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UNIT TERMINAL OBJECTIVE

4-1 At the completion of this unit, the EMT-Intermediate student will be able to apply the principles of kinematics to enhance the patient assessment and predict the likelihood of injuries based on the patient's mechanism of injury.

COGNITIVE OBJECTIVES

At the completion of this unit, the EMT-Intermediate student will be able to:

4-1.1 List and describe the components of a comprehensive trauma system. (C-1)
4-1.2 Describe the role of and differences between levels of trauma centers. (C-3)
4-1.3 Describe the criteria for transport to a trauma center. (C-1)
4-1.4 Describe the criteria and procedure for air medical transport. (C-1)
4-1.5 Define energy and force as they relate to trauma. (C-1)
4-1.6 Define laws of motion and energy and understand the role that increased speed has on injuries. (C-1)
4-1.7 Describe each type of impact and its effect on unrestrained victims (e.g., frontal impacts, lateral impacts, rear impacts, rotational impacts, rollover). (C-1)
4-1.8 Describe the pathophysiology of the head, spine, thorax, and abdomen that results from the above forces. (C-1)
4-1.9 Describe the organ collisions that occur in blunt trauma and vehicular collisions. (C-2)
4-1.10 Describe the effects that restraint systems (including seat belts, airbags, and child safety seats) have on the injury patterns found in motor vehicle crashes. (C-2)
4-1.11 List specific injuries and their causes as related to interior and exterior vehicle damage. (C-1)
4-1.12 Describe the kinematics of penetrating injuries. (C-1)
4-1.13 List the motion and energy considerations of mechanisms other than motor vehicle crashes. (C-1)
4-1.14 Define the role of kinematics as an additional tool for patient assessment. (C-1)

AFFECTIVE OBJECTIVES

None identified for this unit.

PSYCHOMOTOR OBJECTIVES

None identified for this unit.

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DECLARATIVE

I. Introduction
- A. Epidemiology
  1. A leading cause of death for people 1- 44 years of age
  2. 140,000 unexpected deaths per year
  3. Automobile related deaths are greater than 40,000
  4. Penetrating trauma may exceed blunt in near future
  5. Pre-incident, incident, post-incident phase
- B. History
  1. Complete and accurate history of incident will identify possibility for 95% of the injuries present
  2. Incident site
     - a. Indications of severity of injury
  3. Major factors of tissue injury
  4. Amount of energy exchanged
  5. Anatomical structures potentially involved

II. Trauma systems
- A. Components
  1. Injury prevention
  2. Prehospital care
     - a. Treatment
     - b. Transportation
     - c. Trauma triage guidelines
  3. Emergency Department care
  4. Interfacility transportation as necessary
  5. Definitive care
  6. Trauma critical care
  7. Rehabilitation
  8. Data collection/ trauma registry
- B. Trauma centers
  1. Levels
  2. Qualifications
     - a. Essential
     - b. Desired
  3. Role
- C. Transport considerations
  1. Level of receiving facility
  2. Mode of transport
     - a. Ground
       - (1) If appropriate facility can be reached within reasonable time
       - (2) To a more accessible landing zone for air medical transport
     - b. Air medical
       - (1) Indications
       - (2) Contraindications
       - (3) Procedure

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III. Energy
- A. Physical laws
  - 1. Newton's first law of motion
    - a. A body at rest or a body in motion will remain in that state until acted upon by an outside force
    - b. In a vehicle traveling at 50 mph, the occupant is also traveling at 50 mph
    - c. When the car stops, the occupant continues to travel at 50 mph until some force acts on the occupant
  - 2. Conservation of energy
    - a. Energy cannot be created nor destroyed
    - b. It can be changed in form
    - c. Energy can be absorbed producing deformation of substance
  - 3. Kinetic energy (KE)
    - a. KE = ½ the mass of the object multiplied by the velocity (speed) of the object squared (Mass/ 2 x V^2)
    - b. Velocity (V) influences KE more than mass
    - c. Greater speed means more energy generated
  - 4. Force
    - a. Force = mass x acceleration
    - b. Force = mass x deceleration
    - c. Mass x acceleration = force = mass x deceleration
    - d. To accelerate a bullet from the muzzle of a weapon requires the force from the explosion of the gunpowder; once the bullet is set in motion by this explosion, an equal amount of tissue destruction must occur inside the body to stop it as was used to start it
  - 5. Energy law summary
    - a. Motion is created by force (energy exchange)
    - b. Force (energy exchange) must stop this motion
    - c. If such energy exchange occurs inside the body tissue damage is produced
- B. Energy exchange
  - 1. Cavitation
    - a. Energy exchange produces particle motion
    - b. Temporary cavity
      - (1) Short lived
      - (2) Produced by stretching
      - (3) Dependent on the elasticity of the object involved
      - (4) Produces particle compression at the limits of the cavity
    - c. Permanent cavity
      - (1) Visible when the energy exchange has been completed
      - (2) Produced by compression and destruction
  - 2. Interaction between two bodies
    - a. At least one must be in motion
    - b. Both can be in motion
  - 3. Dependent on number of particles involved in the interface of the interaction
    - a. Density of the interacting bodies
      - (1) Air density (few particles)
        - (a) Lung

(b) Intestinal tract
(2) Water density (more particles)
(a) Vascular system
(b) Liver
(c) Spleen
(d) Muscle
(3) Solid density (thick particles)
(a) Bone
(b) Asphalt
(c) Steel
b. Area on interaction
(1) Shape of object
(2) Position of object
(3) Fragmentation of object

C. Types of trauma based on ingress
1. Blunt
a. Tissue not penetrated
b. Cavitation away from site of impact
c. Cavitation in direction of impact
2. Penetrating
a. Tissue penetrated
b. Cavitation at 90° to bullet pathway
(1) Tissue in line to penetration is crushed

IV. Blunt trauma
A. Vehicle collisions
1. Frontal
2. Lateral
3. Rear
4. Rotational
5. Roll over
B. Occupant collisions
1. Frontal impacts
a. Down and under
(1) Feet impact floor pan
(2) Knees impact dash
(a) Tibia impact
i) Knee dislocation
ii) Popliteal artery disruption
iii) Knee support disruption
(b) Femur impact
i) Femur fracture
ii) Acetabular posterior fracture dislocation
(3) Torso rotates
(a) Steering column
(b) Dash
(c) Windshield

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b. Up and over
(1) Head impact
(a) Windshield
(b) Roof
(c) Mirror
(2) Chest impact
(a) Steering column
(b) Dash
(3) Abdominal impact
(a) Steering column
(b) Dash

2. Lateral impacts
a. Vehicle moves into and impacts body
(1) Chest
(2) Pelvis
(3) Body moves laterally
(a) Neck
i) Rotates
ii) Lateral flexion
iii) Combination

3. Rear impacts
a. Vehicle seat pushes body
(1) All body parts in contact with seat move
(2) Body parts not in contact dragged along with torso
b. Secondary impact if vehicle hits another object
(1) Similar to frontal impact

4. Rotational impacts
a. Part of vehicle stops; the rest remains in motion
b. Combination of frontal and lateral impacts

5. Roll overs
a. Difficult to predict the body impacts

C. Organ collisions
1. Two types of injury from blunt trauma
a. Compression
b. Change in velocity
(1) Acceleration
(a) Shear
(b) Avulsion
(2) Deceleration
(a) Shear
(b) Avulsion

2. Organ collisions with different vehicular collisions
a. Frontal impacts
(1) Head
(a) Compression
i) Skull fractures
ii) Cerebral contusion

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(b) Deceleration
- i) Opposite end separation
- ii) Hemorrhage
- iii) Brain stem stretch

(2) Neck
- (a) Compression
  - i) Vertebral body
    - a) Compression fracture
    - b) Hyperextension injury
      - Posterior element compression
      - Anterior body separation
    - c) Hyperflexion injury
      - Anterior body compression
      - Posterior element separation
- (b) Shear
  - i) Not significant

(3) Thorax
- (a) Chest wall
  - i) Compression
    - a) Fracture rib(s) - producing single rib fractures, flail chest, and/ or pneumothorax
  - ii) Shear
    - a) Fracture thoracic spine
- (b) Heart
  - i) Compression
    - a) Contusion
    - b) Rupture
  - ii) Shear
    - a) Not significant
- (c) Aorta
  - i) Compression
    - a) Not significant
  - ii) Shear
    - a) Junction arch and descending portions
    - b) Aortic origin at the aortic valve
    - c) At the diaphragm
- (d) Lung
  - i) Compression
    - a) Pneumothorax
    - b) Rib fracture and penetration
  - ii) Shear
    - a) Not significant

(4) Abdomen
- (a) Abdominal cavity
  - i) Diaphragm
    - a) Compression tears
    - b) Shear - not significant

ii) Abdominal wall
a) Compression tears
b) Shear - not significant
(b) Liver
i) Compression
a) Burst type injuries
ii) Shear
a) Tears from Ligamentum Teres
b) Avulsion of liver from inferior vena cava at the hepatic veins
(c) Spleen
i) Compression
a) Burst
ii) Shear
a) Avulsion of pedicle
(d) Gastrointestines
i) Compression
a) Rupture
ii) Shear
a) Avulsion of mesenteric vessels from aorta or vena cava
b) Tears along mesenteric vessels
c) Avulsion of vessels from intestine
(e) Gall bladder
i) Compression
a) Rupture
ii) Shear
a) Avulsion from liver
b) Avulsion of cystic duct

b. Lateral impacts
(1) Head
(a) Compression
i) Similar to frontal except lateral and compression is on the side of the impact to the vehicle
(b) Shear
i) Shear of brain and vessels opposite side of the impact
(2) Cervical spine
(a) Compression
i) Minimal unless head hits the top of the passenger compartment or the support for the windows
(b) Shear
i) Two fold mechanism
ii) Rotation
a) Center of gravity of the head is anterior to the pivot point of the head and the spine at the odontoid process; as lateral impact occurs the torso and then the C-spine are pushed under the

head; the head rotates in relative position to the body, toward the impact

b) The center of gravity of the head is also cephalad to the point of support at the cervical spine; as the lateral forces push the torso away from the point of impact the motion of the head produces lateral flexion of the head

c) The combination of these two forces is lateral flexion of the neck opening the facets opposite the side of impact and rotation of the vertebral bodies in relation to each other; the result is jumped facets and if the force is great enough significant torsion of the spinal cord

(3) Thorax
- (a) Compression
  - i) Impact of the door into the thorax
    - a) Lateral ribs - Fractures and flail chest
    - b) Lung - Pneumothorax
    - c) Spleen or liver - Lacerations and hemorrhage
- (b) Shear
  - i) Lateral motion of the thoracic spine as the torso is pushed away from the impact
  - ii) Thoracic aorta moves with the spine
  - iii) Arch and heart do not move until traction on the arch
  - iv) Shear forces tear the aorta at the junction of the movable arch and the descending aorta that is attached to the thoracic spine

(4) Abdomen
- (a) Compression
  - i) Liver or spleen depending of the side of the impact
  - ii) Kidneys depending of the side of the impact
  - iii) Diaphragm similar to frontal impact
- (b) Shear
  - i) Abdominal aorta moves with the lumbar spine
    - a) Shear of the renal vessels
    - b) Shear of the splenic vessels

(5) Pelvis
- (a) Compression
  - i) Impact on the femur
    - a) Femoral head driven through the acetabulum
    - b) Fracture of the ileum
    - c) Sacro-iliac joint fracture
    - d) Fracture of the other bones of the pelvis
- (b) Shear

(6) Extremities
- (a) Compression
  - i) Clavicle compressed between the humerus and the

sternum
ii) Lateral compression of the humerus
(b) Shear

c. Rear impacts
(1) Physics
(a) Energy (velocity) imparted to the rear
i) Moves all attached parts of the vehicle
ii) Occupants in direct contact with vehicle move also
iii) Parts of the occupants not in direct contact do not move until pulled along
a) Newton's first law of motion
b) Unrestricted body parts will be separated or at least stretched by this differential velocity
iv) The force of the energy exchange depends on the differential energy of the two vehicles and the exchange of energy between the two
(2) Head
(a) Compression
i) Into structures behind the seat
ii) Energy of compression depends on the force of the change of energy between the vehicle and the impact into the head
(b) Shear
i) Separation of the brain and skull in front
(3) Neck
(a) Compression
i) Unrestrained occupant into the top of the passenger compartment or into the rear seat
(b) Shear
i) Head restraint not in the correct position to move the head forward with the motion of the vehicle
ii) Neck hyperextended over the malpositioned head restraint; usually only ligamentous and tendon stretch and no fractures
(4) Torso
(a) As most of the torso is in contact with the seat and springs of the seat, only minimal differential energy is exchanged onto the body parts
(b) Unless there is rebound when the vehicle hits another vehicle there is little injury to the torso
(5) Extremities
(a) The extremities move with the torso and receive very little differential exchange

d. Rotational impacts
(1) In the pure rotational impact, one part of the vehicle hits an immovable object, while the rest continues in motion (Newton's first law of motion)
(2) As the one part stops and the rest of the vehicle continues to move the

vehicle moves around the fixed point
(3) The motion to the occupant is a combination of two motions
(a) Frontal and lateral
(b) Rear and lateral
(4) The injuries are combinations of the two motions with emphasis on the initial impact motion
e. Roll overs
(1) Pattern of injuries is very difficult as the unrestrained occupant can hit all parts of the vehicle
f. Ejections
(1) If the force is such and the occupant is unrestrained, then ejection is possible
(2) The major injuries occur inside the vehicle and on the way out rather than afterward on impact with the ground or some other object
(3) Since the major part of the injuries occur on the way out, the EMT-Intermediate can better predict the injuries by focusing on the first part of the collision rather than the latter portion

D. Restraints
1. Restraints are systems for absorbing the energy of the impact before the occupant hits something hard and limiting the distance the body has to travel, thus helping to decrease velocity (speed)
2. Belt restraint
a. Contrary to popular belief the belt restraint works in lateral impacts as well as in frontal impacts (they are not quite as effective in lateral impacts because the hard parts of the passenger compartment are closer on the sides than in the front, therefore the belt systems do not have as much distance to be effective)
b. The benefit of the belt restraint can be seen on any Sunday at the automobile race track
c. Lap belts
(1) Attached to the floor behind the occupant at a 45° angle to the floor
(2) Benefits
(a) Hold the lower torso closely to the seat and away from the dash or steering column
(b) Prevent
i) Forward motion of the lower torso in frontal collisions
ii) Moves the torso with the vehicle and away from the impact in lateral impact collisions
iii) Multiple impacts in rollover collisions
iv) Ejection
v) Forward motion of the pelvis by supporting the anterior part of the pelvis
(c) No impingement on the soft intra-abdominal contents
(3) Limitations
(a) Upper torso is not supported
(b) If positioned above the anterior iliac spine, the belt stops the forward motion of the body against the lumbar spine with the intra-abdominal organs crushed between the belt and the spine

(c) High position can fracture or dislocate the lumbar spine
(d) Increased intra-abdominal pressure can rupture the diaphragm

d. Shoulder restraints
(1) Benefits
(a) Prevent
i) Forward motion of the upper torso in frontal impact collisions
ii) Hyperflexion of the upper torso around the lap belts preventing spinal injuries
(b) Moves the upper torso with the vehicle in lateral impact collisions
(2) Limitations
(a) If worn without the lap belt, neck injuries can occur
(b) Lessened benefit if the seat is very close to the dash or steering column

e. Air bags
(1) Benefits
(a) Supplemental protection
(b) Frontal impact protection only with frontal bags
(2) Limitations
(a) Minimally effective alone
(b) Can produce significant injuries if too close to the occupant
i) Bag expansion
ii) Protective cover into the face or chest
(c) Projects standing children into the seat producing cervical spine fractures
(d) Facial and forearm abrasions
(e) Deployed air bag may hide structural damage to the vehicle that may aid in assessment

f. Child safety seats
(1) Age and types
(2) Proper use
(3) Injury patterns
(4) Proper use with airbags

E. Motorcycle collisions
1. Frontal impact
a. Bike stops
b. Occupant continues forward
(1) Impacts parts of the bike
(a) Face
(b) Chest
(c) Abdomen
(d) Upper legs (femur)
(2) Ejected over the bike
(a) Into vehicle
(b) Onto ground
(c) Into objects in the path

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(3) Injuries
(a) Cervical spine fractures
(b) Torso
i) Compression injuries
a) Solid organ crush
b) Hollow organ rupture (e.g., lungs)
ii) Deceleration (shear injuries)
a) Aorta
b) Pedicled organs
(c) Compound tibia/ fibula fractures

2. Angular impact
a. Collapse of bike onto vehicle
(1) Legs trapped between bike and vehicle
(2) Open fracture and/ or dislocation
b. Lateral motion of torso into vehicle
c. Injuries
(1) Cervical spine
(a) Similar to lateral impact in vehicle
(2) Torso
(a) Compression
i) Lateral chest
ii) Lateral abdomen
(b) Deceleration
i) Aorta
ii) Pedicled organs

3. Protection
a. Head
(1) Helmet
(a) 300% increase in brain injury without helmet
(b) Spine
i) Small protection
ii) No increase
b. Skin
(1) Leathers
(2) Very protective during slides on asphalt
c. Ankles and feet
(1) Strong boots

F. Pedestrian versus motor vehicle
1. Injury pattern depends on
a. Height
b. Body area facing impact
2. Three phases
a. Vehicle-pedestrian impact
(1) Legs
(a) Feet stay in place on asphalt
(b) Legs pushed by bumper
(c) Torso moves after the legs

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(2) Torso
(a) Pelvis
(b) Crushed by front of vehicle
(c) Lateral or posterior angulation
i) Lumbar fractures
ii) Thoracic fractures

b. Pedestrian rotates onto hood
(1) Impact onto torso
(a) Compression injuries
(b) Acceleration (shear) injures
(2) Cervical spine
(a) Severe flexion or lateral flexion
(b) Torsion
(c) Fractures and dislocations

c. Pedestrian rolls off onto the ground (asphalt)
(1) Beside vehicle
(a) Impact into the ground as fall from height
(2) In front of vehicle
(a) Run over by the vehicle
(b) Dragged by the vehicle

G. Falls

1. Factors
a. Height of fall
b. Surface of the impact
c. Objects struck during the fall
d. Body part of first impact

2. Feet first
a. Impact onto calcaneus
b. Continued motion of the torso
(1) Ankles, knees, femur
(2) Acetabulum, pelvis
(3) Spine
(a) Break the “S”
(b) Arch
i) Convexity stretched and opened
ii) Concavity compressed
(4) Torso
(a) Deceleration (shear)
i) Liver
ii) Kidney
iii) Spleen
iv) Aorta

3. Head first
a. Compression
(1) Skull fracture
(2) Brain
(a) Contusion

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(b) Laceration
(3) Spine
b. Deceleration (shear)
(1) Aorta
(2) Kidney
(3) Other
4. Parallel to ground
a. Compression
(1) All parts of the impact

V. Penetrating injuries
A. Energy exchange
1. Number of particles involved
a. Density of tissue
(1) Gas
(a) Lung
(b) Gastrointestinal tract
(2) Liquid
(a) Blood vessels
(b) Muscle
(c) Solid organs
i) Spleen
ii) Liver
iii) Kidney
iv) Other
(3) Solid
(a) Bone
b. Area of interaction
(1) Deformation of bullet
(2) Tumble
(3) Fragmentation
2. Cavitation
a. Permanent
(1) Visible when examined
(2) Crushed tissue
b. Temporary
(1) Compression wave of tissue particles
(2) Away from the pathway of the bullet
(3) Lasts only a few microseconds
(4) Tissue damage produced by stretch
3. Available energy
a. $KE = M/ 2 \times V^2$
(1) Velocity more important than the mass
b. Mass x acceleration = force = mass x deceleration
(1) The energy used to place the mass in motion must be completely exchanged into the body tissues to stop the mass
c. Energy potential

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(1) Continuum of energy increase
(2) Can be broken down into artificial but workable groups
(3) Energy
(a) Low energy objects
i) Hand driven
a) Knife
b) Ice pick
c) Ax
d) Other
ii) Minimal cavitation
iii) Damage only by cutting edge
(b) Medium energy
i) Muzzle velocity greater than 1500 feet/ second
ii) Hand guns, low power rifle
iii) Small projectile
iv) Cavitation 6-10 times bullet frontal area
(c) High energy
i) Muzzle velocity less than 1500 feet/ second
ii) Military high velocity small caliber weapons
a) Examples (M16, AK 47/74)
b) Other
iii) Cavitation 20-30 times frontal area of missile
(d) Implications of soft body armor

B. Anatomy
1. Organs injured
2. Pathway of missile
a. Entrance wound
(1) Hole is crushed inward
(2) Round or oval shaped
(3) Rim
(a) Dark
(b) 1-2 mm width
(c) Produced by grease and other substance on the bullet
(4) Abrasion
(a) Produced by spinning of the bullet
(b) Largest with greatest contact of skin
i) Larger when impact is at an angle
(5) Burn
(a) Flame from barrel
(b) End of weapon 4-6 inches from the skin
b. Exit wound
(1) Pushed outward
(2) Stellate or slit

VI. Blast
A. Introduction
1. The blast effect is broken down into three phases depending on the type of force that

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occurs during that phase
2. Each phase has a different energy pattern

B. Phases
1. Primary
a. Pressure wave of the blast
(1) Major effect on gas-containing organs
(a) Organ systems
i) Lungs
ii) Intestinal tract
(b) Pathology
i) Rupture of the organ
(c) Air emboli
b. Heat wave
(1) Burns on unprotected part of body
(2) Skin burns
(3) Eye burns
2. Secondary
a. Struck by flying particles
(1) Glass
(2) Bricks
(3) Wood
(4) Metal
b. Pathology
(1) Compression
(2) Lacerations
3. Tertiary
a. Patient becomes flying object
(1) Impact into other objects
(2) Similar to falls

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