BIOMECHANICS, EPIDEMIOLOGY & TRAUMA MANAGEMENT

Annice CHANG
NC (Trauma), QEH
Objectives

- Review
  - Biomechanics of Injury
  - Trauma Epidemiology
  - Principles of trauma management
- Introduce the components of primary & secondary survey
- Identify priorities in care of the multiply injured patient
What is Trauma?

- Trauma is a term derived from the Greek word for “wound”
  - It refers to any bodily injury leading to tissue damage

- Trauma patient:
  - Suffered from disease of external cause
  - ICD-9 codes 800-959
    - e.g. Pedestrian in MVA E814.7; Fall from tree E884.3
BIOMECHANICS
KINEMATICS
MECHANISM OF INJURY
**Biomechanics**: Study of physiology and mechanics of a living organism using the tools of mechanical engineering.

**Kinematics**: Study of the relationship among speed, mass, direction of force, and physical injury caused by these factors.

**Mechanism of Injury (MOI)**: The mechanism whereby energy is transferred from the environment to the person.

Injury occurs when an external force/energy affects the body beyond its ability to sustain and dissipate the force/energy.
Mechanism of Injuries

- The mechanism whereby energy is transferred from the environment to the person.

- Different forms of energy produce different kinds of injury:
  - Mechanical energy
  - Electrical energy
  - Chemical energy
  - Barometric energy

- Predictable pattern of injuries based on forces applied to the body in trauma.

It’s elementary my dear Watson! Remember to look for the CLUES!!!
Mechanism of Injuries

Factors Affecting Types of Injury

- Ability of body to disperse energy delivered

- Force and energy
  - Size of object
  - Velocity
  - Acceleration or deceleration
  - Affected body area

- Duration and direction
  - The larger the area of force dissipation, the more pressure is reduced to a specific spot.

- Position of victim
Mechanism of Injury

• Blunt
  • Motor vehicle collisions
  • Pedestrian injuries
  • Falls from heights

• Burns and Cold injury
  • caused by heat, electricity, chemicals, friction, or radiation
  • Inhalation injury and CO. intoxication in fire field
  • Combination of injuries

• Hazardous environment
  • Exposure to chemicals, toxins, radiation

• Penetrate
  • Stabbings
  • Gunshots
Motor Vehicle Collisions

- Front impact
- Back impact
- Side impact (T-boned)
- Combined impact.
- Vehicle may be turned over
- Patient may be ejected from vehicle

- The amount of energy and the direction of impact are major factors that determine the outcome of a collision
Pedestrian Injuries

Three predominant MOIs:

- **First impact**: auto strikes body with its bumpers.

- **Second impact**: adult is thrown on hood and/or grille of vehicle.

- **Third impact**: body strikes the ground or some other object.
Falls from Heights

- Severity of injuries impacted by:
  - The height of the fall
  - The surface struck
  - The manner the body impacts onto the surface
  - Physical condition

- Internal organ injuries
  - Sudden acceleration
  - Deceleration
  - Strong compressive forces
Penetrating Trauma

- disruption of skin and tissues in a focused area

- Low velocity:
  - Caused accidentally by an object or intentionally with a weapon
  - Severity depends on:
    - Anatomic area involved
    - Depth of penetration
    - Blade length
    - Angle of penetration

- Medium- and High-Velocity
  - Usually caused by bullets
  - Bullets can change shape and ricochet within the body.
  - Pressure waves cause cavitation.
  - If possible, identify weapon caliber and shooting distance.
Pediatric Trauma

- Smaller body mass
- Less protective muscle and fat
- Less elastic connective tissue
- Cartilaginous skeleton
  - visceral / brain injuries common in the absence of bony injuries

Predispose to ... more severe multisystem injuries
EPIDEMIOLOGY

Data source:
- Center for Disease Control and Prevention
- Center for Health Protection, Vital statistics
- Hospital Authority Statistical Report
- QEH Trauma Databank
- World Health Organization
Epidemiology - Global

• In 2012,
  • Injuries caused 9% of all deaths globally (~5 million)
  • Road traffic injuries claimed nearly 3500 lives each day, making it among the 10 leading causes in 2012.

• In 2013
  • 4.8 million people died from injuries (4.3 million in 1990)
  • 367,000 children less than five died from injuries (766,000 in 1990).

Data source: WHO
Epidemiology - United States, 2013

• More than 193,000 people lose their lives to trauma

• Trauma is leading cause of death for Americans ages 1-44 years, or 47% of all deaths in this age range.

• Trauma is the 3rd leading cause of death overall.

• Trauma injury accounts for 30% of all life years lost.

• The economic burden of trauma is more than $671 billion.
  • fatal injuries $214 billion
  • nonfatal injuries $457 billion
Injury ≠ Accident

Injuries have traditionally been regarded as random, unavoidable “accidents”. During the last few decades, however, a better understanding of the nature of injuries changed these old beliefs. Today, injuries are viewed as largely preventable events.\(^1\) Thus, a better understanding of the risk factors of injuries can often help to reduce the likelihood and severity of injuries.\(^2\) In fact, injuries are multi-causal events which result from a complex interaction of social, economic, environmental, behavioural and biomedical determinants over the life course. Increasing people’s awareness of these factors and adopting appropriate safety measures have been demonstrated to be effective in the prevention and control of the problem.\(^3,4\)

Local Situation of Injury

In Hong Kong, injuries have remained one of the leading causes of death for all age groups, since the 1960s. Injuries accounted for 1 500 to 2 200 annually between 1981 and 2010 (Figure 1). In terms of potential years of life lost at age 75 (PYLL 75, is an indicator of premature mortality), injuries ranked among the ten leading causes of death in Hong Kong from 2001 to 2010.\(^7\)

Figure 1: Number of registered deaths due to injuries, 1981-2010

2500
1,834 registered deaths were related to injuries, 4.0% of total registered deaths

- the 5th leading cause of death overall.
- the leading cause of death for ages 1-44 years (519 deaths), or 33% of all deaths in this age range.

Hospitalization caused by injuries is increasing

- 104,136 episodes were due to injuries, 4.9% of total in-patient discharges and deaths. Falls had the largest share (41,249 episodes or 39.6%).
Injury Pyramid

For every person dying as a result of injury, there are hundreds more that sustain non-fatal injuries and other health consequences.

- 1/16: 193,000 Fatal injuries
- 1/9: 3 million Injuries resulting in Hospitalization
- 1/53: 97,837 Injuries resulting in visits to emergency departments
- 1/3: 307,799 Injuries resulting in visits to primary care facilities
- US, 2013
- HK, 2013

Injuries treated outside the health system, not treated, or not reported
QEH Trauma Statistic

- In 2015,
  - 10.1% of traumatic injuries occur in children (14.1% in 2011)
  - 20 (25.8%) were major trauma with ISS>15 (37, 35.2% in 2011)
STANDARDIZED APPROACH To TRAUMA CARE
The time of death after trauma

Immediate death

Early death

Trimodal Distribution of Death
Trauma Deaths: Prevention

- Immediate (1\textsuperscript{st} peak)
  - Injury prevention
  - Rapid prehospital transport
- Early (2\textsuperscript{nd} peak)
  - Rapid assessment
  - Prompt resuscitation
- Late (3\textsuperscript{rd} peak)
  - ICU care

Golden Hour

R. Adams Cowley, MD
- Care within 60 min.
- Mortality if care given > 60 min.
The beginning of standardized trauma assessment

A tragedy occurred in February 1976 that changed trauma care in the "first hour" for the injured patient.

... An orthopedic surgeon, Dr. Jim Styner, piloting his plane, crashed in a rural Nebraska cornfield...
This family tragedy gave birth to the trauma legend known as A.T.L.S. (ADVANCED TRAUMA LIFE SUPPORT)

A common language & approach to trauma care
Goals of the *A.T.L.S.* course

- Appropriate and timely care
- Algorithm based

**Focus on the first hour**

  - Treat the greatest threat to life first
  - Treat despite lack of definitive diagnosis
  - Do no further harm

- Train practitioners who do not daily care for trauma patients

*ABCDE approach to evaluation and treatment*
ATLS Priorities of Care

- Preparation

- Rapid primary survey & Resuscitation
  - ABCDE + Adjuncts
  - Find and correct life-threatening injuries

- Detailed secondary survey / reevaluation
  - History
  - Head-to-toe Physical exam
  - Laboratory & radiology studies
  - Detect other injuries and formulate treatment plan

- Continued monitoring and re-evaluation

- Transfer to definitive care

Priorities are the SAME for all!
Preparation

- Personnel
- Equipment & Medication
  - Pediatric wall charts / Broselow© tape
- Infection control measures
- Pre-hospital information: MIST
  - Mechanism of injuries
  - Injuries identified
  - S/S
  - Treatment given
Primary Survey & Resuscitation

- Rapid, organized approach to identify life-threatening injuries
- Resuscitation done simultaneously

AIRway with c-spine protection
Breathing / ventilation / oxygenation
Circulation: stop the bleeding!
Disability / neurological status
Expose / Environment / body temperature
Airway with C-spine protection

- In the trauma setting, *spinal injury is assumed* until proven otherwise
- Protection is a priority
  - Do NO harm
  - Prevent secondary injury to cord
- Detection is a secondary priority
Airway Assessment

- Check for airway patency
- Assess need for intubation

<table>
<thead>
<tr>
<th>LOOK</th>
<th>LISTEN</th>
<th>FEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>- conscious state</td>
<td>- vocalization</td>
<td>- tracheal position</td>
</tr>
<tr>
<td>- evidence of injuries</td>
<td>- abnormal sounds</td>
<td>- evidence of injuries</td>
</tr>
<tr>
<td>- airway debris</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Airway Management

■ Beware c-spine – do not flex / hyperextend

■ Establish patency
  ■ Airway maintenance techniques
    • Suction
    • Chin lift / Jaw thrust
    • Oral / nasal airway

■ Definitive airway
  • Oro- / naso-tracheal intubation
  • Surgical airway
    • 1. Needle cricothyroidotomy
    • 2. Surgical cricothyroidotomy
<table>
<thead>
<tr>
<th>Age Related Differences</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children &lt; 6 month are <strong>obligate nose breathers</strong></td>
<td>Anything that obstructs nose in breathing child may obstruct the airway</td>
</tr>
<tr>
<td>Relatively larger tongue, which can obstruct the airway</td>
<td>May necessitate better head positioning or use of airway adjunct</td>
</tr>
<tr>
<td>Shorter tracheal length (newborn: 4-5cm; 18 mth: 7-8cm)</td>
<td>Leading to intubation of right main stem or dislodgement of the ETT</td>
</tr>
<tr>
<td>Narrow tracheal diameter and distance between the rings</td>
<td>Making tracheostomy more difficult</td>
</tr>
<tr>
<td></td>
<td>Needle Vs Surgical cricothyroidotomy</td>
</tr>
<tr>
<td>Cricoid ring is the narrowest portion of the airway</td>
<td>Allows for use of uncuffed tubes in children</td>
</tr>
<tr>
<td>Large airways more narrow</td>
<td>Leads to greater airway resistance</td>
</tr>
</tbody>
</table>
Breathing & Ventilation Assessment

An intact airway **Does Not** assure adequate ventilation!!

- Ensure adequate oxygenation & ventilation
- Look, Listen & Feel

<table>
<thead>
<tr>
<th>Inspect</th>
<th>General</th>
<th>Chest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensorium / Color</td>
<td>Chest rise &amp; symmetry</td>
</tr>
<tr>
<td></td>
<td>Tracheal position</td>
<td>Rate &amp; effort</td>
</tr>
<tr>
<td></td>
<td>Jugular veins</td>
<td>Any injury</td>
</tr>
<tr>
<td>Auscultate</td>
<td>Bilateral breath sounds (+ Heart sounds)</td>
<td></td>
</tr>
<tr>
<td>Palpate</td>
<td>Tracheal position, any injuries</td>
<td></td>
</tr>
<tr>
<td>Percuss</td>
<td>Any dull or hyperresonance</td>
<td></td>
</tr>
</tbody>
</table>
Breathing & Ventilation

AGE RELATED DIFFERENCES

• Faster respiratory rate
• Smaller vital capacity
• Small thorax
  • Transmitted breath sounds
• Diaphragmatic breathers
• Pliant chest walls
• Weak accessory muscles

<table>
<thead>
<tr>
<th>Age</th>
<th>Respiratory Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>40-60</td>
</tr>
<tr>
<td>&lt; 1 year old</td>
<td>30-40</td>
</tr>
<tr>
<td>Child</td>
<td>20-28</td>
</tr>
<tr>
<td>Adolescent</td>
<td>12-20</td>
</tr>
</tbody>
</table>
Breathing & Ventilation Management

Oxygen
- Maximize oxygen delivery to tissues

Ventilate as needed
- Bag-valve-mask device
- Support with mechanical ventilation
  - Frequent evaluation & care of ETT

Address life threatening injuries
- Tension pneumothorax - Needle decompression + chest tube
- Pneumothorax / hemothorax - chest tube
- Open pneumothorax – occlusive dressing, taped on 3 sides
- Massive hemothorax – fluid resuscitation, chest tube +/- surgery
Circulation Assessment

- Assess for organ perfusion
  - Level of consciousness
  - Pulses rate & character
  - Skin color & temperature

- Identify bleeding source

- Causes of Shock
  - Hemorrhagic shock
    - External
    - Internal bleeding: 5 spaces: chest, abdomen, pelvis, long-bones, floor
  - Non-hemorrhagic shock
    - Obstructive (Tension pneumothorax, cardiac tamponade)
    - Neurogenic (Spinal cord injury)
# Classes of Hemorrhagic Shock

For a 70Kg man

<table>
<thead>
<tr>
<th>Blood Loss (% Bld vol)</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 750 ml (10-15%)</td>
<td>750-1500 ml (15-30%)</td>
<td>1500-2000 ml (30-40%)</td>
<td>&gt;2000 ml (&gt;40%)</td>
<td></td>
</tr>
<tr>
<td>CNS</td>
<td>Slightly anxious</td>
<td>Mildly anxious</td>
<td>Anxious, confused</td>
<td>Lethargic confused</td>
</tr>
<tr>
<td>Pulse Rate</td>
<td>&lt;100</td>
<td>&gt; 100</td>
<td>&gt; 120</td>
<td>&gt; 140</td>
</tr>
<tr>
<td>BP</td>
<td>normal</td>
<td>normal</td>
<td>decreased</td>
<td>decreased</td>
</tr>
<tr>
<td>Resp rate</td>
<td>normal</td>
<td>20 - 30</td>
<td>30 - 40</td>
<td>&gt; 35</td>
</tr>
<tr>
<td>Skin</td>
<td>Warm, dry</td>
<td>Slightly cool skin</td>
<td>Pale, cool, diaphoretic</td>
<td>Pale, cool diaphoretic</td>
</tr>
<tr>
<td>U/O</td>
<td>&gt; 30</td>
<td>20 - 30</td>
<td>5 - 15</td>
<td>negligible</td>
</tr>
<tr>
<td>Fluid Resus 3:1 Rule</td>
<td>crystalloid</td>
<td>crystalloid</td>
<td>Crystalloid + Blood</td>
<td>Crystalloid + Blood</td>
</tr>
</tbody>
</table>
AGE RELATED DIFFERENCES

• Small blood volume

• A small amount blood loss can quickly produce hypovolemic shock in child

• Good initial compensation for hypovoleemia

• Smaller, more difficult to cannulate veins
Circulation Management

STOP Bleeding

- Identify source & stop bleeding
  - External bleeding
    - Apply direct manual pressure
    - Splinting of fractures
    - Emergency Tourniquets
  - Internal bleeding
    - Massive hemothorax
    - Cardiac tamponade
    - Massive haemoperitoneum
    - Unstable pelvic fracture

- Early imaging

- Early surgical involvement if internal haemorrhage is identified
Circulation Management

Restore circulating volume

- Obtain venous access
  - Intraosseous or venous cut down if can’t get iv access (3Xs or 90sec)

- T&S + baseline lab test

- Initiate fluid resuscitation
  - Bolus of warmed NS 20ml/kg, repeat as indicated
  - Blood transfusion 10 ml/kg if 3rd fluid bolus needed

- Monitor response, reassess frequently
Disability Assessment

- Baseline neurologic status
  - AVPU scale or Pediatric GCS
    - A = patient is alert
    - V = responds to verbal commands
    - P = responds to pain
    - U = unresponsive

- Pupillary size, symmetry, reactivity

<table>
<thead>
<tr>
<th>Verbal Response</th>
<th>V-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate words/coos</td>
<td>5</td>
</tr>
<tr>
<td>Smiles, fixes/follows</td>
<td></td>
</tr>
<tr>
<td>Cries but consoles</td>
<td>4</td>
</tr>
<tr>
<td>Persistently irritable</td>
<td>3</td>
</tr>
<tr>
<td>Restless, agitated</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>
Disability Management

- Prevent secondary brain injury
  - Secure airway & ventilation
  - Treat hypotension

- Management for head injury
  - Monitor neurologic status
  - Neurosurgical consult as indicated
  - Early CT Brain
  - Prevent & control ↑ICP
Exposure with Environmental control

- Assess all surface areas
- Log-roll with using spinal precautions
  - Examine the spine: note step deformities or pain
  - Assess rectal tone and sensation
  - Check for vaginal/urethral bleeding
- Prevent hypothermia
  - Keep trauma room warm, use blankets and overhead warmer for infants
Adjuncts to Primary survey & Resuscitation

- Full set of Vitals + core $T^\circ$

- Interventions
  - ECG monitoring, pulse oximeter, end tidal CO2,
  - Urinary & gastric catheter insertion
  - Laboratory – ABG, lactate
  - Radiological studies - X-rays, FAST

- Specialty consultation

- Decision making for definitive care

- Preparation for operation / intervention / transfer
Disposition of Trauma Patients

- Dictated by the patient’s condition and available resources (OR, admit, or transfer…)

- Consider Need for Patient Transfer when patient’s needs exceed institutional resources
  - Use time before transfer for resuscitation
  - Do not delay transfer for diagnostic tests
  - Communication between receiving & transfer unit at ALL levels
    - Physician-to-physician and Nurse-to-Nurse communication …
Secondary Survey

A detailed systemic evaluation
- to identify previously undetected injuries
- to confirm suspected injuries

DO NOT begin until …

✓ The primary survey is completed,
✓ Resuscitation efforts are well established, and
✓ The patient is demonstrating normalization of vital functions
Secondary Survey + adjuncts

- “AMPLE” History
  - Allergies
  - Medications
  - Past health
  - Last meal
  - Event

- Initiation of diagnostic studies
  - laboratory studies
  - Additional x-rays pertinent to the site(s) of suspected injury
  - FAST, CT scan, Angiography, MRI if indicated
Continuous & frequent evaluation

✓ On-going evaluation patient’s response to all interventions
  ✓ To assess the adequacy of resuscitation
  ✓ To look for changes and new findings

✓ Continue to reassess using ABCDE format:
Remember…

• Managing an unstable trauma patient is *stressful*.

• Following the “primary / secondary survey” approach will help you organize your thoughts and prioritize management.

<table>
<thead>
<tr>
<th>Primary survey</th>
<th>ABCDEs – rapid organized assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resuscitation &amp; monitor</td>
<td>resuscitate &amp; stabilize by priority</td>
</tr>
<tr>
<td>Secondary survey</td>
<td>AMPLE History, Head-to-Toe evaluation</td>
</tr>
<tr>
<td>Definitive care</td>
<td>early consultation, surgical intervention, transfer</td>
</tr>
</tbody>
</table>
QUESTION ???
## Case scenario

**Male, 4 years old, pedestrian**

<table>
<thead>
<tr>
<th>EMS report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mechanism</strong></td>
</tr>
<tr>
<td>was hit by a taxi as he ran out into the street to chase his soccer ball</td>
</tr>
<tr>
<td>Lying ~15 feet from the point of impact</td>
</tr>
<tr>
<td><strong>Injuries</strong></td>
</tr>
<tr>
<td>Occipital laceration &amp; hematoma</td>
</tr>
<tr>
<td>Abrasions: face, chest, abdomen, limbs</td>
</tr>
<tr>
<td>Deformed &amp; swollen left thigh</td>
</tr>
<tr>
<td><strong>S/S</strong></td>
</tr>
<tr>
<td>Withdraw to pain, pulse 120 bpm</td>
</tr>
<tr>
<td>Very shallow respiration</td>
</tr>
<tr>
<td><strong>Treatment given</strong></td>
</tr>
<tr>
<td>BVM assisted ventilation</td>
</tr>
</tbody>
</table>
Case Scenario
What Injury pattern can be predicted?

- Occipital laceration & hematoma
  → ? Head injury

- Multiple abrasions
  → ? Chest injury
  → ? Abdominal injury
  → ?? injuries

- Left thigh deformity
  → ? # pelvis, limb injury
Just Arrived AED…

<table>
<thead>
<tr>
<th>Priority of TRAUMA CARE</th>
<th>Please select from the list below</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Which should be done FIRST?</td>
<td></td>
</tr>
<tr>
<td><strong>2.</strong> What’s next?</td>
<td></td>
</tr>
<tr>
<td><strong>3.</strong> “2” done, next priority is…</td>
<td></td>
</tr>
</tbody>
</table>

a. Check vital signs  
b. Apply a neck collar of appropriate size  
c. Test motor & sensory function over 4 limbs  
d. See relative for AMPLE history  
e. Prepare for intubation  
f. Provide pre-warmed IV fluids
But I am **NOT** working in A&E ...
Just Arrived PICU...

• The FIRST Priority of care is
  a. Perform neuro-observation
  b. Check airway patency & breathing effectiveness
  c. Remind MO to prescribe prn sedation
  d. Provide a splint for left leg
Just Arrived PICU...

- 3 hours after admission, patient becomes agitated, ventilator with high pressure alarm "on"....
  a. Inform MO
  b. Give prn sedation
  c. Reassess ABCD
  d. Order a CXR
Summary

- Trauma assessment & resuscitation in organized and efficient manner
  - Do no further harm
  - Treat greatest threat to life first
  - Treatment before diagnosis

- Frequent reassessment for dynamic change
  - If patient’s condition changed, go back and reassess ABCD.

- On-going evaluation patient’s response to all interventions
Teamwork required for TEAM to succeed