Stabilization and Transportation of Pediatric Head-Injured Patients

NCRTAC Trauma Conference 2018

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HEALTH SYSTEM

Objectives

By the end of the session, you will be able to:

1. Identify five distinct characteristics of the child as a trauma patient
2. Discuss key elements of the primary management priorities for a pediatric trauma patient
3. Describe the primary management of the following critical injuries in children:
   a. Disability with altered mental status
   b. Central nervous system

Case Presentation

A seven year-old boy was hit by a car (40 mph) while riding his bike. Unhelmeted.

- VS: HR 135; BP 75/55; RR 40; Sat 92% RA
- Eyes closed, withdraws from pain, moans
- Swelling over L temperoparietal area, R arm deformity w/ active bleeding, abrasions

Initial concerns? First steps?

Epidemiology

10 Leading Causes of Death by Age Group, United States – 2015

	Age Groups										
Rank	**<1**	**1-4**	**5-9**	**10-14**	**15-24**	**25-34**	**35-44**	**45-54**	**55-64**	**65+**	**Total**
1	Congenital Anomalies 4,826	Unintentional Injury 1,235	Unintentional Injury 755	Unintentional Injury 763	Unintentional Injury 12,514	Unintentional Injury 19,795	Unintentional Injury 17,818	Malignant Neoplasms 43,054	Malignant Neoplasms 116,122	Heart Disease 507,138	Heart Disease 633,842
2	Short Gestation 4,084	Congenital Anomalies 435	Malignant Neoplasms 437	Malignant Neoplasms 428	Suicide 5,491	Suicide 6,947	Malignant Neoplasms 10,909	Heart Disease 34,248	Heart Disease 76,872	Malignant Neoplasms 419,389	Malignant Neoplasms 595,930
3	SIDS 1,568	Homicide 369	Congenital Anomalies 181	Suicide 409	Homicide 4,733	Homicide 4,863	Heart Disease 10,387	Unintentional Injury 21,499	Unintentional Injury 19,468	Chronic Low. Respiratory Disease 131,804	Chronic Low. Respiratory Disease 155,041
4	Maternal Pregnancy Comp. 1,522	Malignant Neoplasms 354	Homicide 140	Homicide 158	Malignant Neoplasms 1,469	Malignant Neoplasms 3,704	Suicide 6,936	Liver Disease 8,674	Chronic Low. Respiratory Disease 17,457	Cerebro-vascular 120,156	Unintentional Injury 146,571
5	Unintentional Injury 1,291	Heart Disease 147	Heart Disease 85	Congenital Anomalies 156	Heart Disease 997	Heart Disease 3,522	Homicide 2,895	Suicide 8,751	Diabetes Mellitus 14,186	Alzheimer's Disease 109,495	Cerebro-vascular 140,323
6	Placenta Cord. Membranes 910	Influenza & Pneumonia 98	Chronic Low. Respiratory Disease 80	Heart Disease 125	Congenital Anomalies 386	Liver Disease 844	Liver Disease 2,861	Diabetes Mellitus 6,212	Liver Disease 13,278	Diabetes Mellitus 56,142	Alzheimer's Disease 110,561
7	Bacterial Sepsis 599	Septicemia 54	Influenza & Pneumonia 44	Chronic Low Respiratory Disease 93	Chronic Low Respiratory Disease 202	Diabetes Mellitus 798	Diabetes Mellitus 1,986	Cerebro-vascular 5,307	Cerebro-vascular 12,116	Unintentional Injury 51,396	Diabetes Mellitus 79,535
8	Respiratory Distress 462	Perinatal Period 50	Cerebro-vascular 42	Cerebro-vascular 42	Diabetes Mellitus 196	Cerebro-vascular 567	Cerebro-vascular 1,788	Chronic Low. Respiratory Disease 4,345	Suicide 7,739	Influenza & Pneumonia 48,774	Influenza & Pneumonia 57,062
9	Circulatory System Disease 428	Cerebro-vascular 42	Benign Neoplasms 39	Influenza & Pneumonia 39	Influenza & Pneumonia 184	HIV 529	HIV 1,055	Septicemia 2,542	Septicemia 5,774	Nephritis 41,268	Nephritis 49,959
10	Neonatal Hemorrhage 406	Chronic Low Respiratory Disease 40	Septicemia 31	Two Tied: Benign Neo./Septicemia 33	Cerebro-vascular 166	Congenital Anomalies 443	Septicemia 829	Nephritis 2,124	Nephritis 5,452	Septicemia 30,817	Suicide 44,193

Data Source: National Vital Statistics System, National Center for Health Statistics, CDC.
Produced by: National Center for Injury Prevention and Control, CDC using WISQARS™.

www.cdc.gov/injury

Epidemiology

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Epidemiology

10 Leading Causes of Injury Deaths by Age Group Highlighting Unintentional Injury Deaths, United States – 2016

Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	Total
1	Unintentional Suffocation 1,023	Unintentional Drowning 425	Unintentional MV Traffic 384	Unintentional MV Traffic 455	Unintentional MV Traffic 7,037	Unintentional Poisoning 14,631	Unintentional Poisoning 13,278	Unintentional Poisoning 13,439	Unintentional Poisoning 9,438	Unintentional Fall 29,668	Unintentional Poisoning 58,335
2	Homicide Unspecified 132	Unintentional MV Traffic 334	Unintentional Drowning 167	Suicide Suffocation 247	Unintentional Poisoning 4,997	Unintentional MV Traffic 7,010	Unintentional MV Traffic 5,075	Unintentional MV Traffic 5,536	Unintentional MV Traffic 5,397	Unintentional MV Traffic 7,429	Unintentional MV Traffic 36,748
3	Unintentional MV Traffic 88	Unintentional Suffocation 118	Unintentional Fire/Burn 78	Suicide Firearm 160	Homicide Firearm 4,553	Homicide Firearm 4,510	Suicide Firearm 3,099	Suicide Firearm 3,873	Suicide Firearm 4,067	Suicide Firearm 5,756	Unintentional Fall 34,673
4	Homicide Other Spec., Classifiable 63	Homicide Unspecified 114	Homicide Firearm 68	Unintentional Drowning 103	Suicide Firearm 2,683	Suicide Firearm 3,298	Homicide Firearm 2,555	Suicide Suffocation 2,112	Unintentional Fall 2,679	Unintentional Unspecified 5,021	Suicide Firearm 22,938
5	Undetermined Suffocation 60	Unintentional Fire/Burn 107	Unintentional Suffocation 35	Homicide Firearm 95	Suicide Suffocation 2,100	Suicide Suffocation 2,643	Suicide Suffocation 2,199	Suicide Poisoning 1,736	Suicide Poisoning 1,538	Unintentional Suffocation 3,631	Homicide Firearm 14,415
6	Undetermined Unspecified 38	Unintentional Pedestrian, Other 82	Unintentional Other Land Transport 24	Unintentional Other Land Transport 64	Unintentional Drowning 530	Undetermined Poisoning 855	Suicide Poisoning 1,144	Homicide Firearm 1,420	Suicide Suffocation 1,474	Unintentional Poisoning 2,459	Suicide Suffocation 11,642
7	Unintentional Drowning 38	Homicide Firearm 64	Unintentional Pedestrian, Other 18	Unintentional Fire/Burn 52	Suicide Poisoning 426	Suicide Poisoning 767	Undetermined Poisoning 788	Unintentional Fall 1,238	Unintentional Suffocation 792	Adverse Effects 2,028	Suicide Poisoning 6,698
8	Homicide Suffocation 19	Homicide Other Spec., Classifiable 64	Unintentional Firearm 16	Unintentional Suffocation 39	Homicide Cut/Pierce 340	Unintentional Drowning 463	Unintentional Fall 515	Undetermined Poisoning 929	Homicide Firearm 738	Unintentional Fire/Burn 1,150	Unintentional Suffocation 6,610
9	Adverse Effects 18	Unintentional Firearm 34	Unintentional Struck by or Against 15	Unintentional Poisoning 28	Undetermined Poisoning 289	Homicide Cut/Pierce 420	Unintentional Drowning 396	Unintentional Drowning 478	Undetermined Poisoning 707	Suicide Poisoning 1,070	Unintentional Unspecified 6,507
10	Unintentional Natural/ Environment 18	Unintentional Poisoning 34	Unintentional Other Transport 14	Unintentional Firearm 23	Unintentional Fall 199	Unintentional Fall 326	Homicide Cut/Pierce 350	Unintentional Suffocation 419	Unintentional Unspecified 625	Suicide Suffocation 859	Undetermined Poisoning 3,827

Data Source: National Center for Health Statistics (NCHS), National Vital Statistics System.
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4	Homicide Other Spec., Classifiable 63	Homicide Unspecified 114	Homicide Firearm 68	Unintentional Drowning 103	Suicide Firearm 2,683
5	Undetermined Suffocation 60	Unintentional Fire/Burn 107	Unintentional Suffocation 35	Homicide Firearm 95	Suicide Suffocation 2,100

www.cdc.gov/injury

Pediatric Trauma

- Traumatic injury = #1 killer of children and adolescents in the United States
- Pediatric mortality in US = 2x other developed countries
- Injuries account for 1/3 of total burden of disease in children by disability-adjusted life years
  - $14B lifetime medical; $66B future wages lost

Wesson 2012.

The Pediatric Patient

- Distinct anatomy and physiology features
- Well-recognized patterns of injury
  - Most serious pediatric trauma = blunt trauma involving the brain
  - Presentation: apnea, hypoventilation, hypoxia
  - Trauma protocols focus on aggressive management of airway and breathing

The Pediatric Patient

<u>Size and shape</u>:

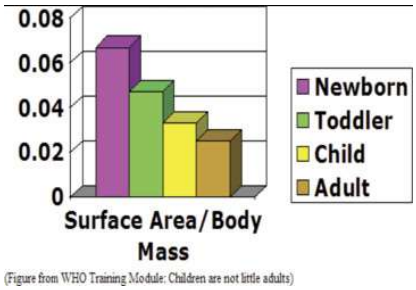
- Smaller body mass → greater force / unit body area

<u>Skeleton</u>:

- Incompletely calcified, more pliable

<u>Surface area (SA)</u>:

- Max SA:mass ratio at birth, diminishes w/ age
- Heat loss



(Figure from WHO Training Module: Children are not little adults)

The Pediatric Patient

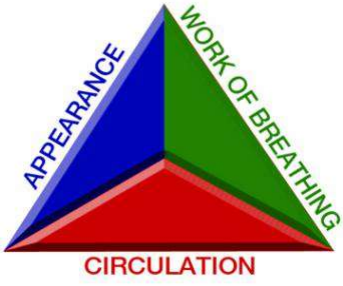
Psychological status:

- Emotional instability → regressive behavior with perceived threats, stress, pain
- Limits history taking
- Soothe & distract → Child Life involvement!

Pediatric Assessment Triangle

Quick and easy approach to evaluating a child

- Tone
- Interactivity
- Consolability
- Look / gaze
- Speech / cry



- Airway sounds
- Positioning
- Retractions
- Flaring

- Pallor
- Mottling
- Cyanosis
- Bleeding

Pediatric Vital Signs

Age Group	Heart Rate	Systolic BP	Respiratory Rate
Infant *O-12 months*	< 160	> 60	< 60
Toddler *1-2 years*	< 150	> 70	< 40
Preschool *3-5 years*	< 140	> 75	< 35
School Age *6-12 years*	< 120	> 80	< 30
Adolescent *≥ 13 years*	< 100	> 90	< 30

Rules of thumb

- SBP = 70 + (2 x age)
- Weight kg = (2 x age) + 10

Broselow Pediatric Emergency Tape

Question Time

What can we say about our patient's vital signs?

7 year-old boy

HR 135; BP 75/55; RR 40; Sat 92% RA

Age Group	Heart Rate	Systolic BP	Respiratory Rate
Infant *O-12 months*	< 160	> 60	< 60
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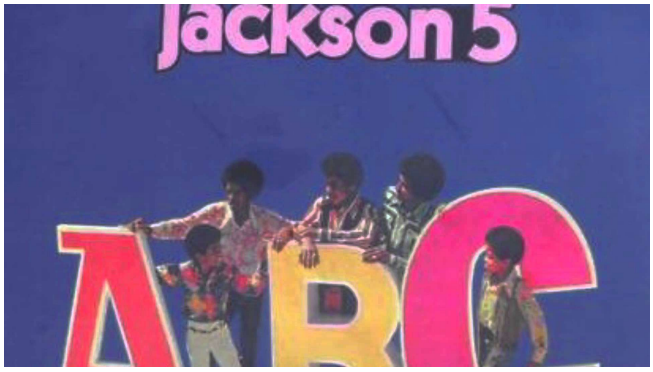


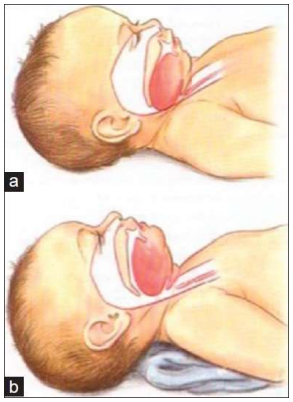
ABCS OF TRAUMA

Primary Survey: Airway

MCC cardiac arrest in children – inability to establish and maintain an airway

<u>Anatomy</u>

- Larger relative occiput → posterior pharynx buckles d/t passive flexion of cervical spine
- Padding beneath entire torso
- Narrow, anterior glottis
- Trachea: 5cm → 7cm @ 18mos



Primary Survey: Airway

<u>Endotracheal tubes</u>

- Narrow cricoid ring forms natural seal around uncuffed ETT → often used in infants
- Toddlers & up: cuffed tubes OK; low risk of tracheal necrosis d/t improved cuff designs
  - Improved ventilation and CO2 management
- Sizing: estimate with tip of pt's pinky finger
  - Approximately 3.0 in newborn, 4.0-4.5 in toddler
  - ETT Size = (Age +16) / 4
- Depth (cm) @ lip: 3x tube size

Primary Survey: Breathing

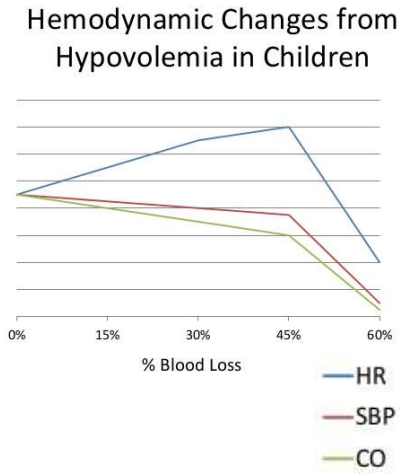
- Normal tidal volumes:
  - 4-6 ml/kg for infants and children
  - 6-8 ml/kg may be required during assisted vent
- Increased potential for iatrogenic barotrauma d/t fragile nature of immature tracheobronchial tree and alveoli
  - Pediatric bag-mask for children under 30 kg

Primary Survey: Breathing

- Assess for potential life-threatening injuries:
  - Pneumothorax, hemothorax, flail chest, rib fractures
- Diaphragmatic breathers → gastric decompression
  - Orogastric tube in babies (obligate nasal breathers)

Primary Survey: Circulation

- Increased physiologic reserve → maintain SBP despite hemorrhage
- Hypotension: decompensated shock, blood loss > 45%
  - Rapid volume infusion
- Tachycardia & poor skin perfusion early signs



Primary Survey: Circulation

- Blood volume:
  - Infant: 80 ml/kg Child: 70 ml/kg
- Bolus: 20 ml/kg warmed isotonic crystalloid
  - Can repeat once, then consider blood products
- Response: slowing of HR, clearing of sensorium, return of peripheral pulses
  - Transient responders & non-responders: candidates for RBC transfusion & possible operative intervention
  - Consider pRBCs: 10 ml/kg
  - Trend towards earlier use of blood products

Primary Survey: Disability

Modified GCS verbal score

Eyes	Verbal	Motor
4 – Spontaneous	**5** – Smiles, Oriented to sounds, Follows objects	**6** – Moves spontaneously and purposefully
3 – To Verbal	**4** – Cries but consolable, inappropriate interactions	**5** – Withdraws from touch
2 – To Pain	**3** – Inconsistently inconsolable, moaning	**4** – Withdraws from pain
1 – No response	**2** – Inconsolable, agitated	**3** – Flexion to pain
	1 – No response	**2** – Extension to pain
		1 – No response

Primary Survey: Exposure

- Larger body surface area ratio → lose heat!
  - Warm fluids, bare huggers, warming lights, warm room temperature
  - Prevents heat loss and secondary coagulopathy associated with hypothermia

Question Time

A 4 year-old girl is struck by a car. She is unconscious at the scene but awake and crying on admission to the hospital. The initial SBP is 70 mm Hg, and the HR is 150 bpm. Estimated weight is 25 kg. Initial treatment of this child includes which of the following?

a) Insertion of an intraosseous infusion device
b) Fluid bolus of 250 ml Ringer's lactate
c) Fluid bolus of 500 ml Ringer's lactate
d) Immediate rapid-sequence intubation
e) Immediate transfusion of 250 cc pRBC

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GUIDELINES FOR THE CARE OF PEDIATRIC PATIENTS WITH MODERATE TO SEVERE TBI

TBI Definitions

Mild TBI

- GCS 14-15
- LOC < 30 min
- Amnesia < 24h
- If CT performed, must be normal
- Synonym: “concussion”

Moderate to Severe TBI

- GCS <= 13
- CT: Diffuse cerebral swelling
- High risk of deterioration
  - Midline shift, herniation, ICH
- Age ≤ 3 and any e/o ICH

Pathophysiology

- TBI = primary injury + secondary injury
  - Primary: occurs at impact, leads to disruption of brain substance and blood vessels
  - Secondary: may result from hypoxia, hypotension, hyperventilation, pyrexia, increased ICP
- Primary injury sets off cascade of processes that can cause secondary injury.
  - Our goal: prevent secondary injury

Pathophysiology
Cerebral Hypoperfusion & Hypoxia

Hypotension = #1 treatable determinant of severe head injury

- Goal #1: rapid & complete restoration of BP

Hypoxia: independent predictor of poor outcome

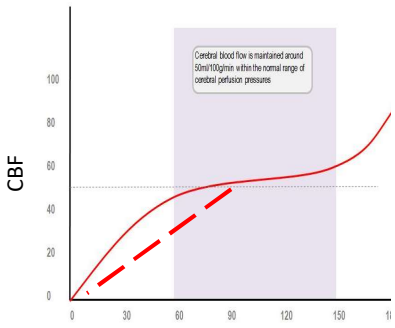
- Modern airway management strategies have decreased frequency and magnitude of hypoxia
- Assisted ventilation, intubation, avoidance of anemia

Pathophysiology
Intracranial Hypertension

- ICP function of volumes of brain, CSF, blood
- Buffering capacity compensates for mild / slow expansion of one or two of these
  - Exceed buffering capacity → ↑ ICP
- Herniation: pressure gradient across incomplete barrier (falx cerebri, tentorium)
  - Tissue damage, direct compression of adjacent vessels
- ↑ Resistance to cerebral blood flow (~CPP)
  - Causes ischemia

Pathophysiology
Cerebral Blood Flow

- Autoregulation maintains CBF over range of CPP
- Autoregulation fails with injury
  → Lower break point shifts
  - Normally satisfactory CPP associated with low CBF
- CPP = MAP – ICP
- Goal: keep CBF normal
  - ICP reduction
  - BP support



Cerebral perfusion pressure

CBF maintained for CPP 50-150

TBI Treatment Strategies

Based on the new guidelines from the Marshfield Medical Center.

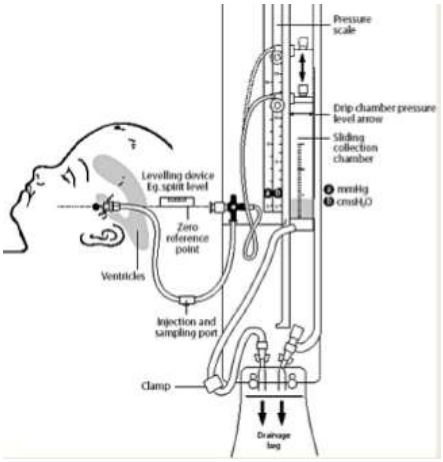
- Assessment & Monitoring
- Airway & Breathing
- Circulation
- Hyperosmolar therapy
- Sedation
- Decompressive strategies
- Barbiturate Coma
- Fluids, Electrolytes, and Nutrition
- VTE prophylaxis
- Adjuncts
- Suctioning

Assessment & Monitoring

- PICU Standards: NIBP, pulse ox, EKG, Foley
- Arterial line strongly recommended
- CT – rapid assessment of intracranial injury
  - Any child with suspected moderate to severe TBI
  - Repeat @ 24-48h for any PICU admission or if:
    - Signs of deterioration, inability to assess neuro status, considering initiating VTE prophylaxis

Assessment & Monitoring

External Ventricular Drain



Neurosurgical Consultation

- Consider ICP monitoring
  - GCS ≤ 8, inaccurate exam

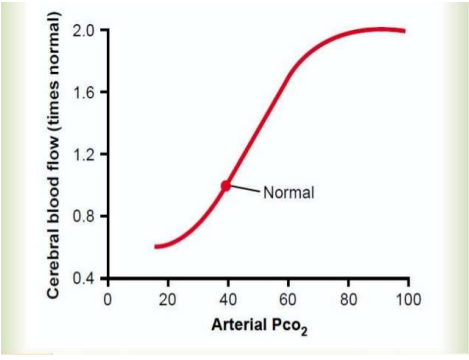
EVD

Fluid-coupled catheters placed in the lateral ventricles

- Preferred method of ICP monitoring:
  - Early warning of herniation
  - Calculate CPP
  - Drain CSF

Airway & Breathing

- Supplemental oxygen to keep sat ≥ 92%
- GCS ≤ 8 … rapid sequence intubation
- Goal: avoid hyper- and hypoventilation
  - CPP primarily driven by P_{CO_2}
  - Normocapnea: pCO2 35-40 mm Hg
  - pH 7.4



Circulation

- CPP = MAP – ICP
  - Higher ICP requires higher MAP to maintain CPP & CBF
  - Target CPP & ICP by age

Age group	CPP Goal	ICP Goal
≤ 3 years	> 40-50 mm Hg	< 15-20 mm Hg
3-12 years	> 50-60 mm Hg	< 20 mm Hg
> 12 years	> 65 mm Hg	

- Pressors can be used to increase MAP
  - Pref: norepi, phenyleph

Hyperosmolar Therapy

Goal: increase osmotic gradient to draw fluid from interstitial compartment into the plasma → reduces brain volume & ICP

- 3% hypertonic saline
  - Target Na of 150; if already > 150, target +5
  - Bolus, recheck w/i 30 min, then maintenance rate
  - Check osmolality and Na every 6 hours
  - Persistently elevated / rising ICP → ↑ goal Na by 5

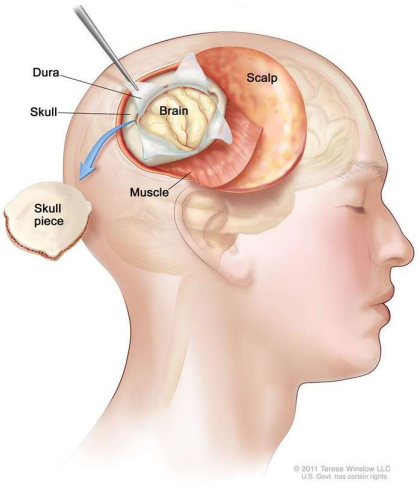
Sedation

- Helps to prevent intracranial hypertension
- Escalation guide:
  - PRN Benzo + PRN Narcotic
  - PRN Benzo + Continuous & PRN Narcotic
  - Continuous & PRN Benzo + Continuous & PRN Narcotic
  - Add scheduled lorazepam alternating w/ chloral hydrate
  - Add Precedex or Clonidine
- Consider daily "sedation vacation"

Decompressive Strategies

<u>Craniectomy</u>

- Fronto-temporo-parietal bone flaps removed; dura opened
- Effectively expands intracranial volume
- Reduces ICP



Barbiturate Coma

- Last resort to control intracranial hypertension in patients who have failed previous attempts
- Monitoring with BIS or NIRS
- Drawbacks
  - Reduces neuro exam to pupils only
  - Can cause hypotension
- Phenobarbital – continue until stable ICP < 20 for 24h, then consider tapering

Fluids, Electrolytes, Nutrition

Enteral nutrition: initiate w/i 24 hrs of PICU admit

- Estimation of caloric needs
  - Resting Energy Expenditure
  - Respiratory Quotient
- Relative contraindication: hi-dose α-agonists
  - Use centrally-administered TPN

Fluids, Electrolytes, Nutrition

Glycemic Control

- Check blood sugars q4h (≤ 3y) or q6h (> 3y)
  - Goal: glucose 80-150
  - If sugar < 60, add 5% dextrose to IVF
  - If persistently > 150, use PICU insulin protocol

Venous Thromboembolism Prophylaxis

- Evaluation for VTE prophylaxis by trauma & NSGY
- Repeat imaging 24-72 hours post-injury
- Start VTE prophylaxis with LMWH in pts > 15 yrs in absence of CT changes
- For 13-15 yrs, start VTE prophylaxis if injury severity score > 25 and > 4 RFs.
  - RFs: > 5d mobility, GCS < 9, CVL, SCI, complex lower ext injury, pelvic fx, inotrope use, CPR during resuscitation, exogenous estrogn therapy, chronic inflammy stat, h/o thrombosis, thrombophilia

Adjuncts

- Maintain normothermia (APAP, Zoll)
- HOB > 30 degs
- Low stimulation environment
- Seizure prophylaxis (Keppra, fosphenytoin)
- Safe suctioning
  - Adequate sedation, mild hyperventilation

Case Presentation

A seven year-old boy was hit by a car (40 mph) while riding his bike. Unhelmeted.

- VS: HR 135; BP 75/55; RR 40; Sat 92% RA
- Eyes closed, withdraws from pain, moans
- Swelling over L temperoparietal area, R arm deformity w/ active bleeding, abrasions

What would you do?

References

- Advanced Trauma Life Support Student Course Manual, 9e.
- Centers for Disease Control. www.cdc.gov
- Gensch. Neuro Critical Care. https://www.slideshare.net/jgensch/neuro-critical-care
- Greenfield's Surgery: Scientific Principles and Practice, 6e.
- Guideline for care of the pediatric patient with moderate to severe TBI. Marshfield Medical Center Trauma Program. 2018.