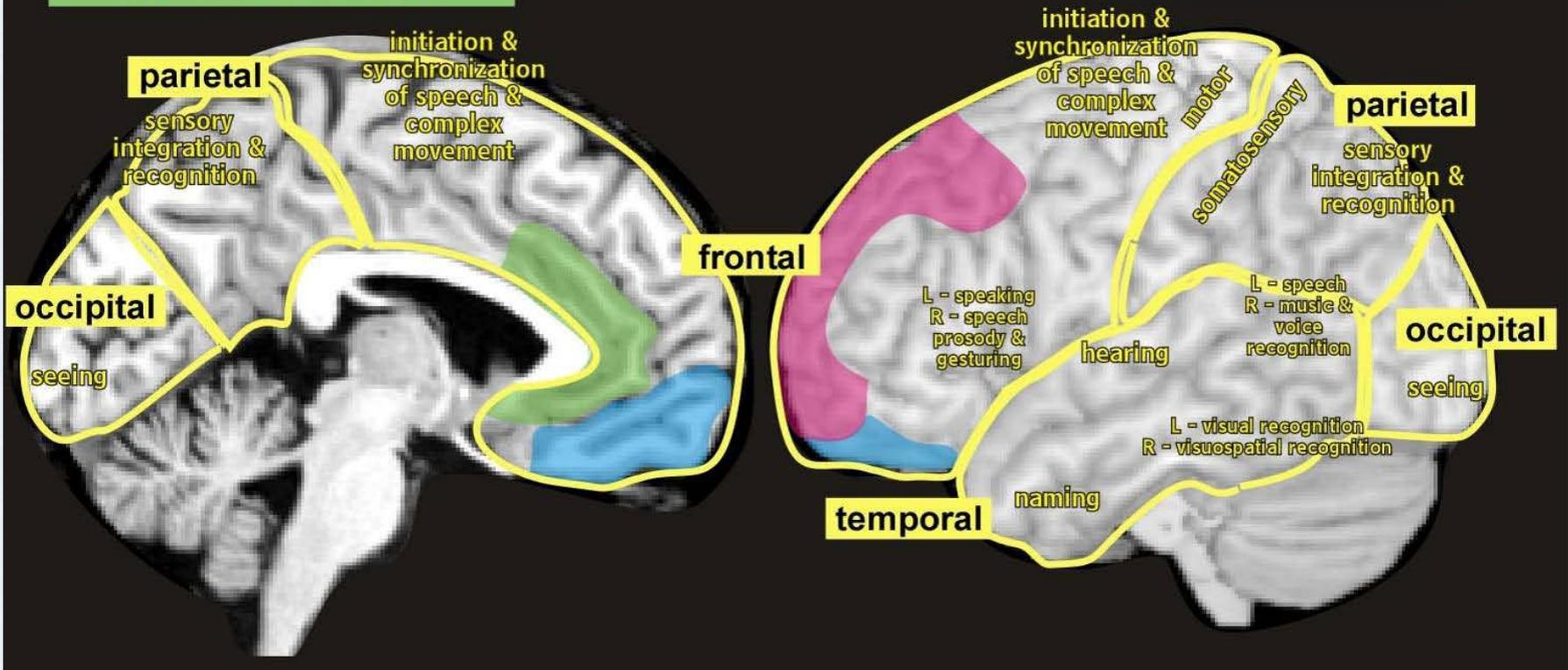


# Major Prefrontal – Subcortical Circuits

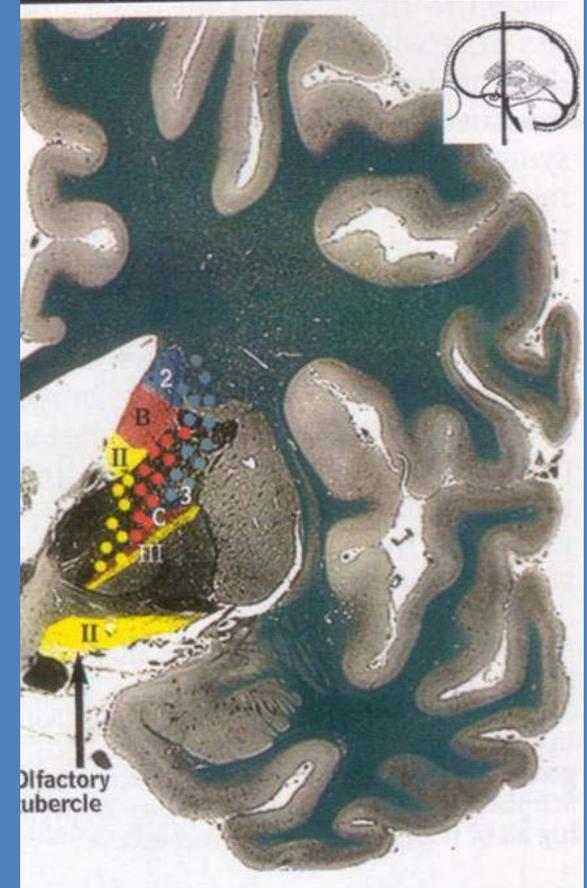
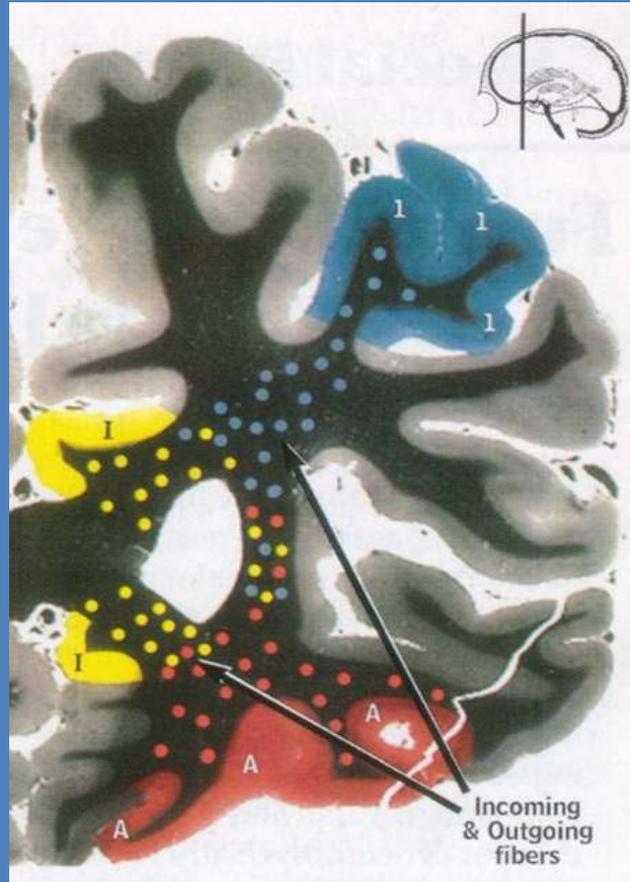
**Anterior cingulate circuit**  
produces motivation by balancing the inhibitory input of the supplemental motor area with its own stimulus that supports wakefulness & arousal

**Orbitofrontal circuit**  
mediates socially appropriate behavior, impulse control & empathy

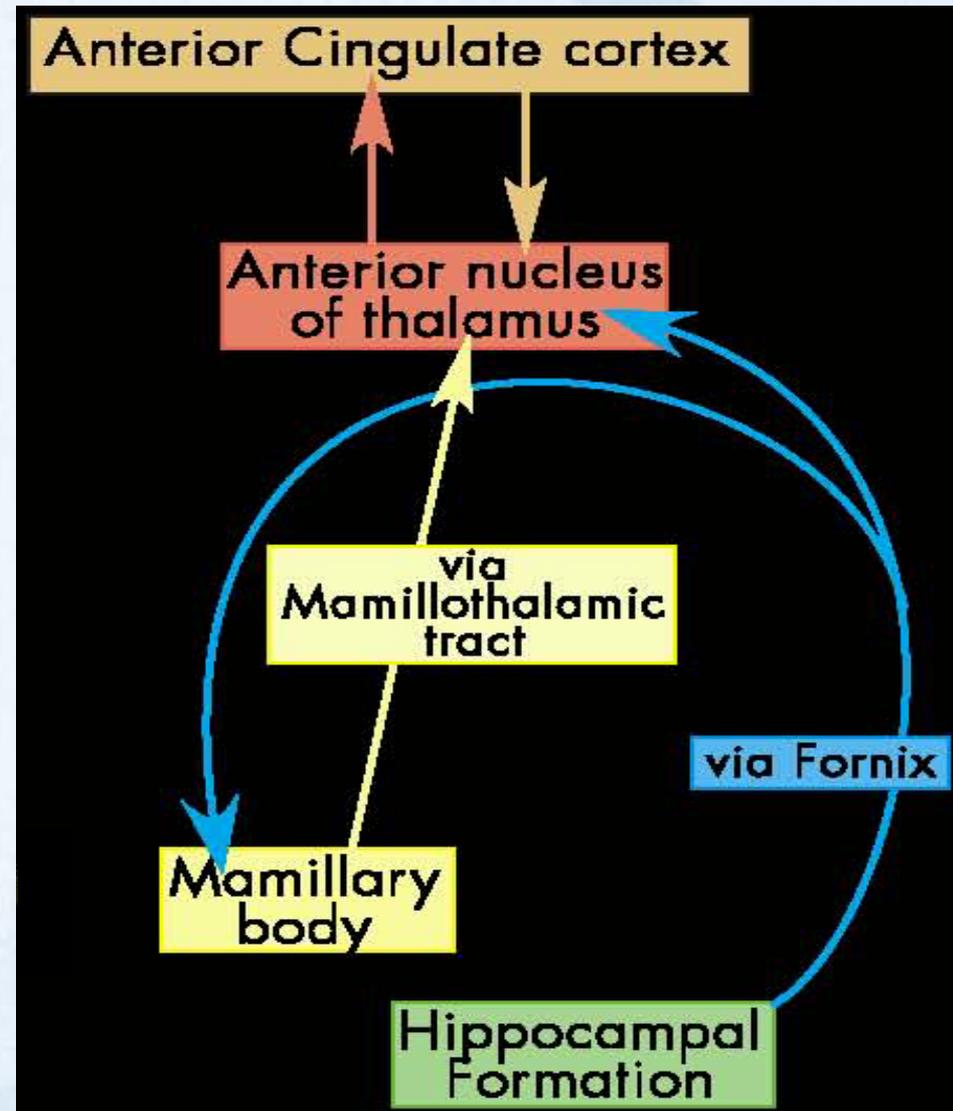
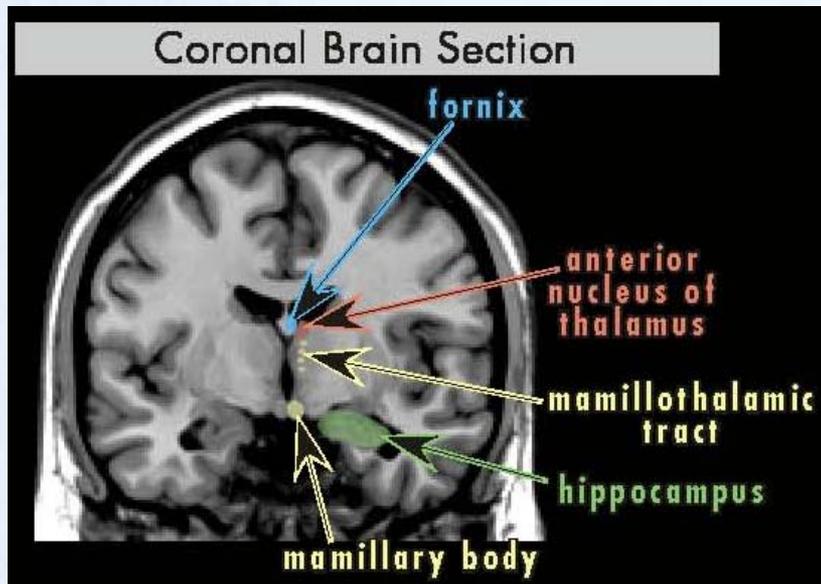
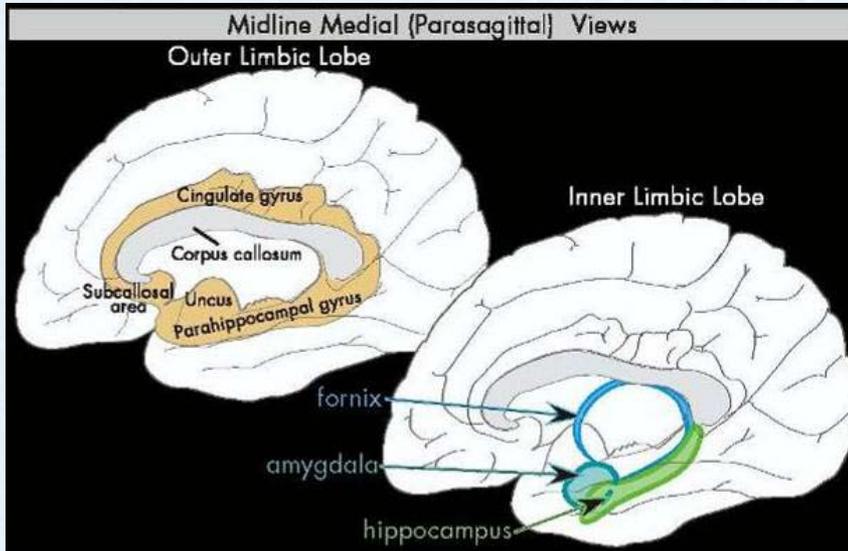
**Dorsolateral circuit**  
mediates executive functions such as organization, planning & attention



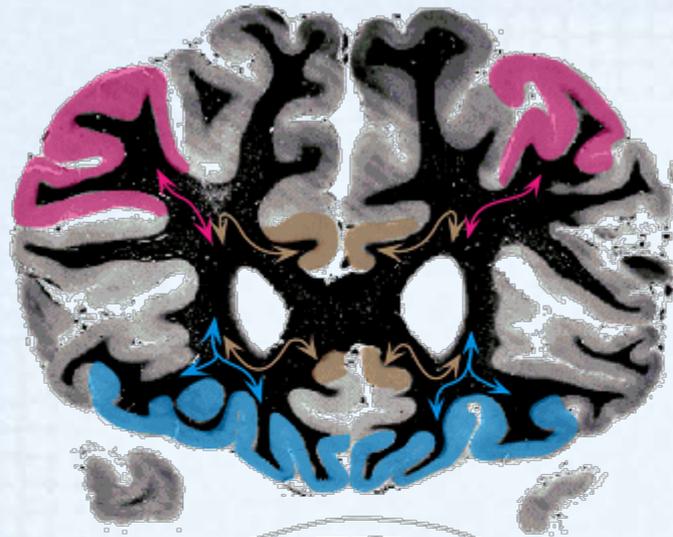
# Prefrontal Circuits: Vulnerable to Injury



# Emotion and Memory



# Cerebellum in Emotion



## Prefrontal Areas:

Dorsolateral prefrontal cortex

Anterior cingulate cortex

Orbitomesial cortex

## Subcortical Areas:

Septal nuclei

Thalamus

Hypothalamus

Amygdala

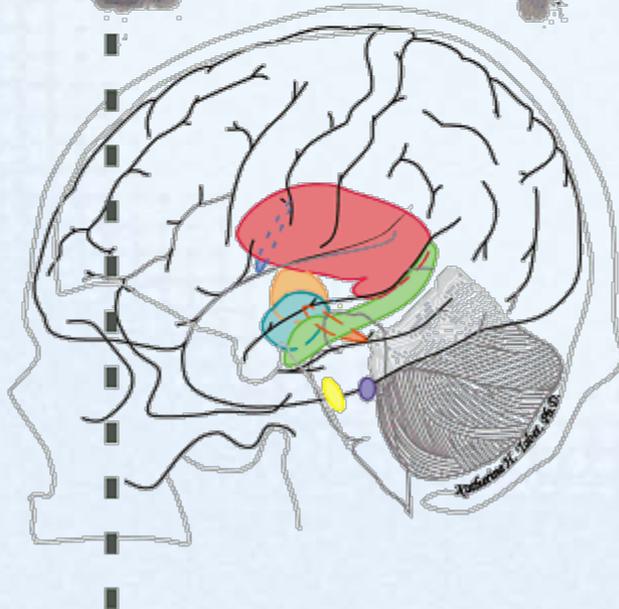
Hippocampus/Dentate Gyrus

## Brainstem Monoamine Nuclei:

Serotonin - Dorsal raphé

Dopamine - Substantia nigra

Norepinephrine - Locus coeruleus



# Major Cortical Association Tracts

Anterior - lack of emotional affective response to pain; anxiety; OCD; depression; panic; akinetic mutism

Posterior - impaired integration of visuospatial & memory processing

**cingulum - long fibers**  
frontal cortex ↔ temporal cortex

**cingulum - short fibers**  
cingulate cortex ↔  
frontal, parietal, occipital & temporal cortex

**superior fronto-occipital (subcallosal) fasciculus**  
orbital & medial prefrontal cortex ↔ parietal cortex

**inferior fronto-occipital fasciculus**  
ventrolateral & dorsolateral prefrontal cortex ↔  
posterior temporal & occipital cortex

akinetic mutism; disordered initiation & preparation of speech movements; transcortical motor aphasia; anomia & reduction of spontaneous speech with normal articulation

R>L - impaired orienting of attention; visual recognition abnormalities

R+L - impaired pursuit eye movements; inaccurate reaching under visual guidance; impaired motion perception

R or R+L - impaired seeing/selecting in crowds; impaired spatial relations; visual agnosia & poor visual memory; impaired recognition of places & directions to get there; getting lost

**inferior longitudinal fasciculus**  
temporal pole ↔ occipital cortex

disorders in recognition (visual agnosia) impaired visual recent memory

R or R+L - impaired face recognition (prosopagnosia); visual object agnosia; visual hypoemotionality if cue presented visually

R+L or L>R - contralateral deficit in color vision (hemiachromatopsia)

L- bilateral misnaming of objects presented by touch (tactoverbal dysfunction)

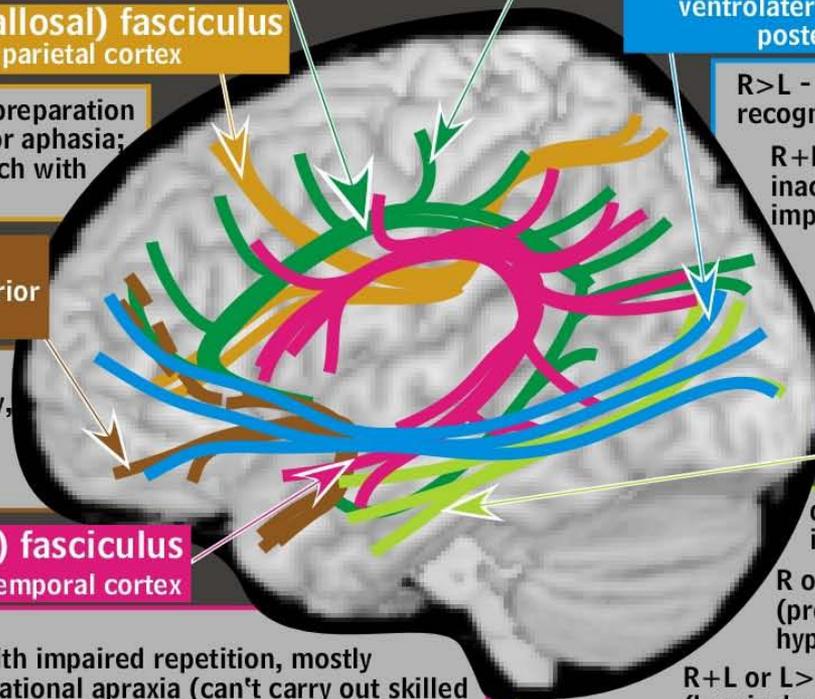
**uncinate fasciculus**

orbital & polar prefrontal cortex ↔ anterior temporal cortex

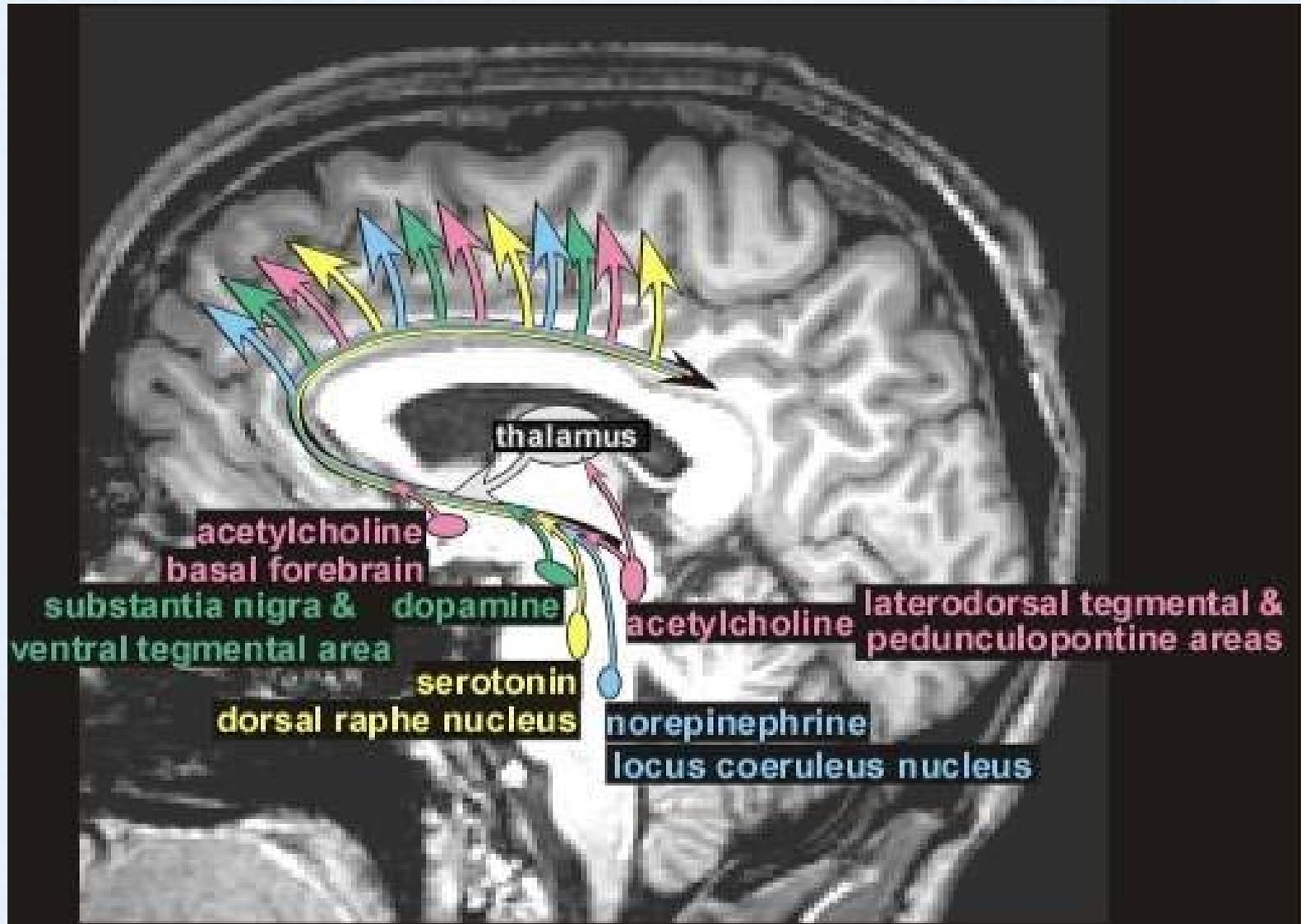
deficits in retrieval of past information:  
R - episodic context-dependent memory, personal experiences, autobiographical  
L - context-free memory, general knowledge of facts

**superior longitudinal (arcuate) fasciculus**  
frontal cortex ↔ parietal, occipital & temporal cortex

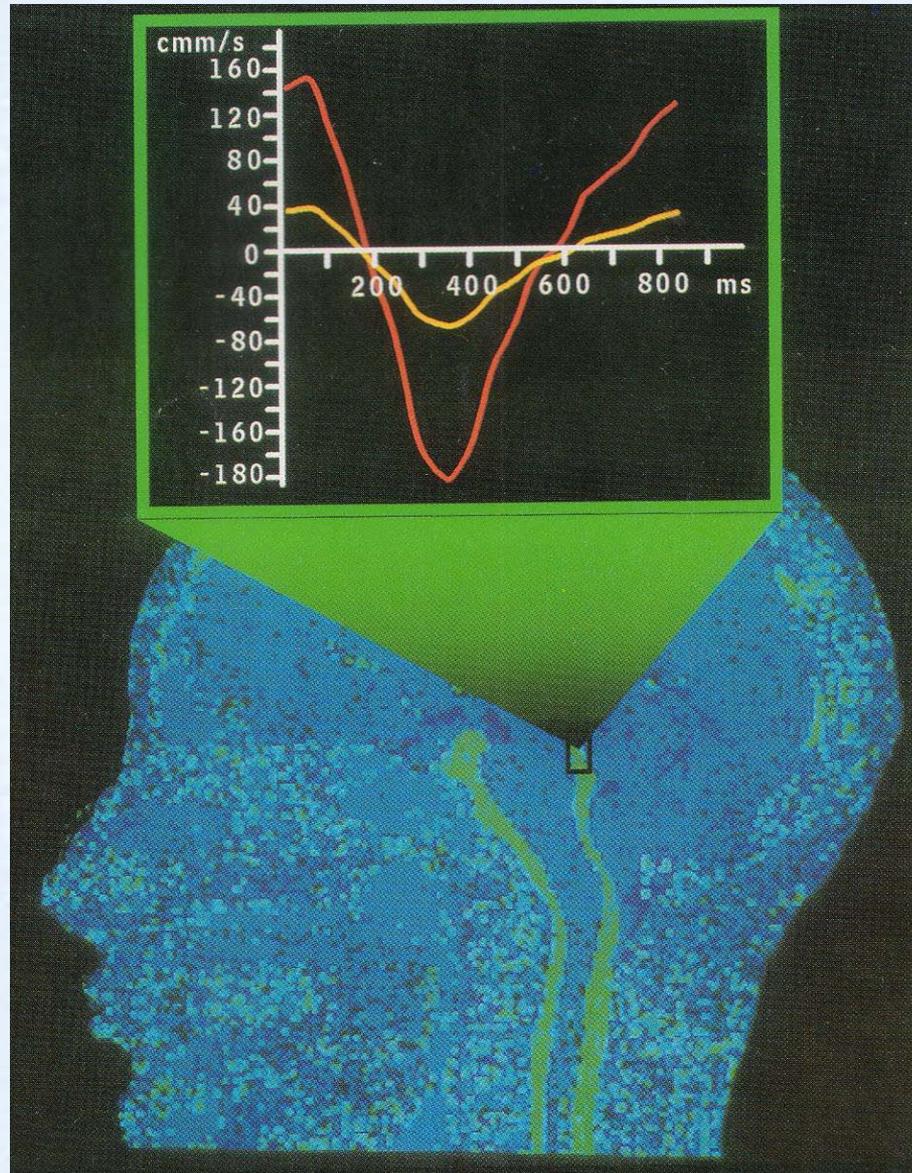
R - left hemispatial neglect  
L - conduction aphasia (fluent aphasia with impaired repetition, mostly preserved language comprehension); ideational apraxia (can't carry out skilled movements; can't carry out commands); depression; speech arrest; anomia  
Posterior injury - transcortical sensory aphasia (impaired auditory comprehension with intact repetition & fluent speech)



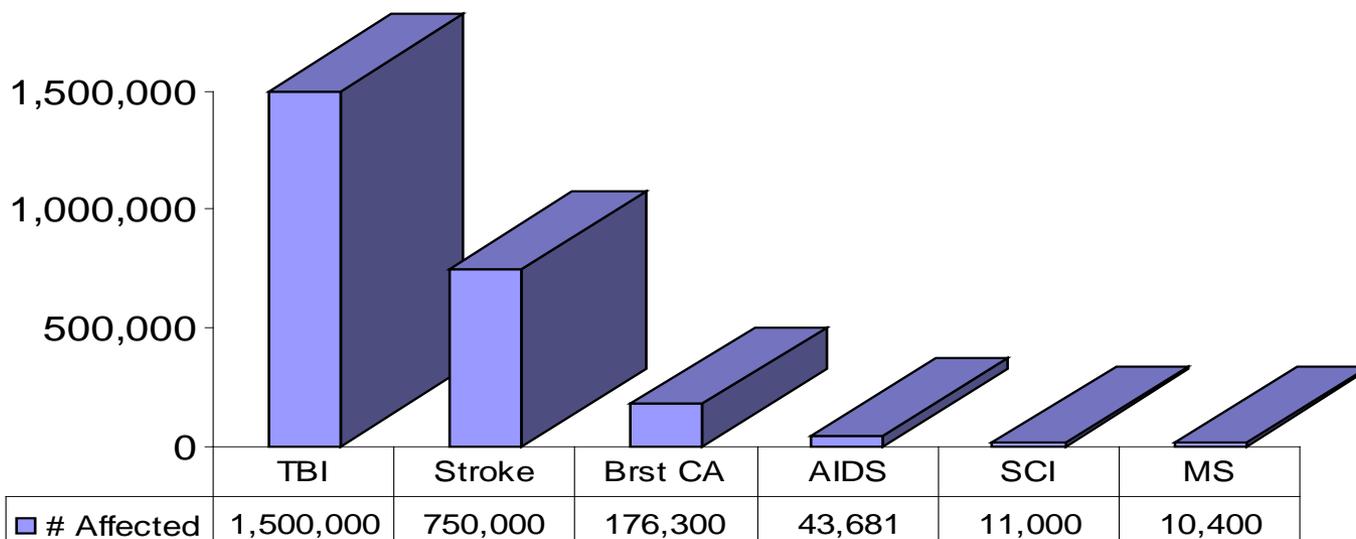
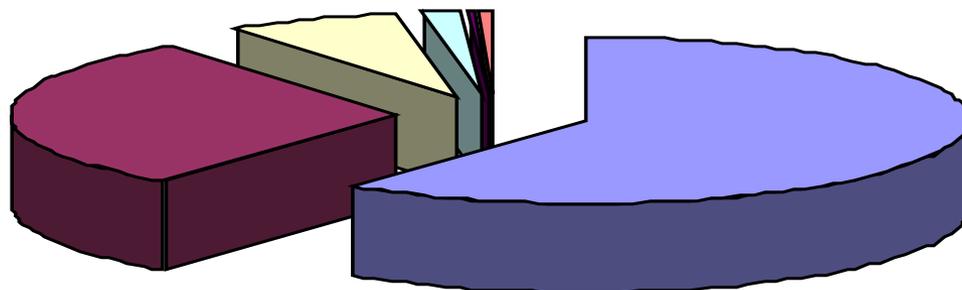
# Anatomy of Neurotransmitters: Emotion, Behavior, and Memory



# Neuropsychiatry of TBI...



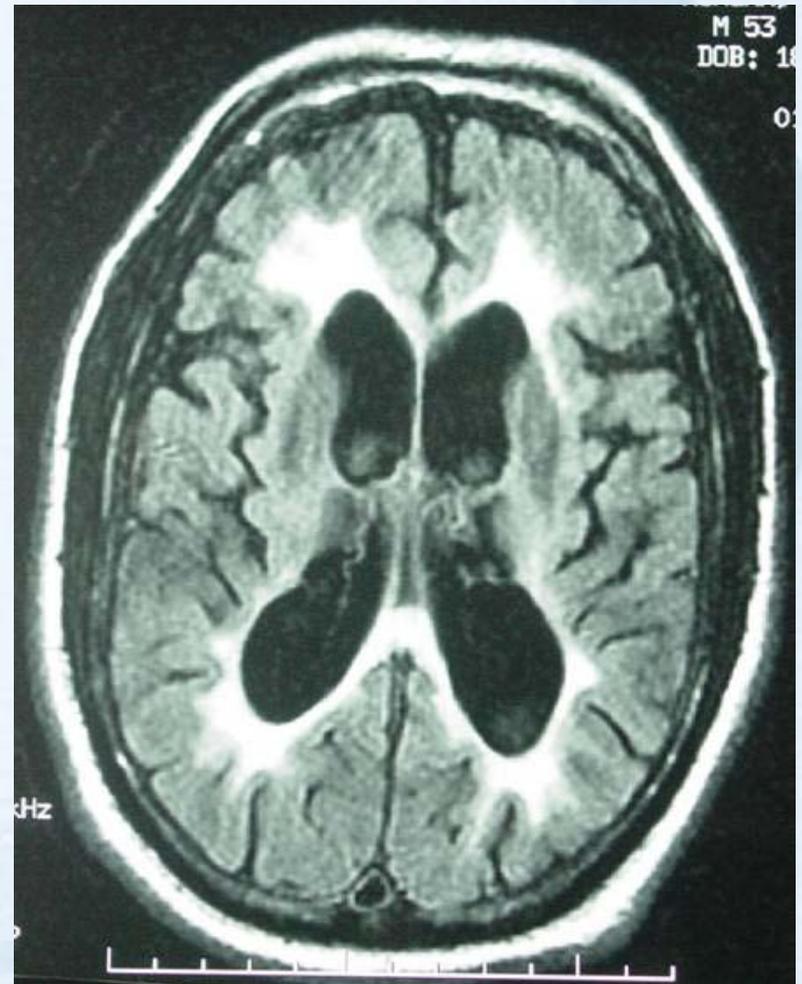
# Comparative Annual Incidence of TBI



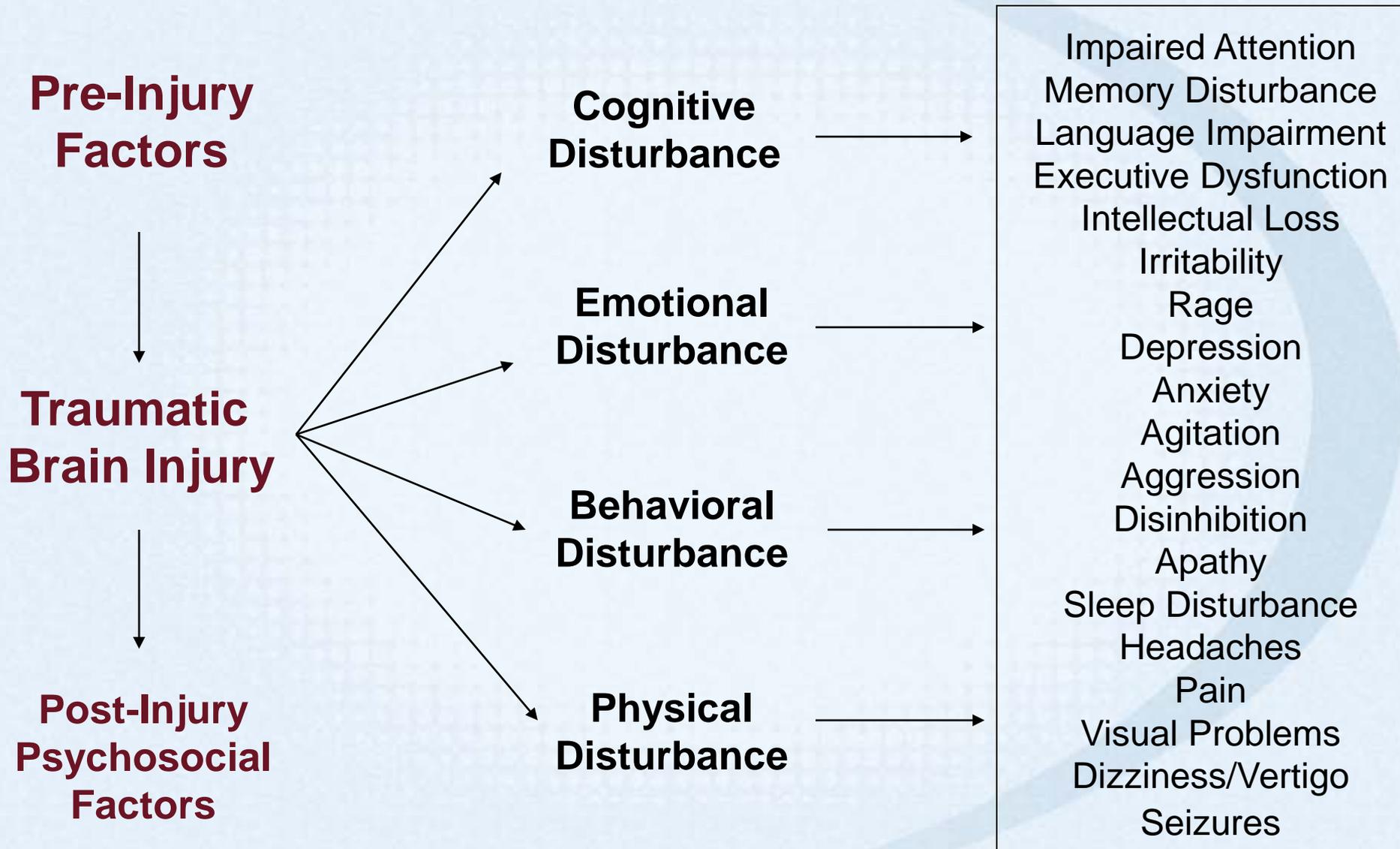
(Used with permission - David Arciniegas, MD, UCHSC; Based on data from the Centers for Disease Control and Prevention, American Cancer Society, American Heart Association, and National Multiple Sclerosis Society. TBI: traumatic brain injury; Brst CA: breast cancer; SCI: spinal cord injury; AIDS: acquired immune deficiency syndrome; MS: multiple sclerosis.)

# Why is TBI (mild) A “Silent” Problem?

- ▶ Multiple factors create the post-injury picture
- ▶ Traditional psychiatry:
  - Clinicians don't ask
  - Patients don't know to tell
- ▶ Brain anatomy and physiology poorly understood
- ▶ Diagnostics new, treatments limited



# Neuropsychiatric Sequelae of TBI



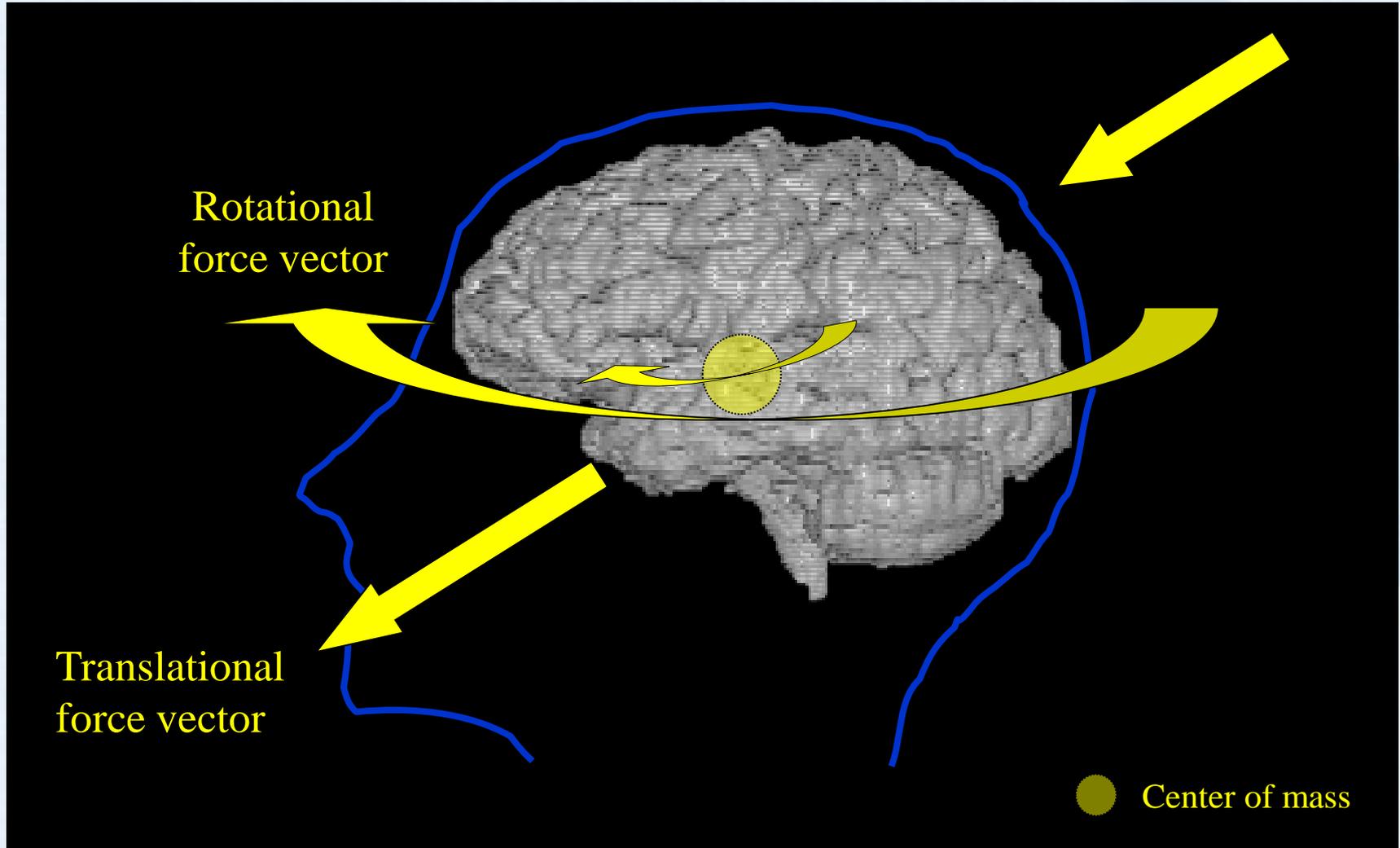
(adapted with permission - David Arciniegas, MD, UCHSC; Arciniegas, Topkoff, and Silver 2000; Silver 1994; McAllister 1994; McAllister 1992)

# Preinjury Factors

- ▶ Baseline cognitive function
- ▶ Psychiatric problems
- ▶ Sociopathy
- ▶ “Risk-taking” & “novelty-seeking” behavior
- ▶ Premorbid behavioral problems (children)
- ▶ Social circumstances
- ▶ Substance Abuse
- ▶ Neurogenetic (ie, APOE-4, COMT, ?other)
- ▶ Age

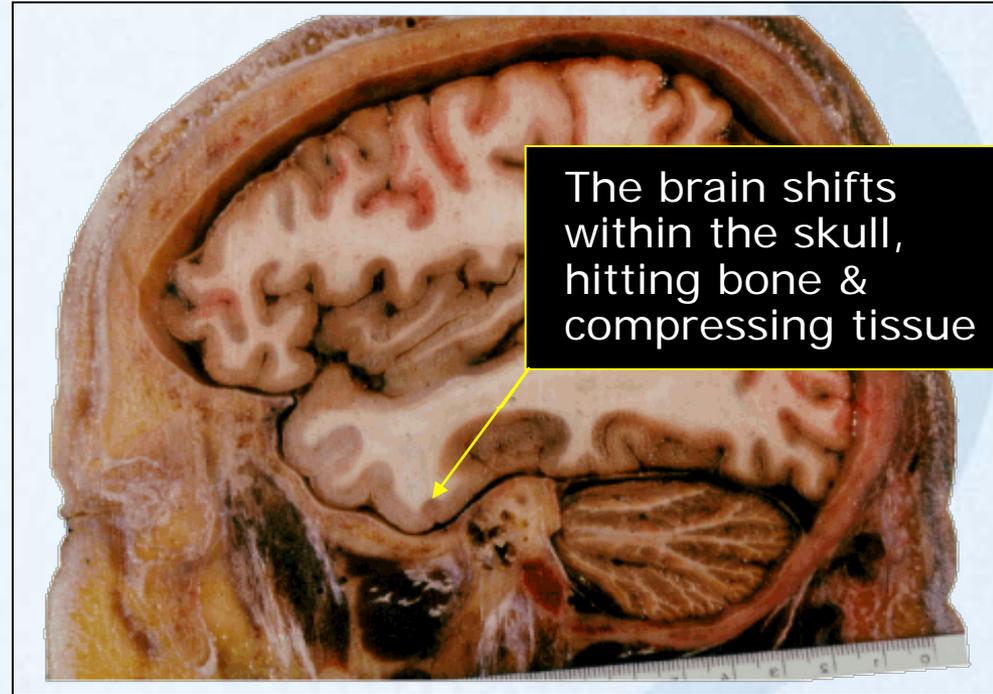
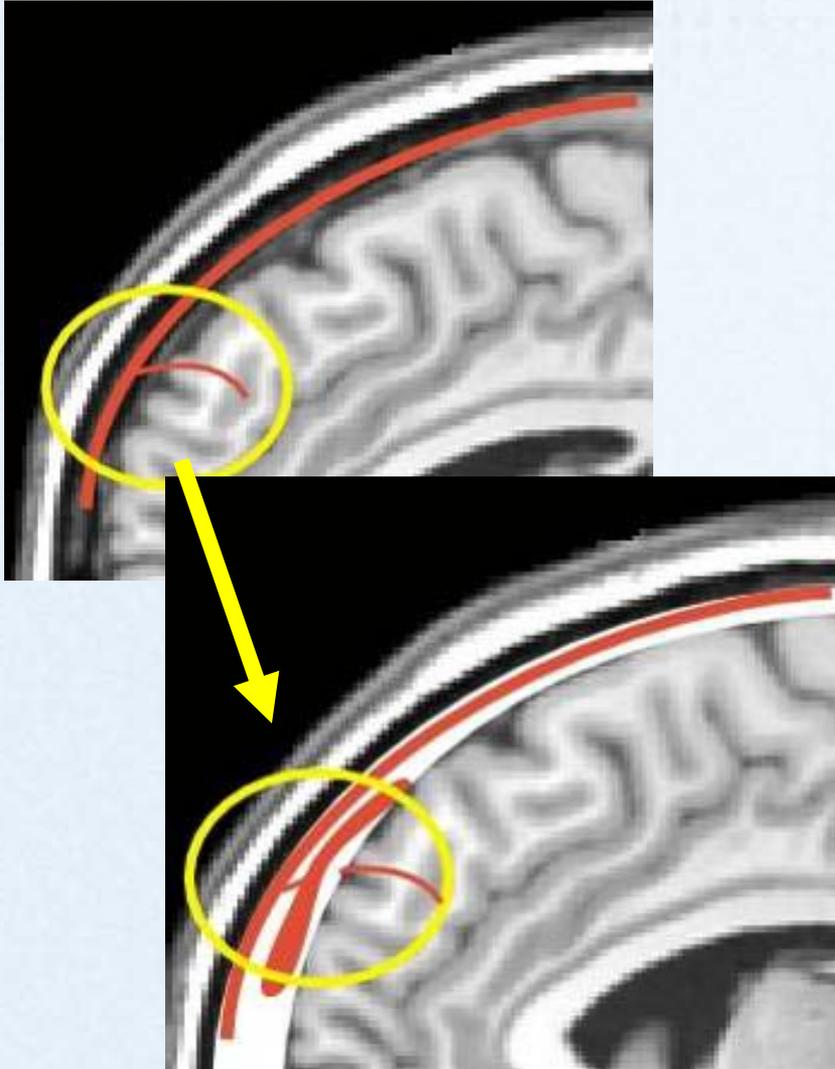


# Injury Factors: Translation, Rotation, & Angular Acceleration Forces



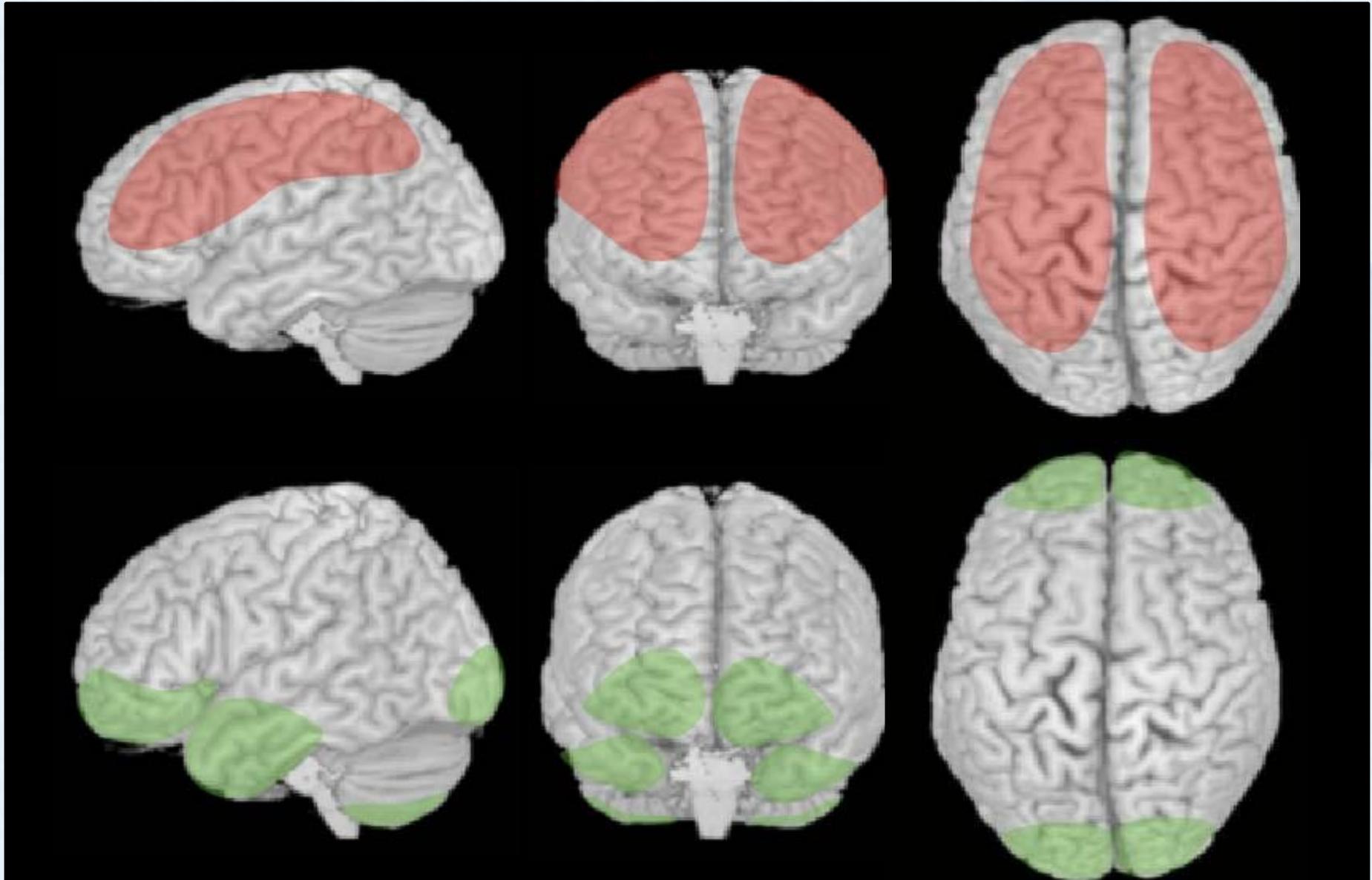
(Figure adapted from Arciniegas and Beresford 2001)

# Common Injuries: Subdural Hemorrhage and Contusions

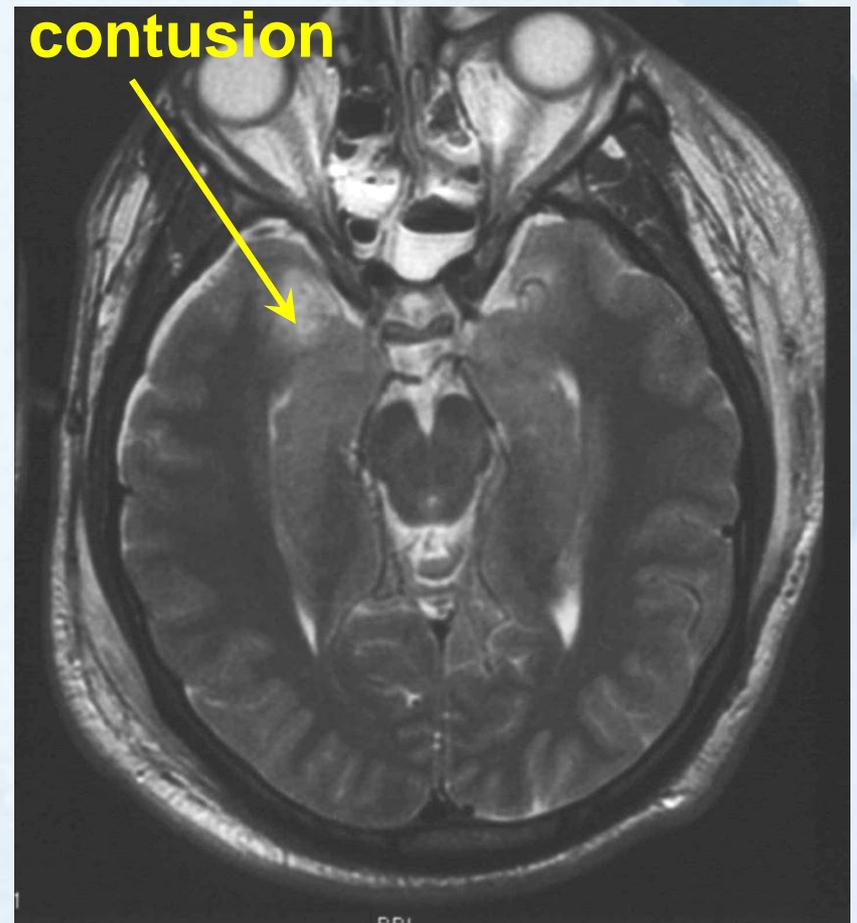


# Where Are The Injuries?

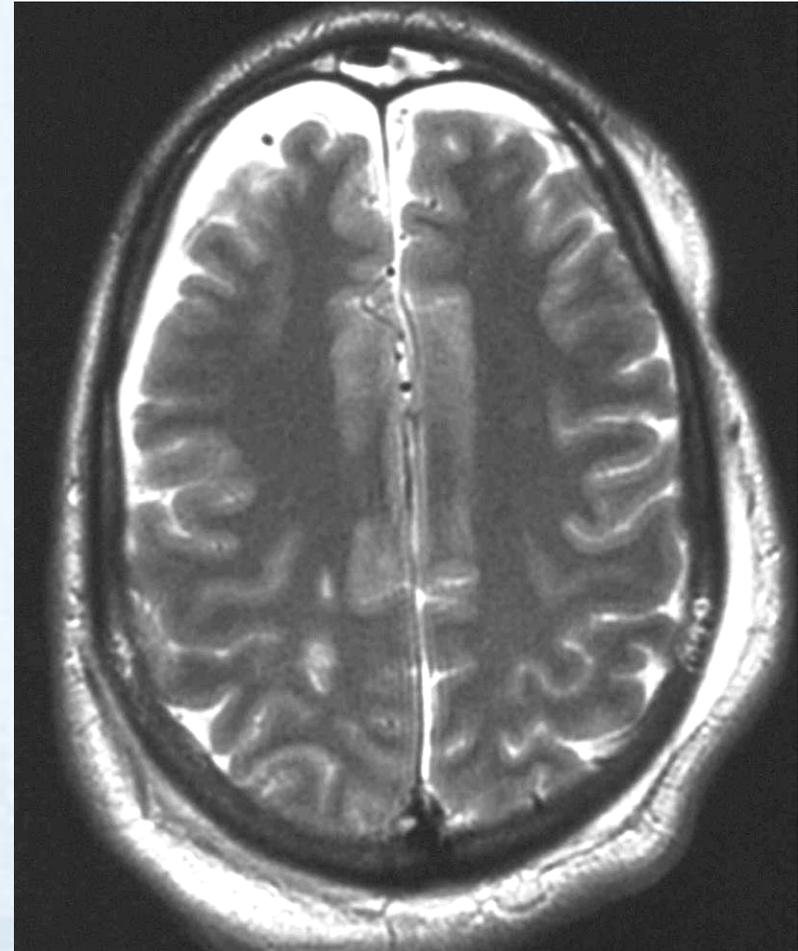
## Subdurals and Contusions



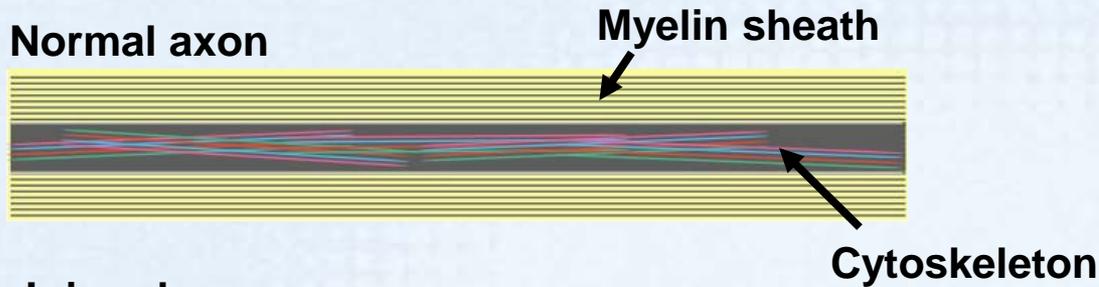
# What Are The Injuries?



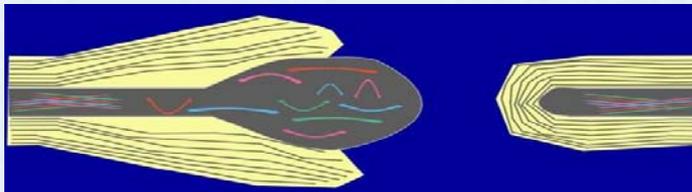
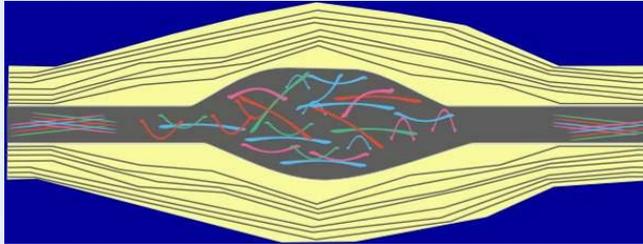
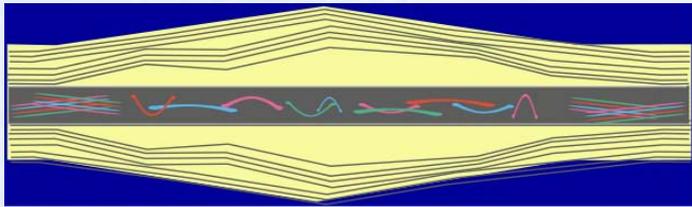
# Diffuse Axonal Injury (DAI)



# Diffuse Axonal Injury (DAI)



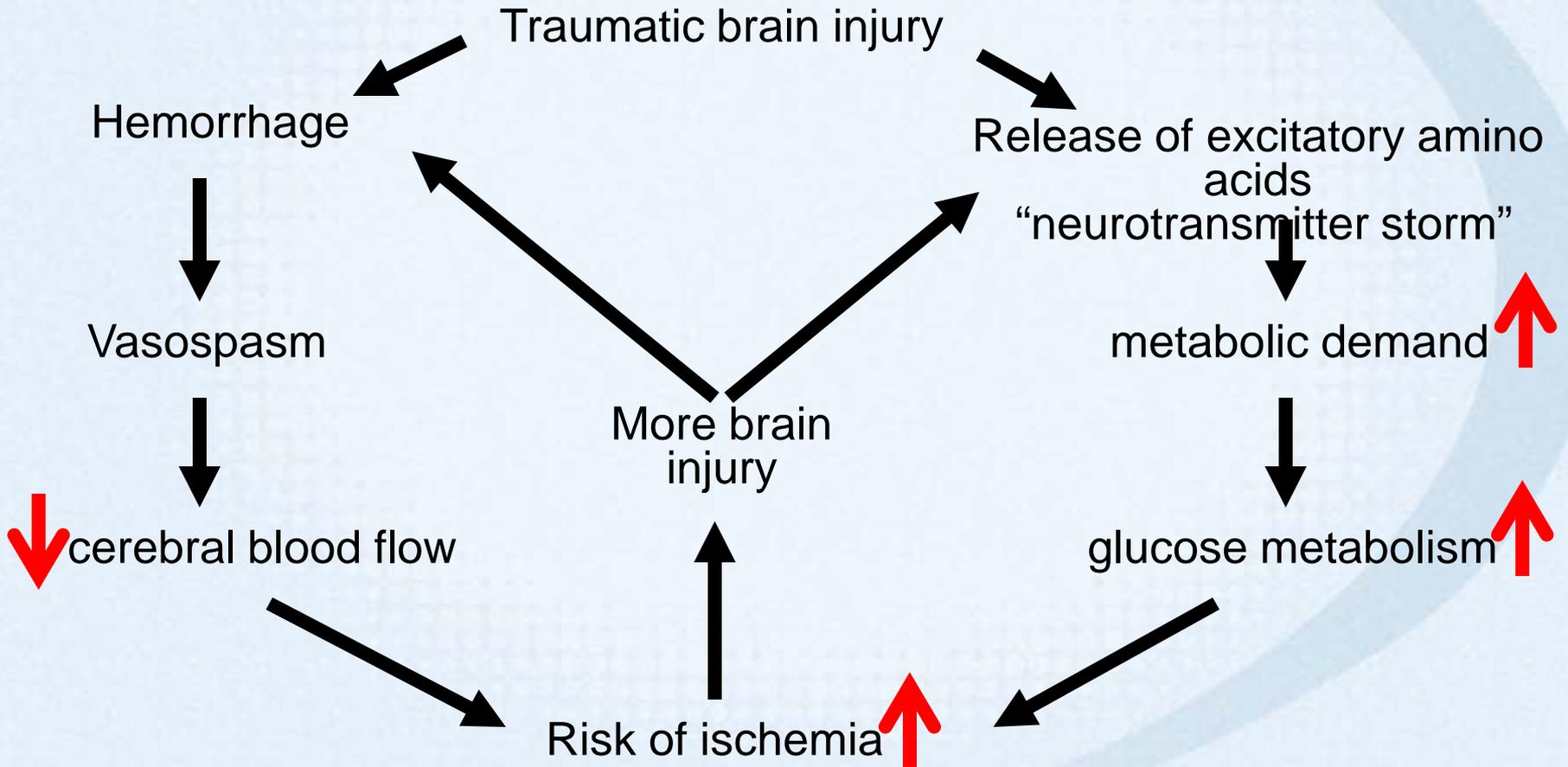
Injured axon



- Progressive slow injury
  - Axon is stretched
  - Increased permeability
  - Calcium influx
  - Damage to cytoskeleton
  - Impaired axoplasmic transport
  - Axonal swelling
  - Detachment and axonal death

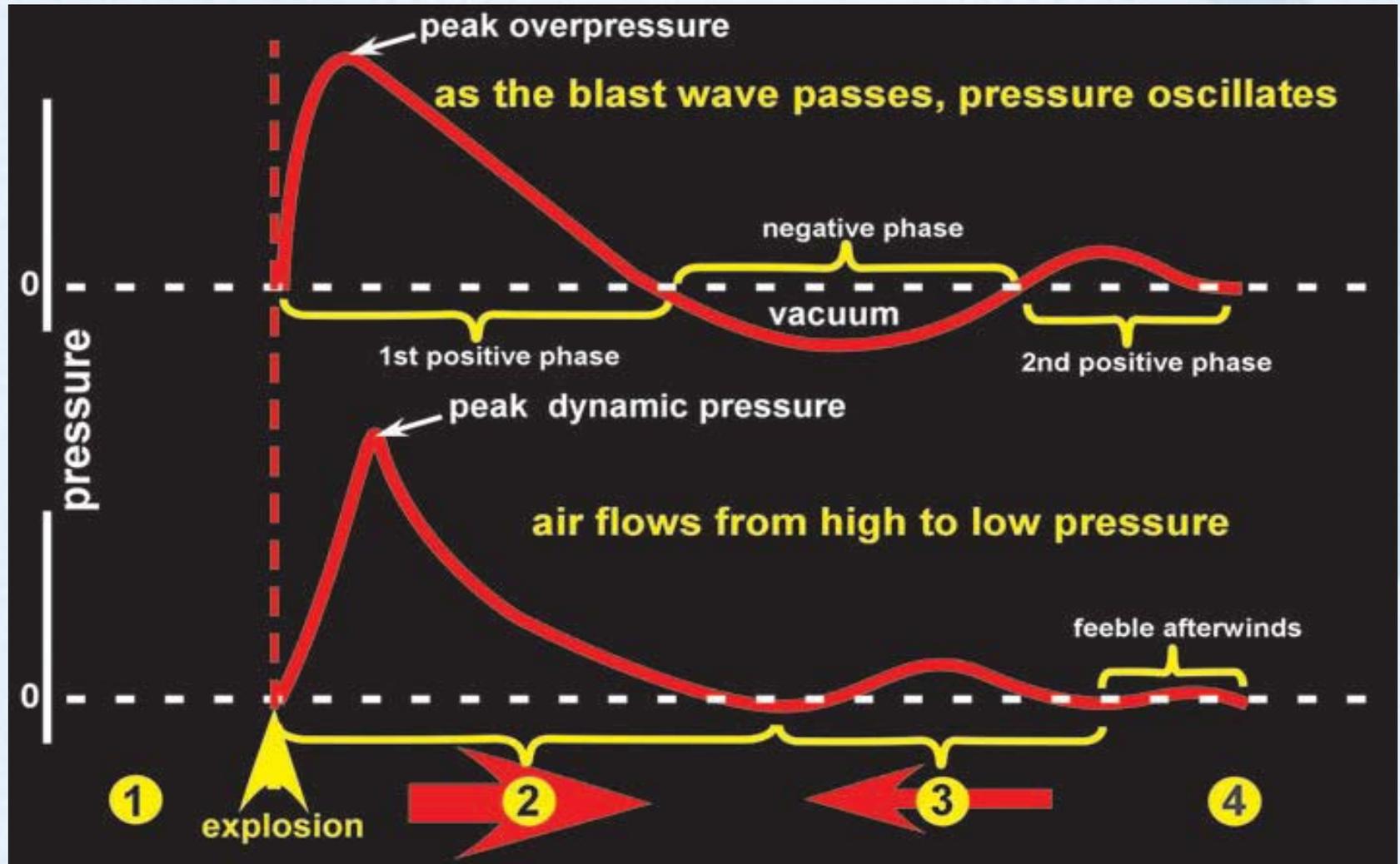
# What Are The Injuries?

## Evolution



(Figure adapted from Yi and Hazell, 2006)

# Blast Injuries: What Is Known?



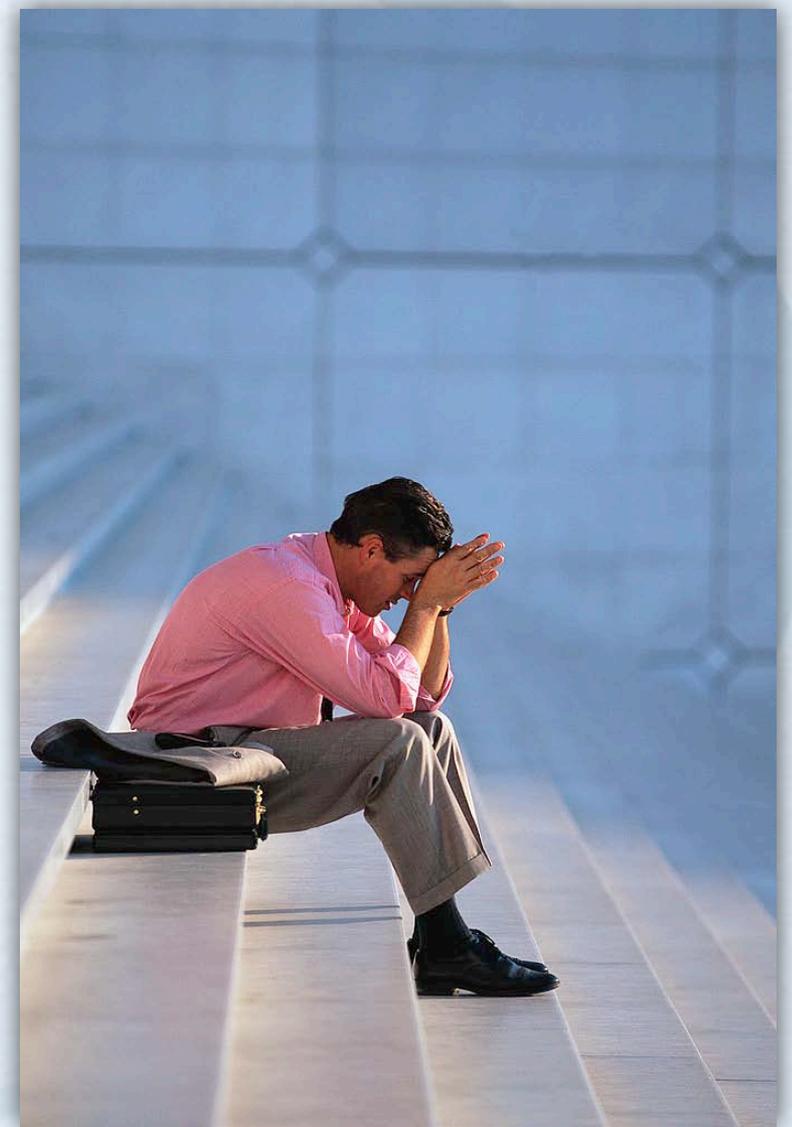
# Neuropsychiatry Post-TBI: What Do We See in Clinic?

- ▶ Impulsivity: common— reason family brings patient to MD
- ▶ Disinhibition: no “filter” on thoughts or actions (misses social cues)
- ▶ Poor control over primal urges
- ▶ Cognitive changes: can't hold concentration & focus
- ▶ Substance Abuse
- ▶ Physical Aggression



# Other MH Problems

- ▶ Personality change
- ▶ Cognitive impairment
- ▶ Depression/Mania
- ▶ Generalized anxiety/panic
- ▶ Post traumatic stress
- ▶ Substance abuse
- ▶ Psychosis
- ▶ Aggression
- ▶ Sleep impairments
- ▶ Affective liability



# Operations Iraqi Freedom/Enduring Freedom: Are There Brain Injuries?



- ▶ 88% IED/mortar attack- 47% about the head (Murray & Reynolds, 2005)
- ▶ 97% explosions (65% IED's, 32% mines)- 53% head or neck (Gondusky & Reiter, 2005)
- ▶ Walter Reed at-risk group, 59% had TBI (Okie, 2005)
- ▶ At least 20% of wounded had some degree of brain injury (Okie, 2005)

# Operations Iraqi Freedom/Enduring Freedom:

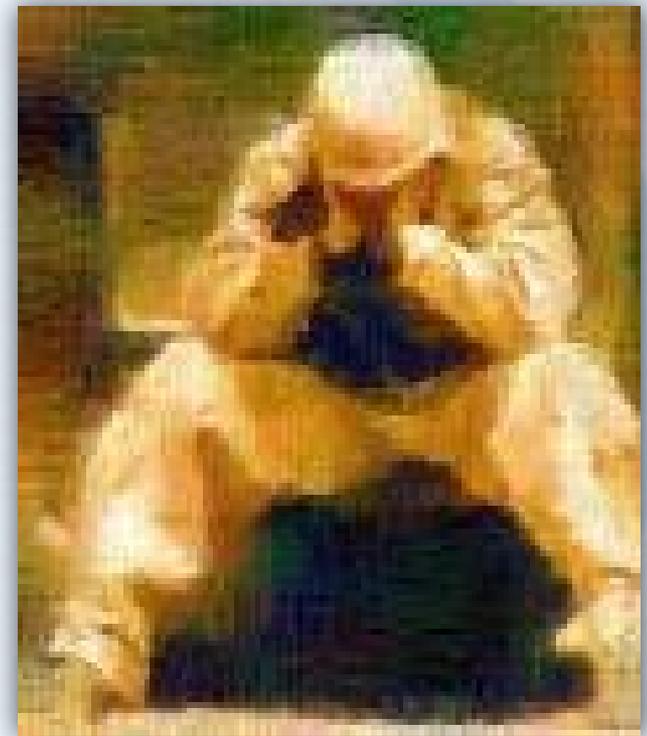
Most Prominent Mild TBI Symptoms – Some Clinics



- ▶ Balance/dizziness
- ▶ Headaches
- ▶ Visual changes (e.g. sensitivity to bright lights)
- ▶ Memory/cognitive deficits
- ▶ Irritability
- ▶ Sleep disturbances
- ▶ Ringing in ears/decreased hearing

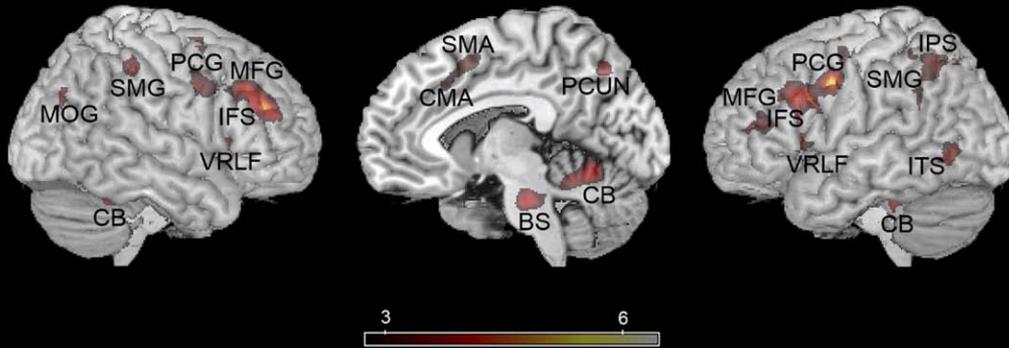
# OEF/OIF Rates of PTSD

- ▶ 19% by screening in US active duty military Hospital in Kuwait (2005); Felker, 2008.
- ▶ 11% by postal card survey of veterans (2005); Schneiderman, 2008.
- ▶ 8-15% post deployment survey; McLay, 2008
- ▶ 9% by post-deployment anonymous survey (2006); Hoge, 2008.
- ▶ 37.8% VA post-deployment clinic

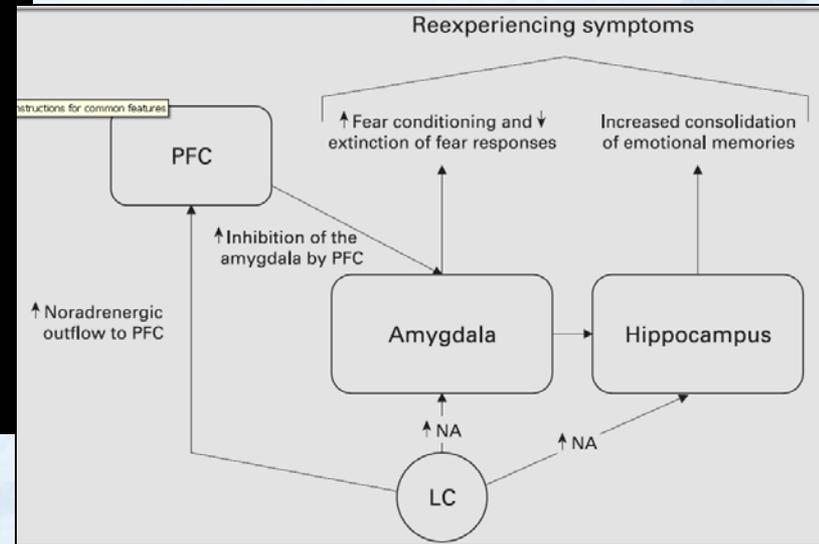
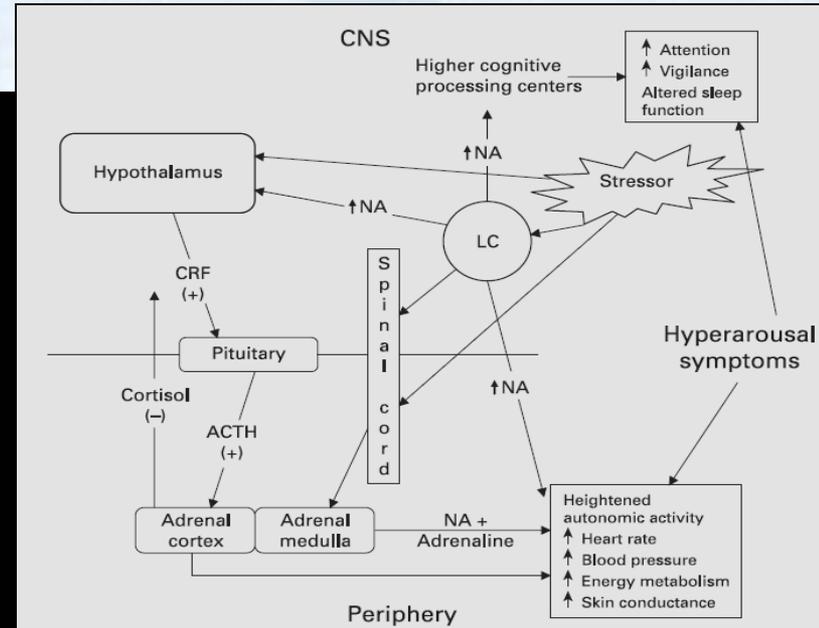
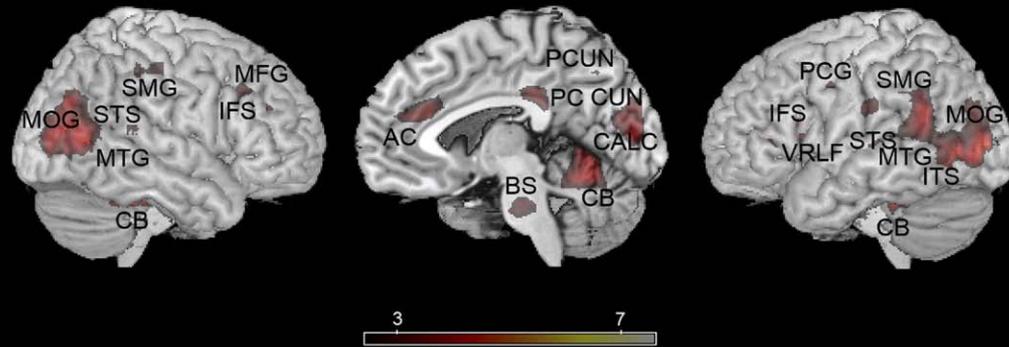


# PTSD

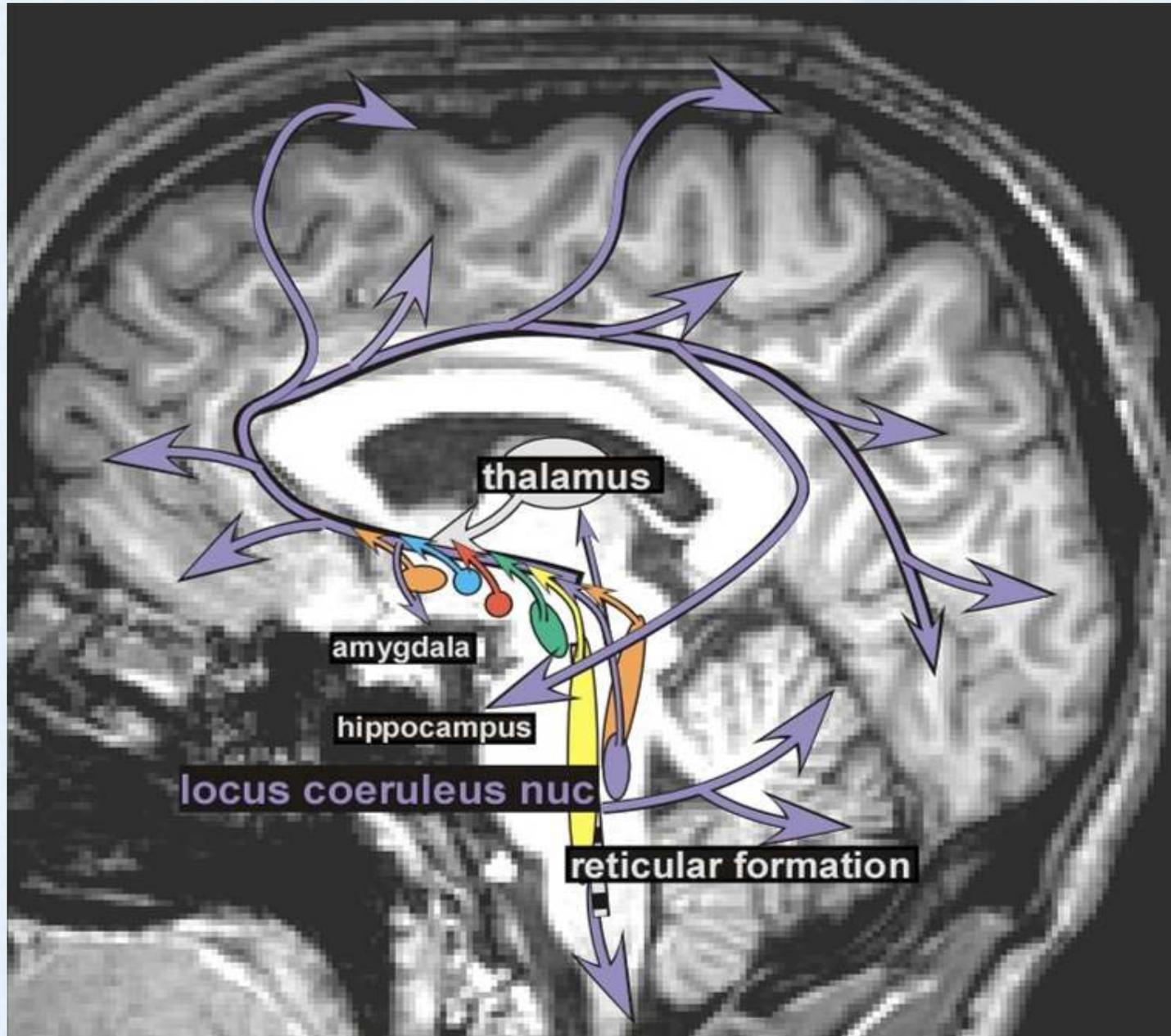
(A) Working Memory Updating (VT>FT): Controls



(B) Working Memory Updating (VT>FT): Controls > PTSD



# Noradrenergic Neurons



# TBI & PTSD - Military

## PTSD in OEF/OIF Veterans

**no TBI**

**level 1 mild TBI**  
altered mental status

**level 2 mild TBI**  
LOC, PTA or head injury

**~7%**

**~34%**

**~47%**

Schneiderman, Braver and Kang (2008) Am J Epidemiol 167:1446–1452

# PTSD and TBI: Common Symptoms



- ▶ Decreased concentration
- ▶ Agitation/irritability
- ▶ Insomnia
- ▶ Social isolation / detachment
- ▶ Impaired memory
- ▶ Affect and Mood disturbances

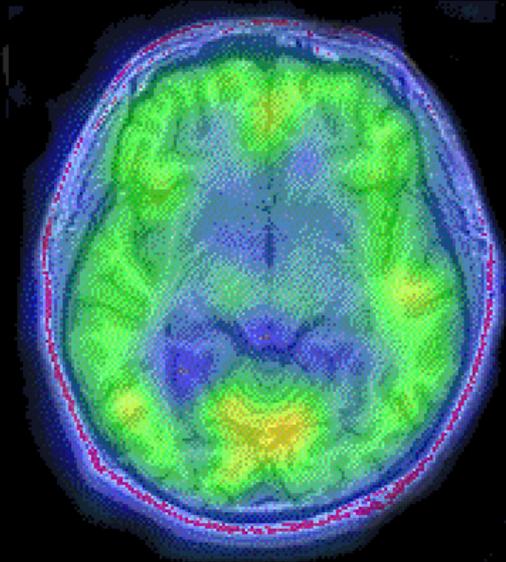
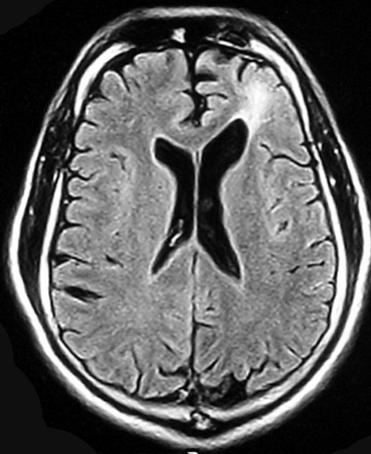
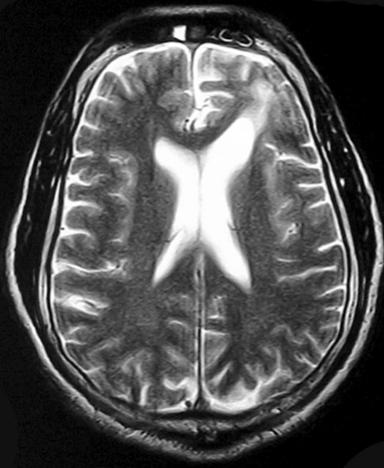
# Assessment



## Don't forget to ask:

- Seizures
- Verbal interactions
- Physical aggression
- Substance abuse
- Inappropriate actions
  - (dangerous behaviors, social actions)
- Cognitive function
- Eating, sexual activity, spending habits, etc...

# Diagnostic Imaging...



# Reasons to Image

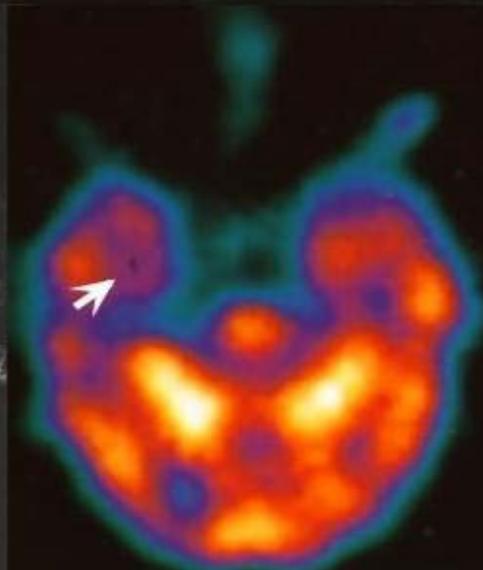
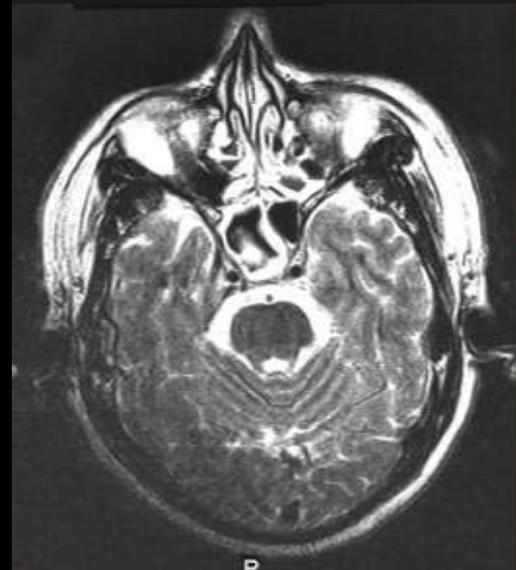
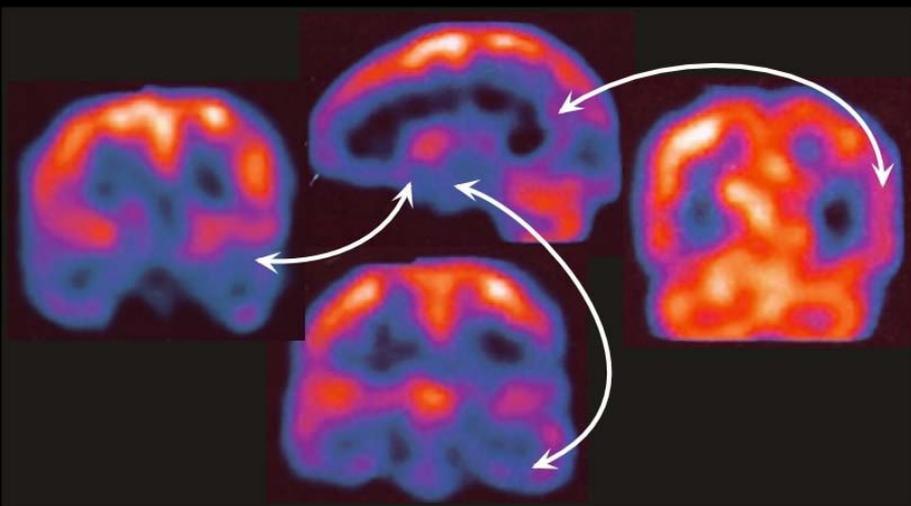
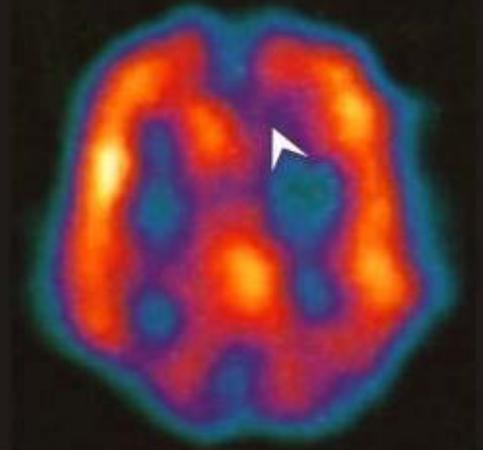
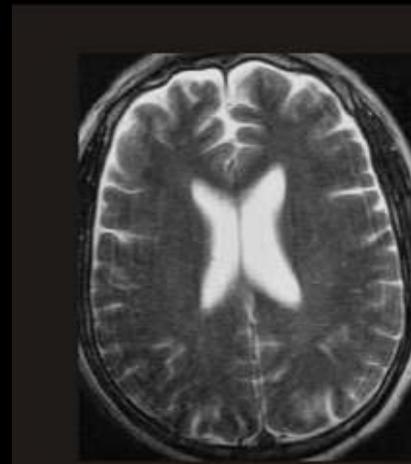
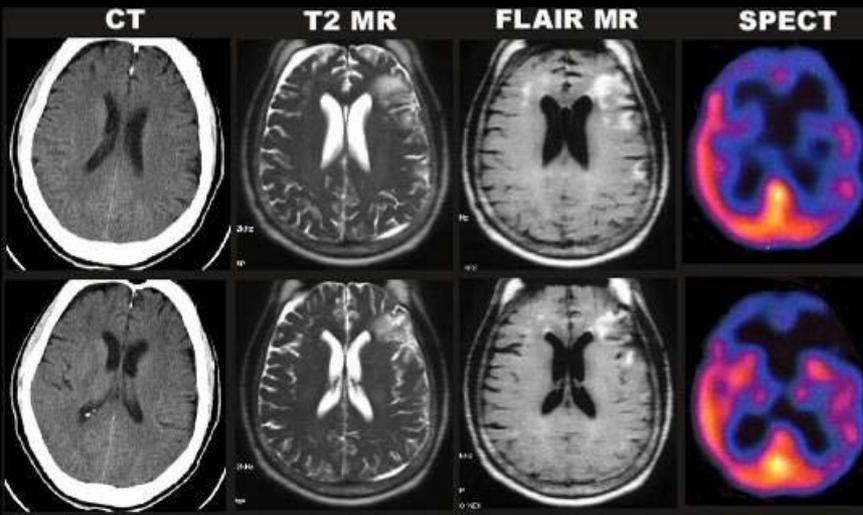
## Medical Conditions or Working Diagnoses

- ▶ Traumatic brain injury (i.e. sudden deceleration or blast injuries)
- ▶ Significant alcohol abuse
- ▶ Seizure disorders with psychiatric symptoms
- ▶ Movement disorders
- ▶ Autoimmune disorders
- ▶ Eating disorders
- ▶ Poison or toxin exposure
- ▶ Delirium

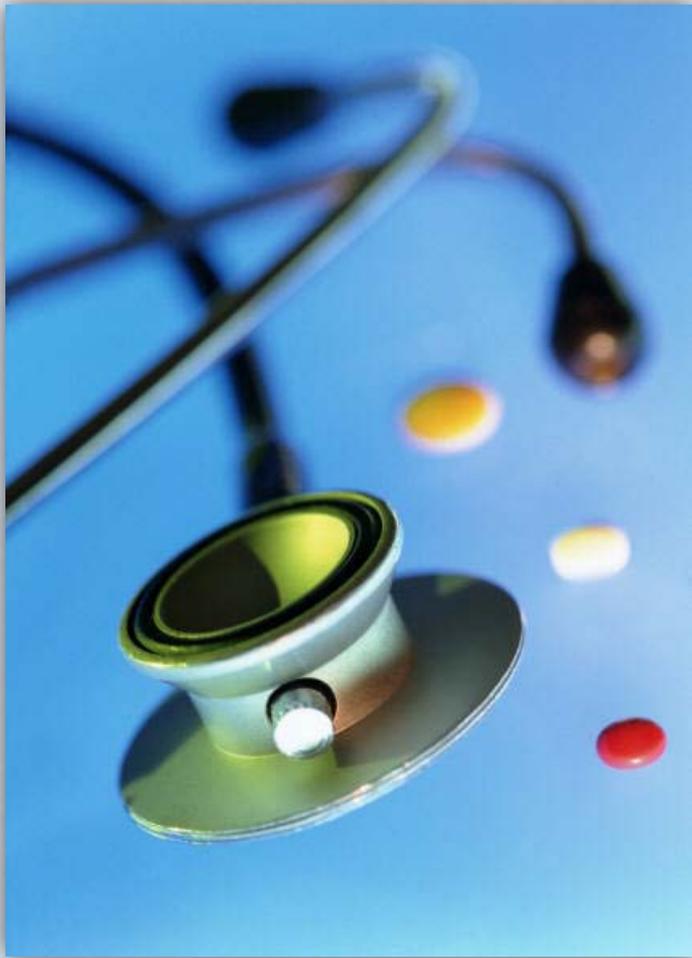
## Clinical Factors

- ▶ Psychiatric symptoms outside “clinical norms” or with any unusual presentation or course
- ▶ New onset mental illness after age 50
- ▶ Presentations at an atypical age for the working diagnosis
- ▶ Initial psychotic break with focal neurological signs
- ▶ Catatonia
- ▶ Dementia or cognitive decline
- ▶ Sudden personality changes

# Imaging of TBI



# Pharmacologic Treatment



- ▶ No large double-blinded placebo-controlled studies (case reports and open labeled studies)
- ▶ No FDA approved medications for chronic psychiatric symptoms due to TBI
- ▶ Medications used today are opinions of experts in field
- ▶ Patients more sensitive to side effects: **watch closely** for toxicity and drug-drug interactions

# TBI Medication Guidelines

- ▶ **“Rule-out” social factors first\*\*\*\***
  - Abuse, neglect, caregiver conflict, environmental issues
- ▶ No large quantities of lethal medications
  - Suicide rate high
- ▶ Full therapeutic trials: under treatment common
- ▶ Start low- Go slow!



# Discontinue Conflicting Agents

- ▶ Minimize benzodiazepines, anticholinergic, seizure-inducing or antidopaminergic agents
  - impairs cognition
  - increases sedation
  - impedes neuronal recovery
- ▶ No caffeine
  - agitation / insomnia
- ▶ No herbal, diet, “energy” products
  - mania, hypertensive crisis, aggression

# Medicine in TBI: 1st-Line Agents:



- **SSRI's:** depression; +/- cognition
- **Anticonvulsants:** mood stabilization and seizure prevention
- **Atypical Antipsychotics:** aggression, agitation, irritability (beta blockers for severe cases)
- **Dopamine agonists:** cognition, concentration, focus
- **Cholinesterase Inhibitors:** memory
- **Atypical agents:**
  - Buspirone – emotional stabilization
  - Modafinil – concentration, focus

# Therapy Programs

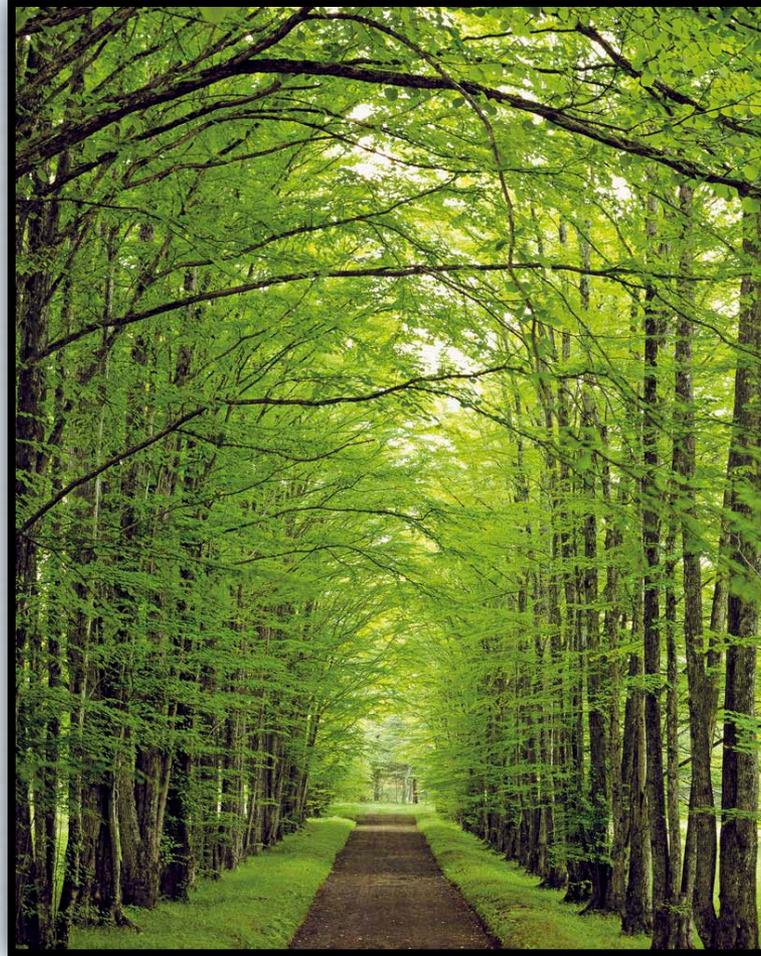
- ▶ Multidisciplinary rehabilitation program VA Polytrauma System of care: <http://www.polytrauma.va.gov>
- ▶ Initial Education + cognitive/behavioral therapies (includes video feedback, role play, skills retraining (Owensworth, 1998))
- ▶ Long term support
  - Group psychotherapy
    - Symptom focused: e.g., anger or substance abuse (Delmonico, 1998)
    - Process group
  - Family therapy (Kreutzer, 2002)
  - Social issues: financial, legal, vocational, education, transportation
- ▶ National/local support groups and programs

# Adjusting PTSD Rx for TBI

## Treatment programs for PTSD must be altered for patients with TBI

- Present information at slower pace
- Use structured intervention approach with agenda, outline, or handouts.
- For group: do not put “on the spot”; Allow to freely contribute or ask PTSD only to respond 1st; then ask dually dx to respond.
- Use refocus/redirection to topic or short sessions with breaks.
- Provide a clear transition between topics. Use agenda, outline, or handout.
- The therapist can frustrate the mTBI patient in trying to fully recall an event that was only partially encoded.

# 2009-10: The Journey Ahead...



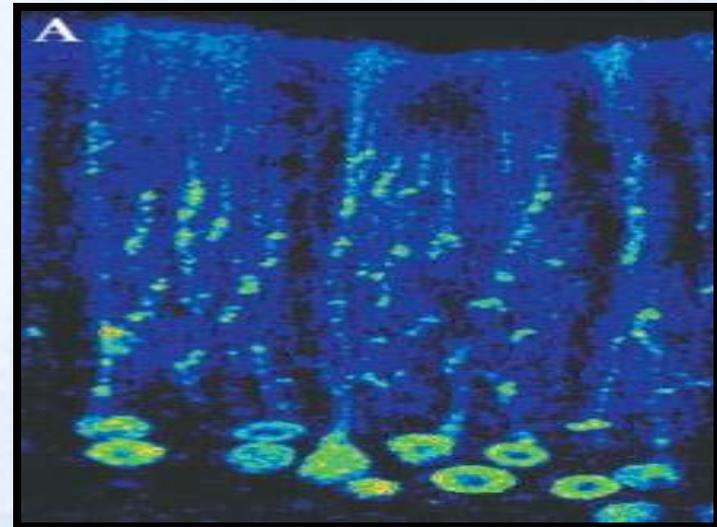
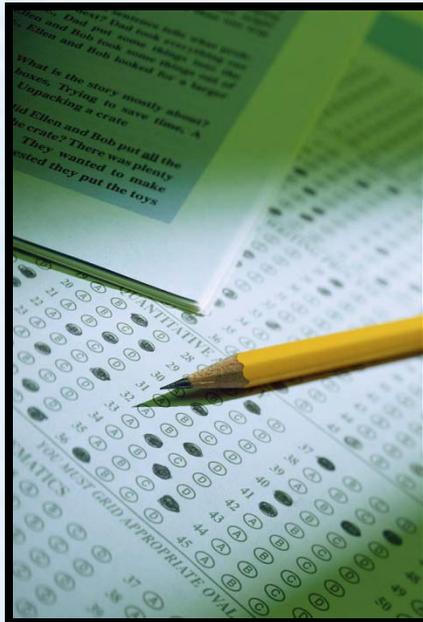
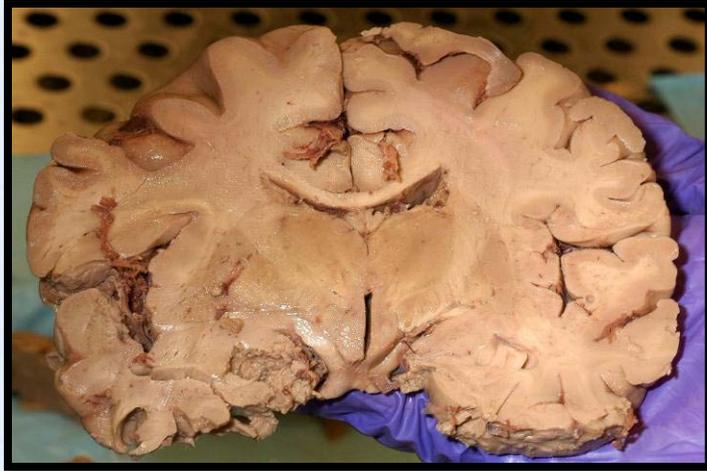
**What should we do?**



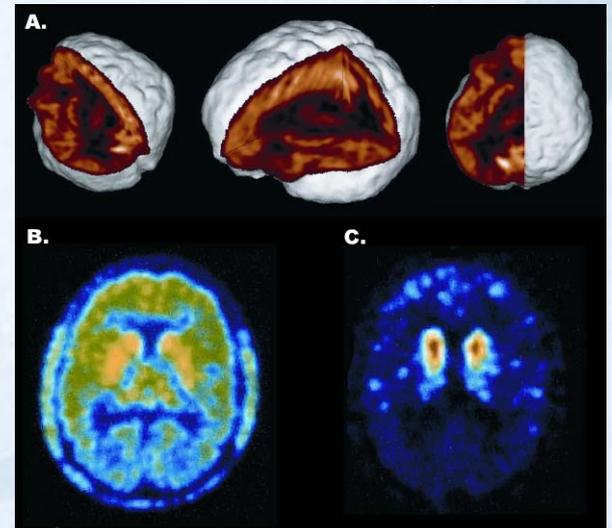
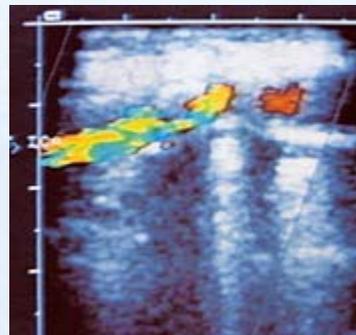
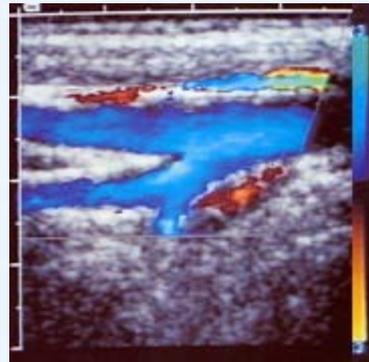
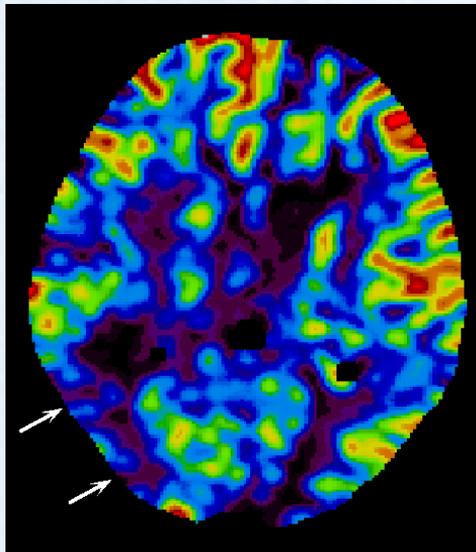
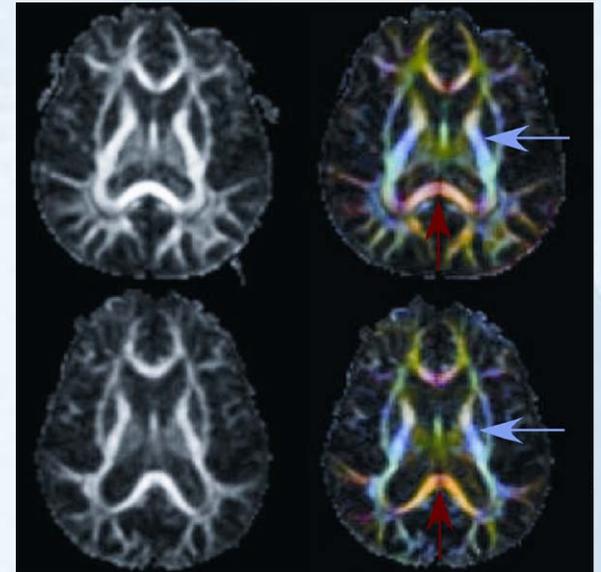
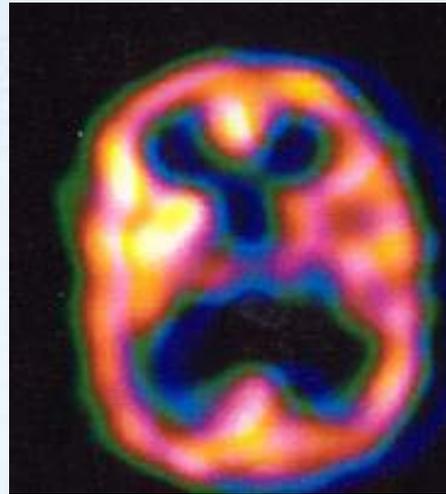
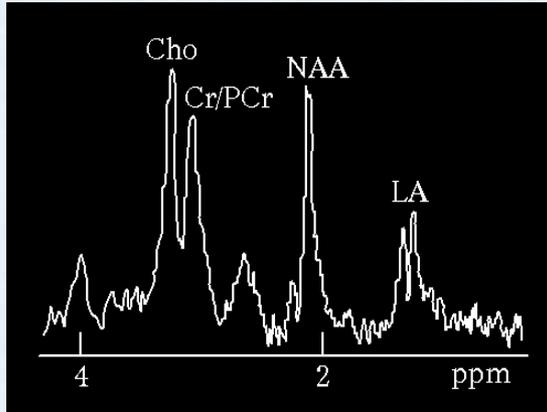
## What We Don't Know...

- Is combat-related injury similar to or different from civilian TBI?
- When are the deficits permanent?
- Can we use the sports-related TBI literature as a guide?
- Is there change in judgment/skill after mild combat-related TBI? If so, for how long?
- What are the best assessment strategies/tools for the immediate and long-term evaluation?
- What are the best acute and longer term treatment protocols?
- What is the prognosis?

# Biological Studies: Understand Injury Patterns



# Newer Imaging Techniques



# Potential New Therapies?



- ▶ Repetitive Transcranial Magnet Stimulation (rTMS)
- ▶ Newer medications
  - anticonvulsants
  - atypical antipsychotics
  - SSRIs
- ▶ Vagal Nerve Stimulation (VNS)



# VISN 6 Mid-Atlantic MIRECC Post Deployment Mental Health



VISN 6 > Education - MIRECC Centers - Windows Internet Explorer  
 http://www.mirecc.va.gov/visn6/education.asp

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VISN 6 > Education - MIRECC Centers

**Education**  
**Clinical**  
**Directions**  
**Directory**  
**Participate in Studies**  
**Site Search**

 **VISN 6**  
*Post Deployment Mental Health*

**The goal of the Education component is to develop educational materials and experiences that positively impact the mental health of OEF/OIF veterans.**

Target audiences for our projects include veterans, families and friends, clergy, community members, health care trainees, and health care providers (VA and non-VA) both within VISN 6 and nationally. Methods of delivery include live presentations, print materials, recordings, and the web. An important aspect of our role is translation of challenging research concepts for multiple audiences in order to bridge the gap between research and clinical care.

Jump to: [Newsletters](#) [TBI Education](#) [Readjustment - Veteran Provider](#) [Readjustment - Clergy](#) [Teaching Tools & Tips](#)

**BI-Monthly Newsletter** - We publish an electronic newsletter every other month to inform all of our target audiences about what we are doing.

[Most recent in color](#) [Most recent in grayscale](#) [View all](#)

**Traumatic Brain Injury (TBI)** - TBI is an area of particular emphasis for us. Prompt identification and appropriate treatment of this condition in combat veterans is the goal.

[Veteran/Family handout](#) [Provider handout](#) [View all](#)

**Readjustment Issues** - Members of the military are deeply affected by their war experiences. Adjustment difficulties are common. These are normal reactions to abnormal experiences. These materials cover some of the issues that are common following deployment.

[Veteran/Family](#) [Provider](#) [Clergy](#)

VISN 6 > Education > Teaching Tools & Tips - MIRECC Centers - Windows Internet Explorer  
 http://www.mirecc.va.gov/visn6/Tools-Tips.asp

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**Teaching Cases**

Applying classroom-derived knowledge of functional anatomy to clinical practice is quite challenging for most learners. Educational research strongly supports the use of guided experiences - in which an expert explicitly draws the learner's attention to key connections - to promote the creation of active (useable) knowledge. This approach helps the learner establish connections between functional neuroanatomy and clinical practice, deepens their interest in the individual aspects of each patient, and enhances their appreciation of pathology and prognosis.

**Case 1:**  
[Amnestic Disorder and Depression due to Cerebral Aneurysm and TBI](#)

**Color Atlases - Sectional Anatomy of the Brain**

- [Axial](#) - Divisions, structures, vascular territories
- [Axial](#) - White matter tracts
- [Coronal](#) - White matter tracts

**Webcast Lectures**

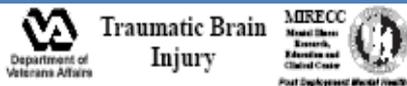
[Medical Informatics 1: Information Design Theory & Practice](#) - Katherine H. Taber, PhD

This website is for educational purposes only. If you are looking for professional medical care, find your local VA healthcare center by using the VA Facilities Locator & Directory.

The VA has founded a national suicide prevention hotline to ensure veterans in emotional crisis have free, 24/7 access to trained counselors. Veterans can call the Lifeline number, 1-800-273-

[WWW.MIRECC.VA.GOV/VISN6/](http://WWW.MIRECC.VA.GOV/VISN6/)

# TBI “Pocket Cards” Patient and Provider



If the head is hit or shaken it can disrupt normal brain function and cause a “concussion” or a “closed head injury”. Such injuries are called “mild” if the person is dazed or confused or loses consciousness for only a short time. Doctors use the term “mild” because concussion is seldom life threatening. However, concussion can result in serious symptoms.

## Common Symptoms of Brain Injury

- ★ “I just don’t feel like myself”
- ★ Problems with memory, attention, or concentration
- ★ Difficulty organizing daily tasks
- ★ Impaired decision making or problem solving - impulsive
- ★ Slowed thinking, moving, speaking or reading
- ★ Easily confused, feeling easily overwhelmed
- ★ Feeling tired all the time
- ★ Change in sleep - much more or much less
- ★ Feeling light-headed or dizzy
- ★ More sensitive to sounds, lights or distractions
- ★ Blurred vision or eyes tire easily
- ★ Headaches or ringing in the ears
- ★ Feeling sad, anxious or listless
- ★ Easily irritated or angered
- ★ Change in sexual interest or behavior

A person with a brain injury is not always aware of their symptoms. They may say that they are “fine” although their behavior or personality has changed. If you notice that your family member or friend has some of these symptoms, and they are getting worse or are not getting better, talk to them about getting help.

## Recovery Following Brain Injury

Some symptoms may be present immediately. Others may appear much later. People experience brain injuries differently. Speed of recovery varies from person to person. Most people with mild injuries recover fully, but it can take time. In general, recovery is slower in older persons. People who have had a previous brain injury may find that it takes longer to recover from their current injury. Some symptoms can last for days, weeks, or longer.

Talk to your health care provider about any distressing symptoms or problems.

## To Promote Healing & Symptom Management

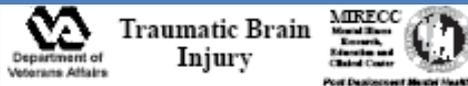
### Things That Can Help

- ★ Get plenty of rest & sleep
- ★ Increase activity slowly
- ★ Carry a notebook and write things down if you have trouble remembering
- ★ Establish a regular daily routine to structure activities
- ★ Do only one thing at a time if you are easily distracted & turn off the TV or radio
- ★ Check with someone you trust when making decisions

### Things That Can Hurt

- ★ Avoid activities that could lead to another brain injury - examples include contact sports, motorcycles, skiing
- ★ Avoid alcohol as it may slow healing of the injury
- ★ Avoid caffeine or “energy-enhancing” products as they may increase symptoms
- ★ Avoid pseudoephedrine-containing products as they may increase symptoms - check the labels on cough, cold, and allergy medicines
- ★ Avoid excessive use of over-the-counter sleeping agents as they can slow thinking and memory

**Resources for More Information & Help:**  
 Centers for Disease Control <http://www.cdc.gov/hcp/tbi>  
 Defense & Veterans Brain Injury Center <http://www.dvbic.org>  
 Brain Injury Association <http://www.biausa.org>



The most common causes of traumatic brain injury (TBI) are falls, motor vehicle accidents, assaults/blows and explosive blasts (active duty military). Severity ranges from “mild” - in which there is a brief change in mental state or consciousness, to “severe” - in which there is an extended period of unconsciousness or amnesia after the injury. Although not life threatening, the long term effects of even a “mild” TBI can be serious.

ICD-9 code 850.0 Concussion without LOC  
 ICD-9 code 850.1 Concussion with LOC up to 1 hour

## Common Symptoms Immediately After Injury

- ★ Being dazed, confused, or “seeing stars”
- ★ Not remembering the injury
- ★ Losing consciousness (knocked out)

All brain injuries are different and so is recovery. Most people with mild injuries recover fully, but it can take time. Some symptoms can last for days, weeks, or longer.

## Common Symptoms Later On

### Motor & Sensory Symptoms

- ★ Headaches
- ★ Fatigue
- ★ Sleep disturbances
- ★ Dizziness
- ★ Seizures
- ★ Hydrocephalus
- ★ Pain
- ★ Spasticity
- ★ Sensory deficits - Visual, Vestibular, Strength & Coordination

### Cognitive & Emotional Symptoms

- ★ Irritability
- ★ Impaired judgement
- ★ Personality change
- ★ Lability
- ★ Slower thinking
- ★ Substance abuse
- ★ Disinhibition
- ★ Physical aggression
- ★ Depression
- ★ Decreased concentration & focus
- ★ Poor control over basic physical urges
- ★ Impulsive/disruptive behavior
- ★ No “filter” on thoughts or actions

Mild TBI, commonly known as concussion, is one of the most common neurologic disorders.

Early mild TBI symptoms may appear subtle, but they can lead to significant, life-long impairment in an individual’s ability to function physically, cognitively, and emotionally.

## Medical Evaluation

- ★ Evaluate and treat patients who present early for somatic complaints and document baseline neurological findings, including cognitive and emotional state
- ★ Assess the ability of the patient to return to everyday activities, such as sports, work, or operating motor vehicles

## Treatment/Clinical Management

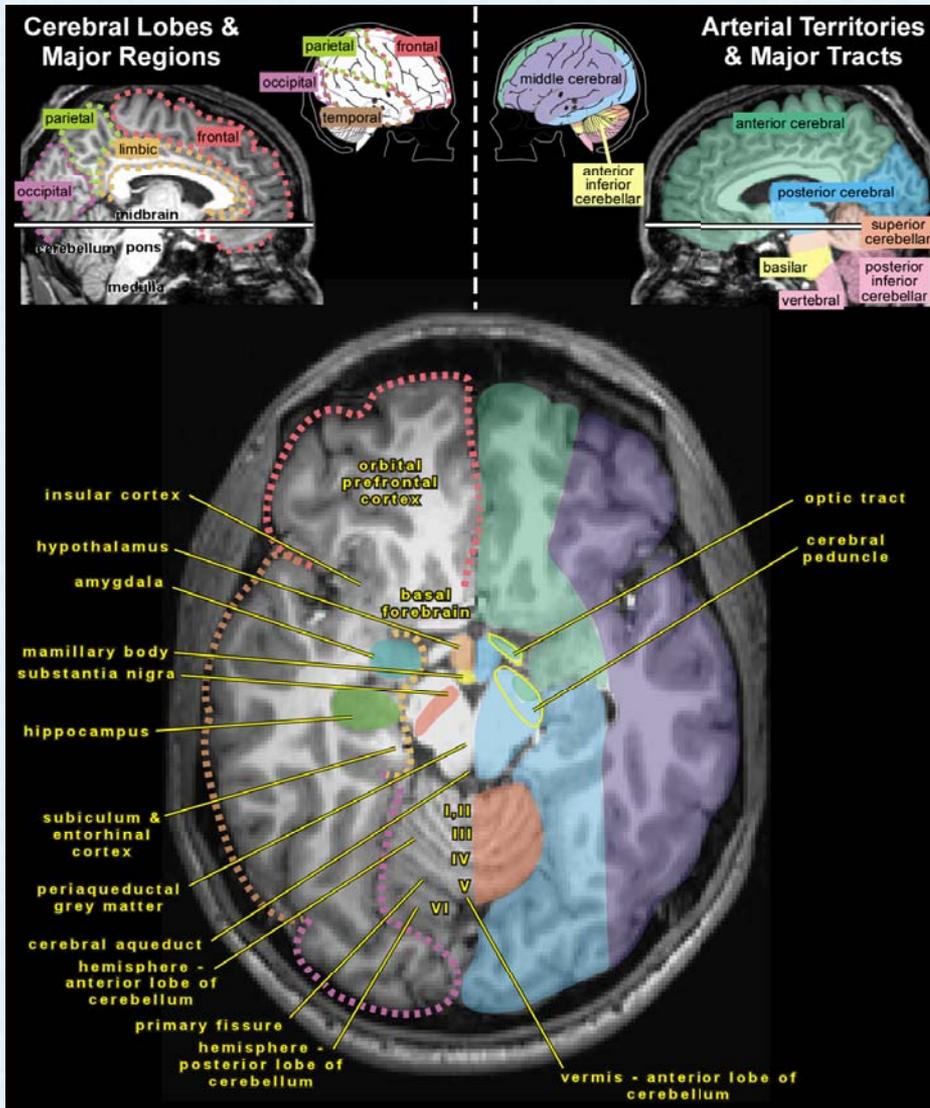
- ★ Educate patients and their families about the treatment plan, expected outcomes, and the importance of avoiding substances that can worsen symptoms such as alcohol, caffeine, diet and energy supplements, and some cold medications
- ★ Prescribe medication, as appropriate, for significant anxiety or depression - these patients are more vulnerable to side effects, so “start low and go slow”
- ★ Avoid medications that can impair cognition, cause over-sedation, or diminish neuronal recovery such as benzodiazepines, anticholinergic and antidopaminergic agents

Physicians can improve patient outcomes when mild TBI is suspected or diagnosed by implementing early treatment. Refer patients, as appropriate, when physical, emotional or cognitive symptoms interfere with normal routines and relationships.

## Resources:

Heads Up: Brain Injury in Your Practice Tool Kit  
[http://www.odc.gov/hcp/pub-wa/ta\\_toolkitbooklet.htm](http://www.odc.gov/hcp/pub-wa/ta_toolkitbooklet.htm)  
 Defense and Veterans Brain Injury Center  
<http://www.dvbic.org/trae.php?pe=Education>  
 Traumatic Brain Injury: A CME Program  
[http://www1.va.gov/medica/TBIfinal\\_web.pdf](http://www1.va.gov/medica/TBIfinal_web.pdf)

# Enduring Educational Materials: brings the anatomy of injury into focus



**WINDOWS TO THE BRAIN**  
Robin A. Hurley, M.D., L. Anne Hayman, M.D., Katherine H. Taber, Ph.D., Section Editors

**Blast-Related Traumatic Brain Injury: What Do We Know?**  
Katherine H. Taber, Ph.D., Deborah L. Warden, M.D., and Robin A. Hurley, M.D.

**Core:** Common types and locations of traumatic brain injury are illustrated on various days, right; middle, and left (right); magnetic resonance images of a young adult with neurophysiologic imaging following a nonlethal blast exposure (see Figure 2 for the color coding).

**Figure 1:** The sequence of changes in microvascular pressure following an explosion is shown by the light blue curve. Due to the explosion, (1) pressure is raised. With the passage of the shock wave (2), the blood vessels are compressed and the fluid flows away from the explosion (3, inset). This is followed by a drop in microvascular pressure to below normal (4), resulting in the increased blood flow (5, inset). Although microvascular pressure is raised after the blast wave subsides (6), it does not return to normal until the vessel walls have healed.

**Figure 2:** The most common types of neuroanatomical traumatic brain injury are diffuse axonal injury, contusions, and subdural hematomas. The acute contusion location for diffuse axonal injury (white) are the subcortical white matter (white matter), insular (parietal/occipital/occipital), uncus, amygdala, deep gray matter, septal nucleus, and septal nucleus. The acute contusion location for subdural hematoma (blue) are the superior/convex surface of the inferior, lateral and anterior regions of the frontal and temporal lobes, with the occipital pole in children. The acute contusion location for subarachnoid hemorrhage (red) are the frontal and parietal convexities.

**Functional Neuroanatomical Atlas of TBI: Application to Blast-Related Brain Injury**  
K. H. Taber, D. L. Warden, and R. A. Hurley

Department of Veterans Affairs

**Introduction**

With the increasing use of improved explosive devices (IEDs) in combat and theater settings, exposure to blast is becoming more frequent. Blast-related injuries are complex and multifactorial in nature, and the precise mechanisms of injury are still unclear. This atlas provides a comprehensive overview of the pathophysiology of blast-related brain injury, including the effects of blast waves, pressure changes, and the resulting damage to brain tissue and structures. The atlas is organized into sections that describe the types of injuries, the underlying mechanisms, and the clinical implications of these injuries. The atlas is intended to serve as a reference for clinicians, researchers, and students in the field of traumatic brain injury.

**Atlas of Traumatic Brain Injury**

**Subdural Hemorrhage (SDH)**

**Contusion**

**Diffuse Axonal Injury (DAI)**

**Subarachnoid Hemorrhage (SAH)**

**Clinical Example**

**Neuroimaging of Traumatic Brain Injury: Promising Methods**

**Positron Emission Tomography (PET) & SPECT**

**Diffusion Tensor Imaging (DTI)**



**Together we can make a difference!**

**Thank you!**