Definitions

- **Kinematics** – Study of energy transfer as it applies to identifying actual or potential injuries
- **Biomechanics** – Study of forces & their effects
- **Mechanism of Injury** - How external forces in the environment are transferred to the body
Newton’s Laws of Motion & Conservation of Energy

- **1st Law of Motion** - A body at rest will remain at rest. A body in motion will stay in motion
- **2nd Law of Motion**
  \[ \text{Force} = \text{Mass} \times \text{Acceleration} \]
- **3rd Law of Motion** – For every action, there is an equal and opposite reaction
- **Law of Conservation of Energy** – Energy cannot be created nor destroyed, but can change form
Energy Forms

- **Mechanical** – Energy transfer from object to object in the form of motion
- **Thermal** – Transfer of heat in the environment to the host
- **Chemical** – Heat energy transfer from chemicals
- **Electrical** – Energy transfer from blast sound waves, radioactivity or rays of the sun
Mechanisms of Injury

Need to Know

- Photographs & history have changed treatment
- Anticipate injuries based on MOI

Types of Injuries

- Fall from height
- Gunshot wound
- Stab wound
- MVC
- Pedestrian struck by motor vehicle
- Ejection from a vehicle
- Blast
- Burn
Transfer of Energy
Transfer of Energy
Transfer of Energy
Transfer of Energy
Kinetic Energy

Kinetic Energy = \( \frac{1}{2} \text{mv}^2 \)
Transfer of Energy

*Damage Depends on:*

1. Mass of the impactor/impacted
2. Velocity of the impactor/impacted
3. Shape of impactor
4. Elastic limits and compressibility contents of impactor and what is impacted
5. Area of body impacted
Transfer of Energy
Transfer of Energy
Transfer of Energy
Transfer of Energy
Transfer of Energy
Transfer of Energy

Steel
Transfer of Energy
Transfer of Energy

Water
Transfer of Energy
Transfer of Energy
Transfer of Energy
Transfer of Energy
Elastic Limit

- The amount of force required to disrupt the structural integrity of an object
- Strength
- Absorbing capacity/compressibility
- Resilience
- Vulnerability
  - Ribs (upper vs lower)
  - Skull vs long bone
  - Abdominal wall vs knee joint
Transfer of Energy

Injuries

Always

Are the Results

of

Transfer of Energy

into the Body
Human Missiles
Elastic Limits—Absorbing Capacity

- Absorbing capacity — ability to absorb energy without producing damage
- Impact
  - Velocity
  - Shape of impactor
  - How impacted
  - Elasticity–Resilience
Shape of Impactor

Simple Rib Fracture

Laceration?

Lung

Rib

Lung

Rib
Shape of Impactor

- Rib
- Lung
- Flail Segment
- Contusion?
Absorption of Energy (automobiles)

1. Padded dash
2. Recessed knobs/handles
3. Collapsing steering column
4. Lap belts
5. Shoulder harness
6. Energy absorbing bumpers
7. 4 point
8. Airbags (front - side)
9. Side bars
10. Side airbags
External Forces

- **Deceleration Forces** – A sudden stop of body’s motion (fall, mvc)
- **Acceleration Forces** – A sudden & rapid onset of motion (pedestrian)
- **Combined Forces**
- **Compression Force** – Force applied at time of impact
  - Stationary objects
  - Objects in motion
  - Blast Forces
Internal Forces

- **Stress** – The internal force that resists the external force
- **Compression** – Crushed from surrounding organs or structures
- **Tensile** – Ability to resist tearing apart when stretched
- **Shear** – Ability to resist a force applied parallel to the tissue (Coup/Countercoup)
Energy May Cause:

- Compression
  - Blunt
  - Blast
  - Penetration
  - Rebound
  - Special

Acceleration - deceleration
Compression-Decompression

Motor

Water

Air
Compression

Water

Air
Energy Propagation

- Moves through body like the metal balls transfer energy to the last one
- Metal balls vs. rubber bumpers vs. balloons
- Moves through body in energy waves with a force and speed
- Dissipation depends on absorbing capacity of structure(s) impacted by the wave
- Damage may occur from from area impacted
Energy Propagation

Waves of Energy

Compression

Dissipation
Compression

Increased Pressure

Exceeds Elastic Limit of Container

Rupture
Fluid-Filled Organs

- Capillaries
- Heart
- Brain
- Liver
- Spleen
- Stomach
- Bladder
- Eyes
Air-Filled Organs

- Middle Ear
- Alveoli
- Small Bowel
- Colon
- Head ?????
Traumatic Asphyxia
Flail Chest

- Fracture of two or more sites on 2 or more adjacent ribs
- 50% not clinically evident due to muscle spasm during the first hours post injury
- Chest wall instability with paradoxical movement
- Children have compliant chest walls rarely fracture ribs
Flail Chest
Flail Chest
Radiographic Signs

- Segmental rib fractures of multiple ribs
- Panel moves in with inspiration and out with expiration
- Other evidence of thoracic trauma
Rupture of Diaphragm

Compression

Decompression

Diaphragm

Pop

Diaphragm

Stretch

Snap

Rebound
Organ Specific Compression Injuries

- **Head** – Open & closed skull fractures. Depressed skull fractures & hemorrhage
- **Thoracic** – Fractured ribs & sternum. Flail chest, pneumo/hemo thorax. Cardiac dysrhythmias, contusion, atrial or ventricular rupture
- **Abdominal** – Solid organ rupture, vascular hemorrhage, hollow organ rupture & diaphragmatic hernia
Penetrating Trauma

Does NOT
Occur
In a
Straight Line
Types of Penetrating Injuries

- Knives, needles, ice picks – Low velocity
- Impalement – Low velocity
- Explosions & Shrapnel
- Firearm wounds – medium to high velocity
  - Temporary cavitation
  - Permanent cavitation
  - Deformation
  - Fragmentation
  - Range
  - Type of tissue
Bullets

Rotation
Looses Energy
- Splash
- Tumbles
- Bounces

Entry/Exit - Poor relationship between entry-exit-damage

Bullet type
Velocity – High or low velocity
Shotguns

- Short range & low velocity
- Multiple pellets in a larger shell
- Shell contains pellets, gunpowder & plastic/paper wad of unsterile material
  - 12 Gauge 6 Shot - Concentrates 275 pellets into a 7 inch circle at 12 yards
http://visualstoryteller.files.wordpress.com/2010/02/gunshot-wounds.pdf
Acceleration-Deceleration

- Sudden Stop or Acceleration
- Hit with kinetic energy
- All have compression component
- Move at different rates depending on mass
- Stress at points of attachment
- Shearing forces
Organ Specific Deceleration Injuries

- **Head** – Bruising, crush injuries, lacerations, tearing of blood vessels with hemorrhage
- **Thoracic** – Aortic shearing at ligament arteriosum & cardiac tamponade
- **Abdominal** - Splenic capsule tears, shearing at kidney, spleen, & liver hepatic duct pedicles
Human Missiles

Causes

- Ejections
  - Human Cannonball
  - Snowmobiles
  - Motorcycles
  - Bicycles
  - Cars/Trucks, etc.
  - ATV’s – Golf carts

- Falls from Heights
  - Sky diving
  - Explosions
  - Wind (tornado)
Human Missiles

Factors

Acceleration

Flight

Deceleration (impact)
Acceleration-Deceleration

10

1
Acceleration-Deceleration
Acceleration-Deceleration

Stress Points

10

1
Acceleration-Deceleration

- Sudden Stop or Acceleration
- Hit with kinetic energy
- All have compression component
- Move at different rates depending on mass
- Stress at points of attachment
- Shearing forces
Shearing Forces

Shearing Occurs

whenever

Two Structures of Different Densities or Mass

Are Moving

at Different Rates
Shearing Forces

Greatest Shear Occurs at Points of Attachment
Attached Organs

- Heart - aorta
- Liver, spleen, kidney's
- Duodenum
- Lungs – bronchi
- Brain – venous sinuses
- Extremities
Trauma-Related Brain Injuries

- Concussion
- Epidural hemorrhage
- Subdural hemorrhage
- Intra-cerebral hemorrhage
- Brain mostly $\text{H}_2\text{O}$—compressible—not tolerate compression—decreased perfusion
Patterns of Injuries

- Falls – Based on point of impact & surface
- Motor Vehicles – 1\textsuperscript{st}, 2\textsuperscript{nd} & 3\textsuperscript{rd} impact
  1\textsuperscript{st} – Vehicle strikes on object – Victim accelerates
  2\textsuperscript{nd} - Occupant strikes the interior of the vehicle
  3\textsuperscript{rd} – Internal organs collide within the body cavities
Potential Patterns of Injuries

- **Frontal/Head-On**
  - *Up & Over* – Head & chest lead the way (No seatbelt)
  - *Down & Under* – Lower extremity & pelvic fractures (Seatbelt above pelvis)

- **Lateral/T Boned**

- **Rotational/Angular Impact**

- **Rear Impact**

- **Rollover**

- **Ejection**
Motorcycle Injuries

- Head-On – Head, neck, compression injuries
- Angular Impact – Open fractures of femur & lower legs, dislocation of malleolus
- Laying the Motorcycle Down – Slide away from the bike – Abrasions & fractures on the contact side
ATV’s & Snowmobiles

- Head & neck injuries
- Extremity soft tissue and fractures
- Clavicle fractures
Pedestrian Struck

- **Adult**
  - Thrown on the hood &/or windshield
  - Lateral impact

- **Child**
  - Thrown from the impact away from the vehicle
  - Run over
  - Triad of Injuries (Waddell) – Head, thorax & extremities
### Table 7. Overview Of Explosion-Related Injuries.*

<table>
<thead>
<tr>
<th>System</th>
<th>Injury or Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory System</td>
<td>Ruptured tympanic membrane, disruption of the ossicles, damage of the cochlea</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Myocardial contusion, myocardial infarction from air embolism, cardiogenic shock, peripheral vascular injury, peripheral ischemia from air embolism, shock</td>
</tr>
<tr>
<td>Extremity Injuries</td>
<td>Fractures, amputations, crush injury, compartment syndrome, burns, cuts, lacerations, acute occlusion of an artery, air embolism-induced injury</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Viscus perforation, hemorrhage, fracture/rupture of liver or spleen, mesenteric ischemia from air embolism, sepsis</td>
</tr>
<tr>
<td>Neurologic System</td>
<td>Concussion, closed brain injury, open CNS injury, stroke from air embolism, spinal cord injury. Primary blast injury can cause concussion without a direct blow to the head.</td>
</tr>
<tr>
<td>Ocular Injury</td>
<td>Perforated globe, foreign bodies, air embolism, and orbital fractures. Up to 10% of blast injury survivors have significant eye injuries.</td>
</tr>
<tr>
<td>Renal Injury</td>
<td>Renal contusion, kidney laceration, acute renal failure due to shock or rhabdomyolysis, testicular rupture</td>
</tr>
<tr>
<td>Respiratory System</td>
<td>Blast lung, hemothorax, pneumothorax, pulmonary contusion, pulmonary hemorrhage, arteriovenous fistula (air embolism), airway epithelial damage, aspiration pneumonitis, sepsis. Blast lung is a direct consequence of the HE overpressure wave. It is the most common fatal primary blast injury among initial survivors of an explosion.</td>
</tr>
</tbody>
</table>

Blast Injuries

- **Primary Blast** – Sudden changes in environmental pressure results in rupture of eardrums, blast lung, CNS & abdominal hemorrhage/bowel perforation
- **Secondary Blast** – Struck by debris with lacerations, fractures, amputations
- **Tertiary** – Victim propelled through space & strikes an object
- **Quaternary** – Other illnesses or diseases caused by explosion (COPD, asthma, MI, burns, hypertension)
Vertical Falls

- **Distance/Height** - >15 feet associated with severe injuries
- **Body position/landing** – Position in which they fell
  - Head first – Children
  - Feet first - Adults
- **Type of surface**
Absorbing Capacity??

- Ground
- Tree
- Wall
- Snow
- Water
- Ice
- Playground surface
- Net
- Air bags
- Collapsible structures
- Helmet
- Restraints
- Roll bars
Human Missiles

“We fly through the air with the greatest of ease”

But

What happens when we

Take off?

Land?
Humans confront most threats with the most vulnerable parts of their bodies!!!!
Occlusive/Obtrusive Injuries

- Drownings
  - Water enters the lungs with shearing force causing the lungs to expand and bleed
  - Dry drowning – Laryngeal spasm from water with airway obstruction

- Hanging, Strangulation & Compression
  Asphyxia
  - Constricts blood flow & O2 perfusion
  - Edema, obstructing the airway
Most Trauma-Induced Injuries Are Preventable!!!