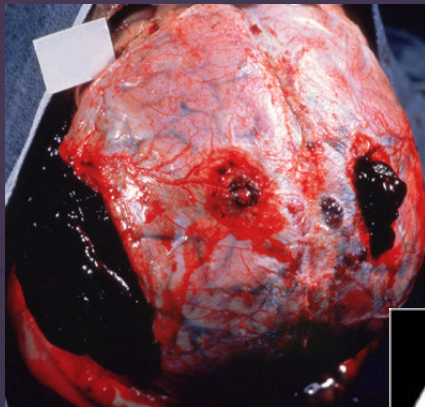
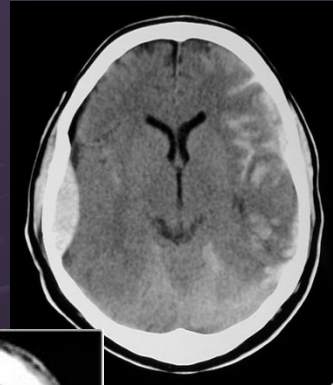


Extracranial Consequences of Intracranial Injury

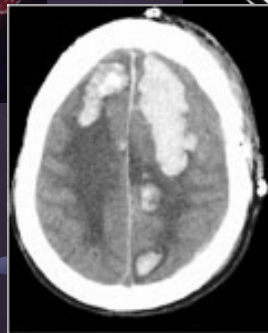
Susan Evans, MD
Carolinas Medical Center
Ross Trauma Center
September, 26, 2012



EDH



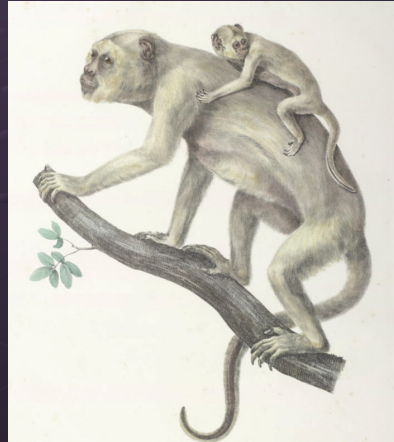
EDH
SDH
SAH



ICH

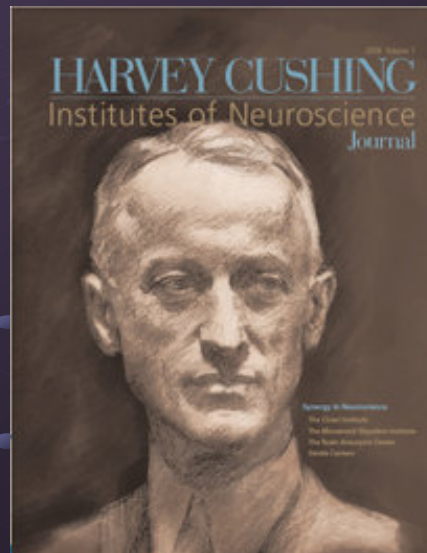
Epidemiology of TBI

- Leading cause of mortality in young, healthy people
 - 1.4 million TBIs annually
 - 50,000 deaths annually
- Necessary organ

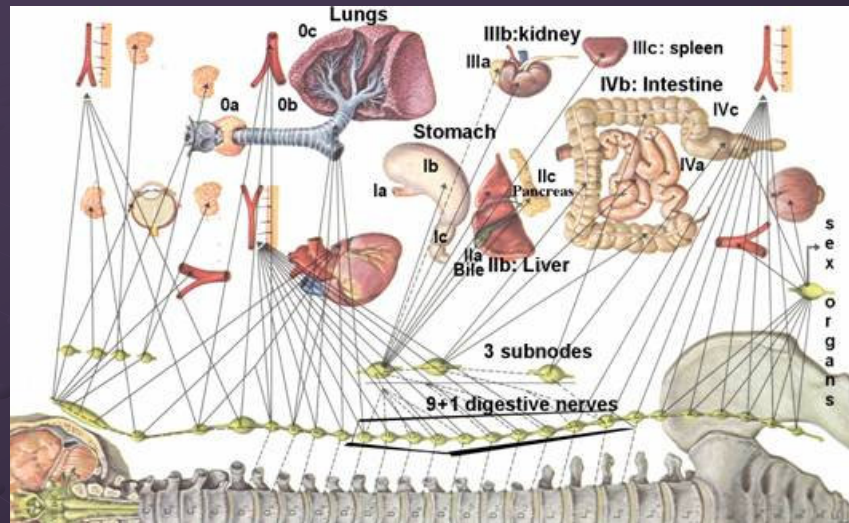


Cerebral-Systemic Regulation

- Cushing's Response
- Apnea



Cerebral input to Organs

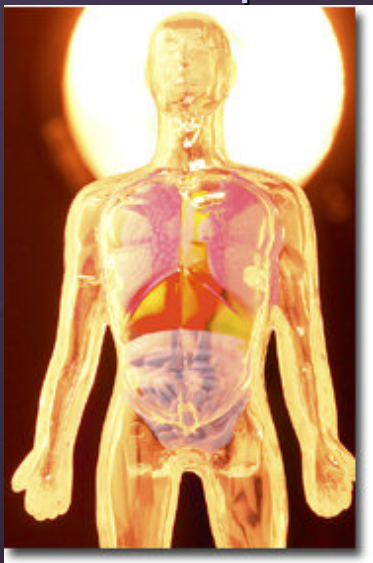


Systemic Consequences of TBI

Cardiac
52%(18%)

Endocrine
53%

Hepatic
8%

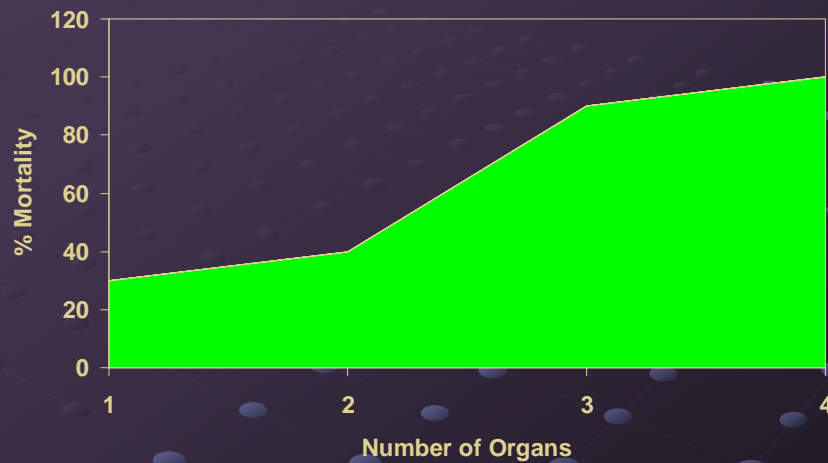


Pulmonary
81%(23%)

Hematologic
36%(4%)

Renal
7%(1%)

Organ Dysfunction following Cerebral Hemorrhage



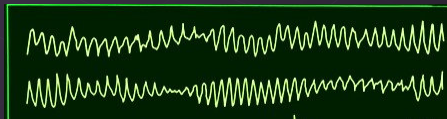
Zygun et al. Crit Care Med 33(3): 654-660, 2005.

Brain death is a donor factor consistently associated with inferior graft function and recipient outcome in all forms of solid organ transplantation.

Rostra et al. Transplantation 85(4): 597-606, 2008.

Extracranial Consequences: Cardiac

- Sinus tachycardia
- Prolonged QTc
- Sinus bradycardia
- Lethal dysrhythmic tachycardias



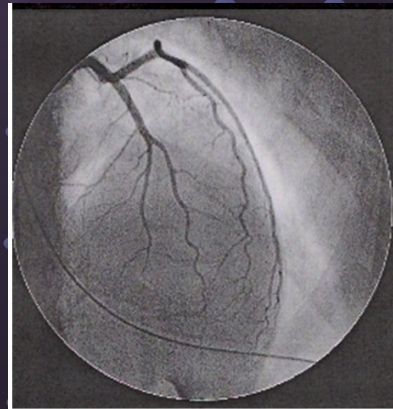
Neurogenic Stunned Myocardium

- Tako-tsubo cardiomyopathy
- Apical ballooning
- Broken heart syndrome



Neurogenic Stunned myocardium

- Cardiac dysfunction
- ST elevations – diffuse
- Troponin elevations



Neurogenic Stunned Myocardium

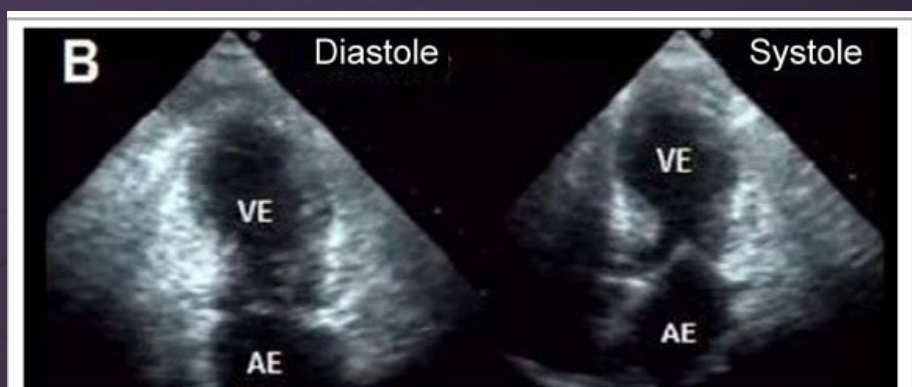
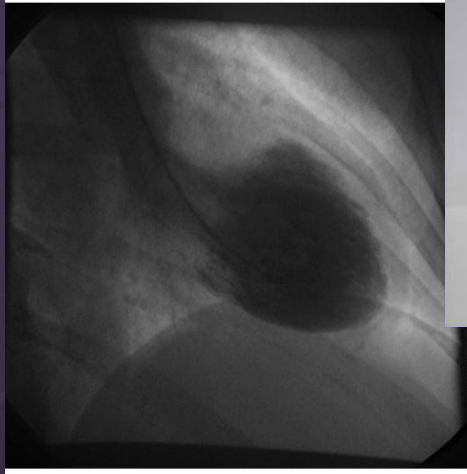


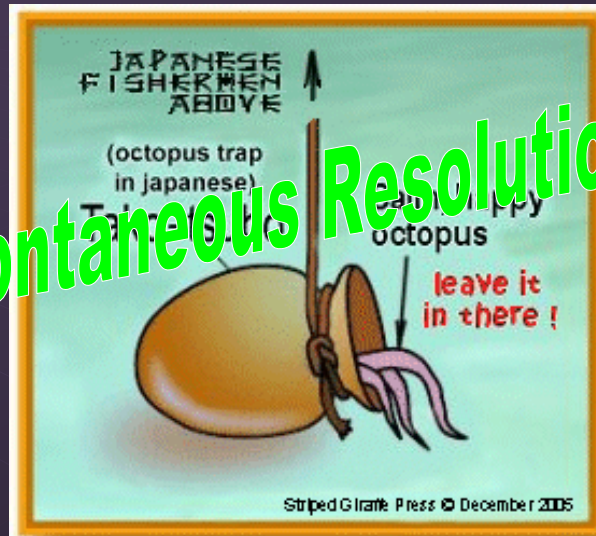
Fig. 3 - Echocardiogram performed on admission day shows left ventricle diastole and systole with apical aneurysmal dilation – typical in Takotsubo cardiomyopathy. EA - left atrium, VE - left ventricle.

Tako-tsubo



Tako-tsubo

Spontaneous Resolution!



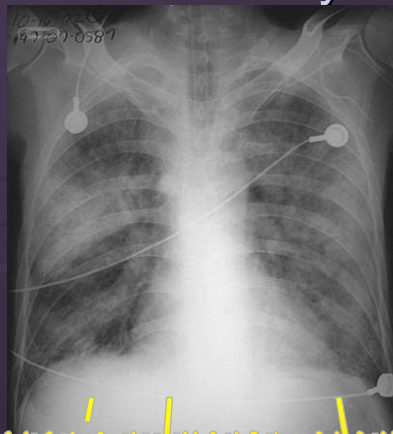
Cardiac Consequences: Therapy

- β -blockade?
- α_2 -agonists?
- β -agonists?

Support and Wait

Extracranial Consequences: Pulmonary

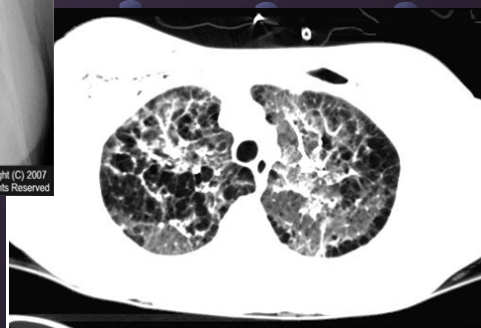
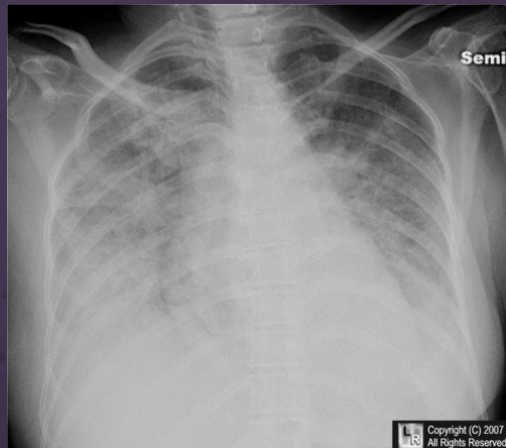
VAP



ALI

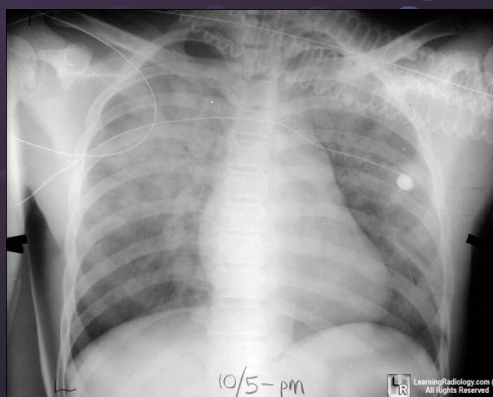
Neurogenic pulmonary edema - NPE

Neurogenic Pulmonary Edema



Neurogenic Pulmonary Edema

- Venoconstriction
- Cardiac Failure
- Permeability



NPE - Venosconstriction

Norepinephrine infusion into sheep caused greater constriction of postcapillary vessels than precapillary vessels.

Minnear et al. J Appl Physiol 50: 1353-1357, 1981.

NPE – Cardiac Insufficiency

- 7 patients – isolated TBI
- Pulmonary edema – 5 clinicians
 - Clinical features
 - Radiographic features
 - Hypoxia
- All patients received catecholamines

Bahloul et al. Am J Crit Care. 15(5): 2006

NPE – Cardiac Insufficiency

- Cardiac assessment
 - Echocardiogram - 3
 - Pulmonary artery catheters - 3
 - Mixed venous oxygen - 1

NPE cardiac induced

Bahloul et al. Am J Crit Care. 15(5): 2006

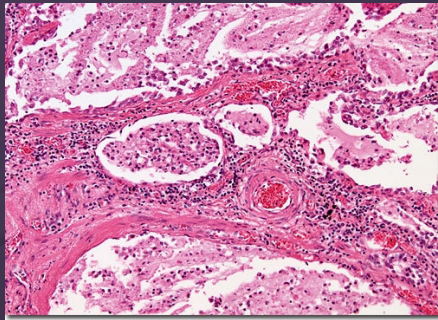
NPE – Cardiac Insufficiency

Postmortem myocardial biopsies

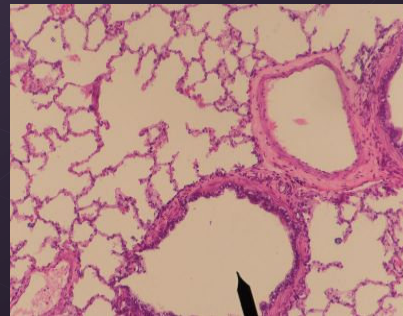
 **Interstitial Edema**

Bahloul et al. Am J Crit Care. 15(5): 2006

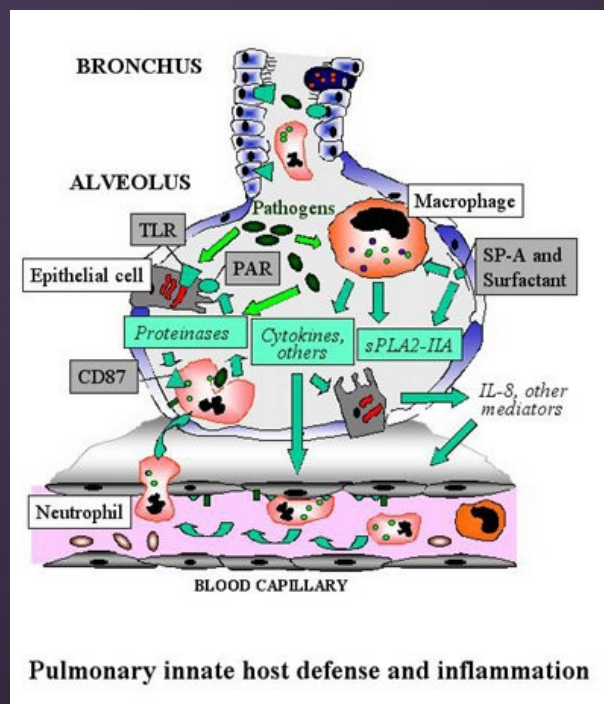
NPE - Hyperpermeability



Transudate & Exudate



Normal Lung



Pulmonary innate host defense and inflammation

NPE - Hyperpermeability

- 102 Rats – Lateral percussion TBI
 - Sham
 - 24hour
 - 3 days
 - 2 weeks
- Measurements
 - BAL – proteins/cells
 - Immunihistochemical staining
 - Immunoblotting
 - Evans Blue Extravasation – BBB integrity

Kalsotra et al. J Cereb Blood Flow Met. 27: 963-974, 2007.

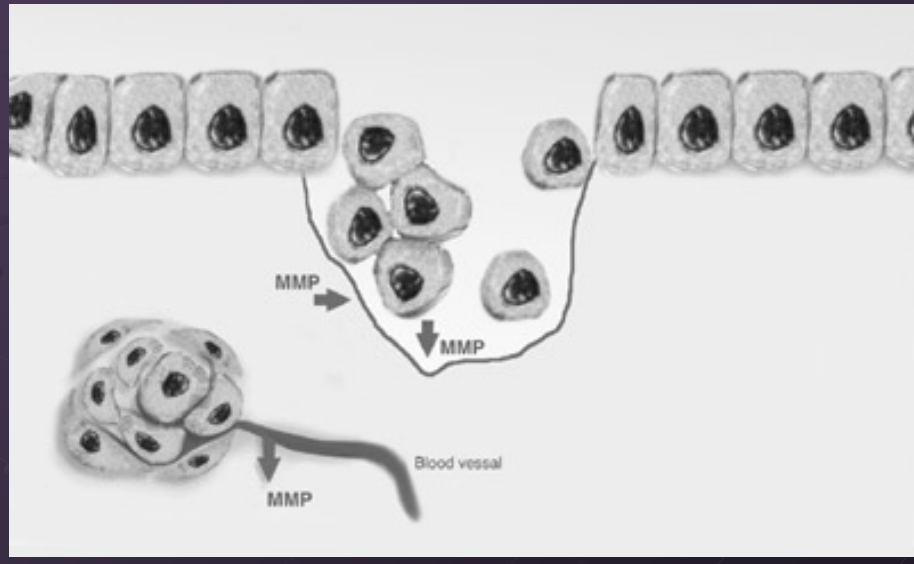
NPE - Hyperpermeability

	Sham	24 hours	2 weeks
Macrophage	=	↑↑↑	↑
Neutrophils	=	↑↑	=
LTB4*	=	↑↑↑	↑
BBB integrity	=	↓↓	↓

**Not in serum*

Kalsotra et al. J Cereb Blood Flow Met. 27: 963-974, 2007.

Metalloproteinases



NPE - Hyperpermeability

- 14 Rats (6 control, 8 experimental)
- TBI – fogarty catheter through burr-hole
- Euthanized at 4 hours
- Measurements
 - Immunihistochemistry
 - Immunofluorescence

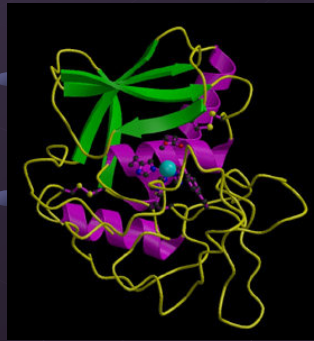
NPE - Hyperpermeability

	Brain Stem Death
H&E	Interstitial edema, Increased alveolar macrophages
ET-1	Alveolar macrophages, PMNs, epithelial, endothelial, smooth muscle cells
MMP-2	Epithelial cells, PMNs, alveolar macrophages
MMP-9	Bronchial epithelium, alveolar macrophages, PMNs, erythrocytes

Sutherland et al. J Heart Lung Transplnt 26(10): 1040-1047, 2007

Pulmonary Consequences: Therapy

- Supportive care
- Cardiac optimization
- Prophylax/diagnose VAP



Dysautonomia

- Tachycardia
- Tachypnea
- Fever
- Hypertension
- Decerebrate/decorticate posturing
- Increased muscle tone
- Profuse sweating

Extracranial Consequences: Dysautonomia

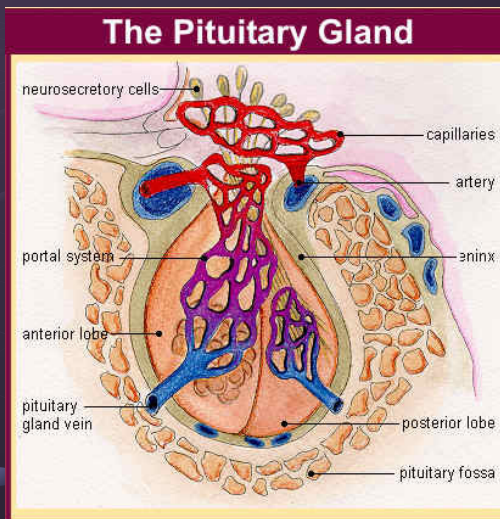
- Dysregulation of the autonomic nervous system
- Paroxysmal sympathetic storm
- Acute hypothalamic instability
- Paroxysmal autonomic instability with dystonia
- Midbrain deregulatory syndrome
- **Brainstem attack**

Dysautonomia

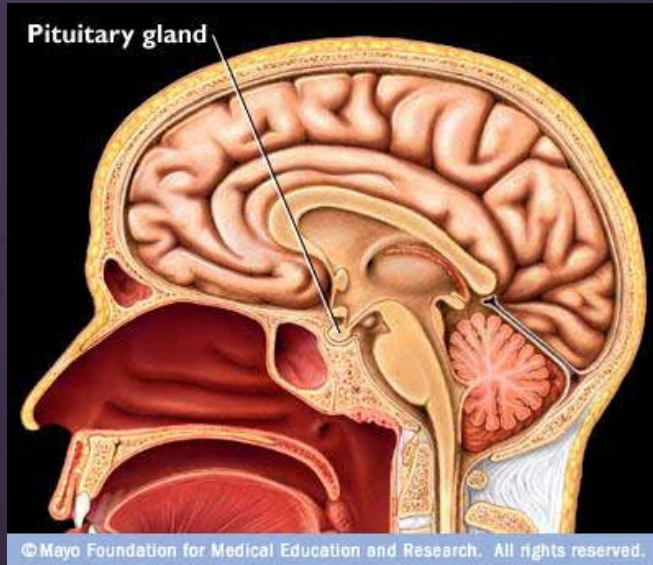
- Variable stimulus
- 10% of patients with TBI
- Associated with more severe brain injury
- Associated with worse outcomes
- No generally accepted therapies

Extracranial Consequences: Endocrine

- Anterior pituitary
 - ACTH
 - TSH
 - FSH/LH
 - Prolactin
 - GH
- Posterior pituitary
 - Oxytocin
 - ADH (vasopressin)



Pituitary



Extracranial Consequences: Endocrine

- Incidence modified by method of measurement
- Symptoms often attributed to TBI
 - Anergia, lethargy, reduced muscle mass
- Autopsy studies:
 - 26-86% injury to the pituitary gland, stalk, or hypothalamus
- Dysfunction due to ischemia, edema or inflammation

Extracranial Consequences: Anterior Pituitary

- Acute incidence: 2-53%
- Long term incidence: 15-68%
- Associations of hypopituitarism:
 - ↓ GCS
 - CT: cerebral edema
 - DAI
 - BSF
 - LOS ICU
 - MRI – pituitary abnormalities

Schneider et al. JAMA 298(12): 1429-1438, 2007.

Extracranial Consequences: Hypernatremia

- Diabetes Insipidus
- Incidence: 3-26%
- Associations
 - Greater severity of TBI
 - Cerebral edema
- Low incidence of long-term dysfunction
- **Not** associated with anterior hypopituitarism

Agha et al. Br J Neurosurgery 21(2): 210-216, 2007.

Extracranial Consequences: Hyponatremia

- Syndrome of Inappropriate Antidiuretic Hormone
 - Incidence: 2-36%
 - Presence 2-18 days after TBI
- Cerebral Salt Wasting
 - Incidence: 1%
 - Transient
 - Unrelated to severity of head injury

Agha et al. Br J Neurosurgery 21(2): 210-216, 2007.

TBI Therapy and Non-neurologic Organ Dysfunction

- Barbiturates
- Hypothermia
- Maintaining CPP

Hirashima et al. *Neurochem Res* 22: 1249-1255, 1997.
McKeating et al. *Br J Anesth.* 78: 520-523, 1997
Robertson et al. *Crit Care Med* 27: 2086-2095, 1999.

Summary

- Seek extracranial abnormalities in brain injury
- EKG/ECHO in patients with hemodynamic instability
- Cardiac catheterization in patients with localizing EKG abnormalities
- Supportive care of patients with neurogenic pulmonary edema
- Monitor for VAP

Summary

- Screen for endocrine dysfunction in higher levels of TBI/SAH
- Screen for endocrine dysfunction if symptoms occur
- Replace deficient endocrine hormones

Thank You!

