


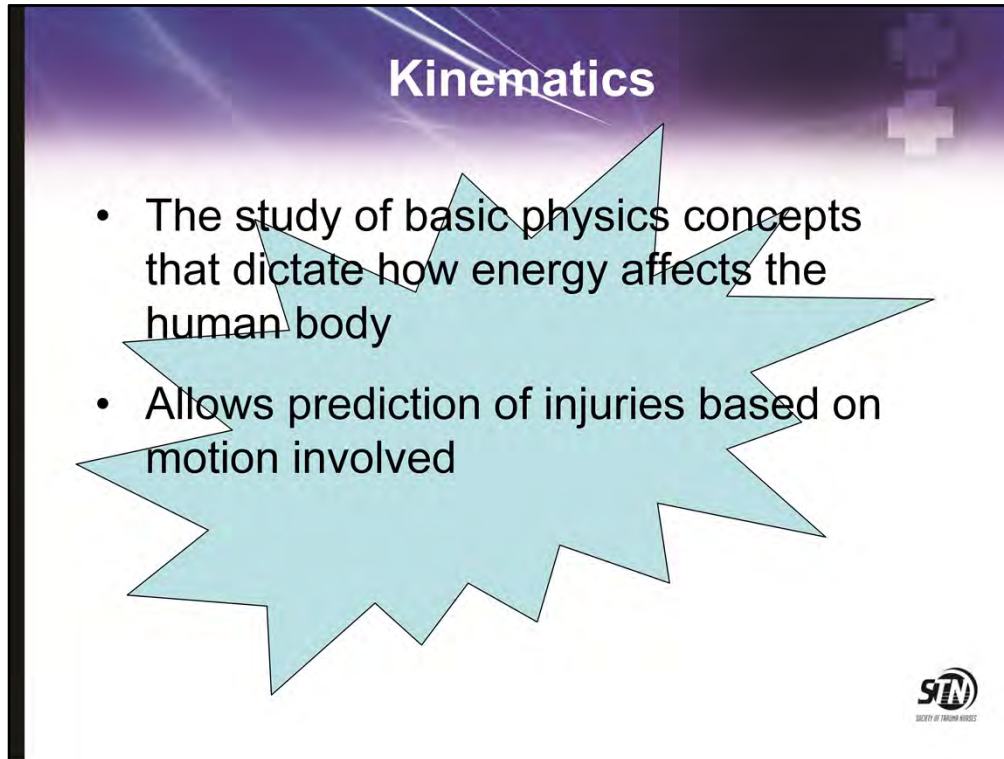
Objectives

At the conclusion of this presentation the participant will be able to:

- State how the fundamental principles of physics apply to various types of injuries
- Given a specific mechanism of injury, predict injury patterns



There are two main learning objectives for this presentation.

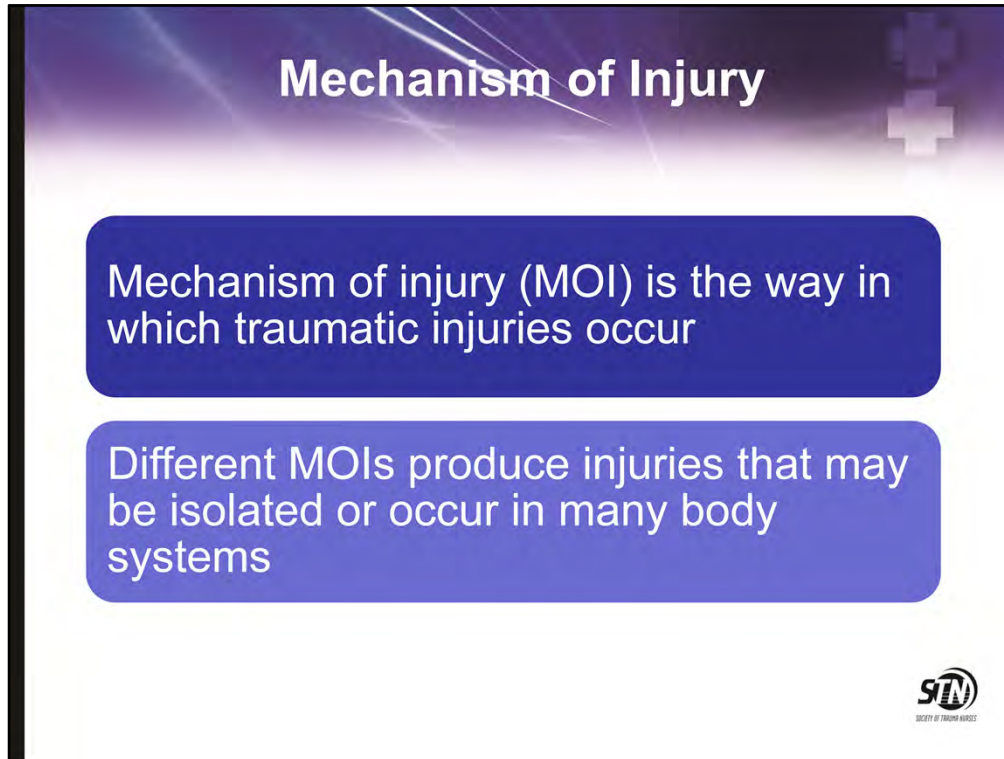
A presentation slide with a purple gradient background. At the top center, the word "Kinematics" is written in a bold, white, sans-serif font. Below the title, there is a large, light blue, multi-pointed starburst graphic. Inside this starburst, two bullet points are listed in black text. In the bottom right corner of the slide, there is a small logo for STN (Society of Trauma Nurses) which includes the letters "STN" in a stylized font and the full name "SOCIETY OF TRAUMA NURSES" in smaller text below it.

Kinematics

- The study of basic physics concepts that dictate how energy affects the human body
- Allows prediction of injuries based on motion involved

STN
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Many times, kinematics and mechanism of injury are used interchangeably. However, as you will note, kinematics is the actual study of motion of the body.



All injury except thermal and radiation relate to the relationship of the host and the moving object.

The most common MOI types include MVC, MCC, Fall, Assault, Bicycle, Pedestrian, GSW, Stab wound, etc.

Position, collision pattern, trajectory of projectiles, etc contribute to specific injury patterns that will be reviewed.

One may have an isolated injury such as a head injury or orthopedic injury. Or, a victim may have multiple injuries which may include more than one body system such as a head injury, orthopedic injury, spleen rupture, etc.



“Trauma” is the damage to the human body that results when it is exposed to EXCESSIVE ENERGY, beyond its tolerance.

It is the dissipation of that energy to/within the person.

Let’s step back and gain perspective.



Some types of trauma may result from the withholding of essential energy. For instance, depriving a human of basic needs such as essential oxygen...

We would not ordinarily think of trauma in this manner, but in the broad sense, one could consider this injury from this perspective.



A hanging may lead to oxygen deprivation by interrupting blood flow to the brain.

Not only does this anoxic injury occur, but we also consider the more physical effects that the patient may experience such as an injury to the cervical spine, larynx, trachea, etc.

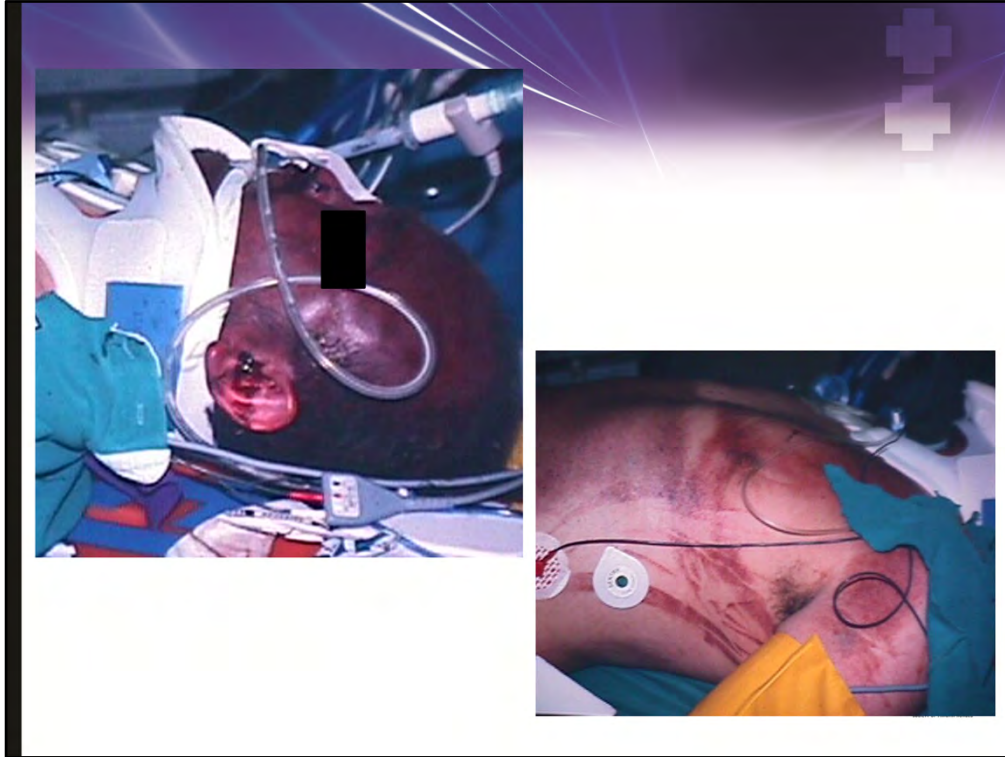


Or “traumatic asphyxia” may result from a man trapped in a trench cave-in.

Traumatic asphyxia is produced by a sudden increase in venous pressure due to severe compression or crushing injury of the thorax or upper abdomen, or both. The mechanism is similar to hanging where insufficient or no oxygen and carbon dioxide are exchanged on a ventilatory basis as a result.

However, the patient may experience more of a physical injury.

Next slide.



This middle aged Caucasian male patient was crushed when he fell into a trash compactor. One can see the venous engorgement as noted in his face as well as the abrasions and contusions on his torso resulting from the prolonged crushing effect.



And although many trauma care providers may not think of it as classic trauma, dehydration, the withholding of essential water, is another type of injury.



Even starving to death would meet this definition.

Some may relate this better to malnourishment, starvation, etc that are sometimes seen in cases of abuse/neglect.

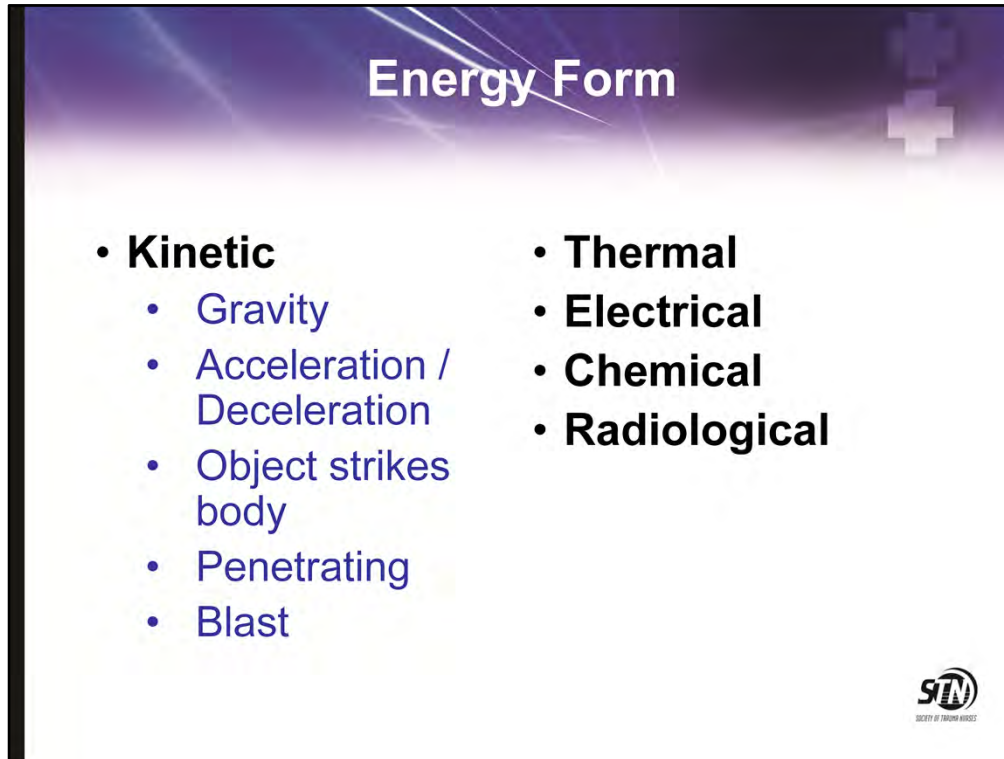


Hypothermia, frostbite, and other types of cold injury result from inadequate heat energy reaching the human body.

Most commonly seen on the digits and extremities.



But what we want to focus on here is the “Trauma” that is damage to the human body that results when it is exposed to EXCESSIVE ENERGY, beyond its tolerance.



Energy comes in many different forms. Most commonly seen by trauma care providers is damage as a result of “kinetic” energy – energy as a result of motion. Falls result from gravitational energy. Motor vehicle crashes usually involve deceleration energy transfers. Moving objects can strike the body. A special type of moving object is the blast wave in an explosion.

Other forms of energy that may result in tissue damage are: thermal, electrical, chemical, and radiological.

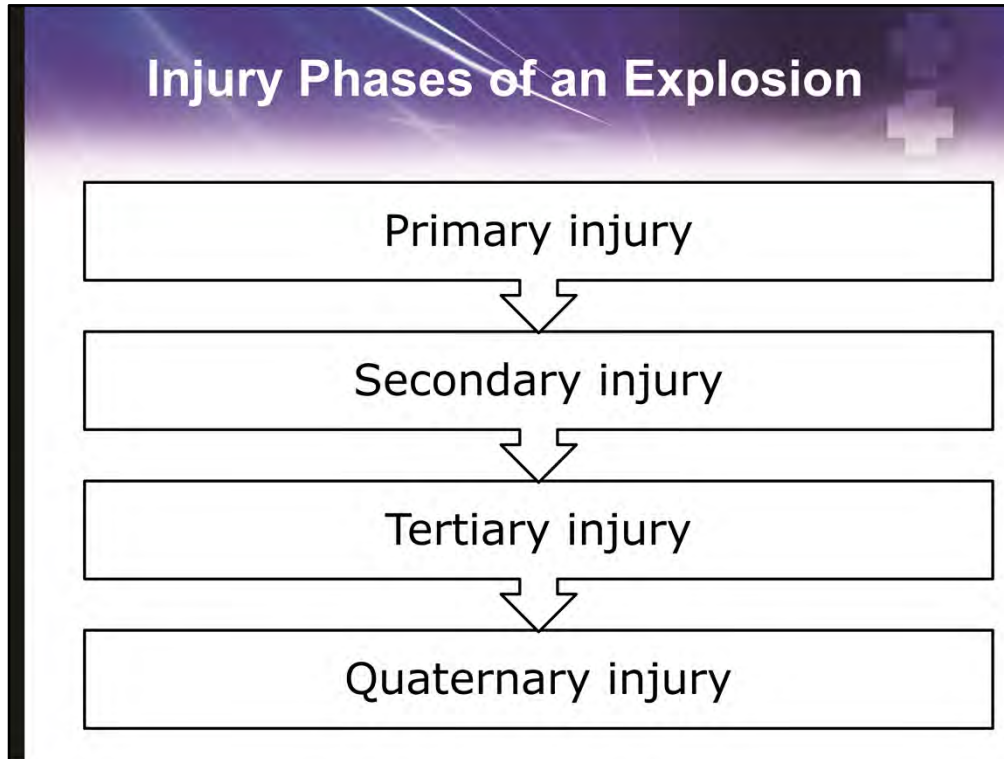
Let’s briefly review the latter prior to our discussion on the energy transfer we normally think of in trauma.



Trauma due to explosions is often due to mixed energy forms: damage from the blast wave itself, a special form of moving energy, often resulting in trauma to air-filled organs, and to the brain...

BUT ALSO, trauma resulting from being thrown (like a fall), in penetrating injury (impalement by fragments), and burns (from thermal energy).

There are technically four phases of blast injury potential



Primary – result of stress and shear waves; Tearing of structures from attachments by high local forces such as injuries to the lung parenchyma, the visceral pleura (pneumothorax or hemopneumothorax), solid organs, bowel and mesentery are seen.

Secondary – results from projectiles (flying debris) energized by the explosion and may be penetrating or blunt.

Tertiary – results from the body being displaced (thrown) during the external blast forces and may result in crush injuries and/or amputations that occur in structural collapse as an example

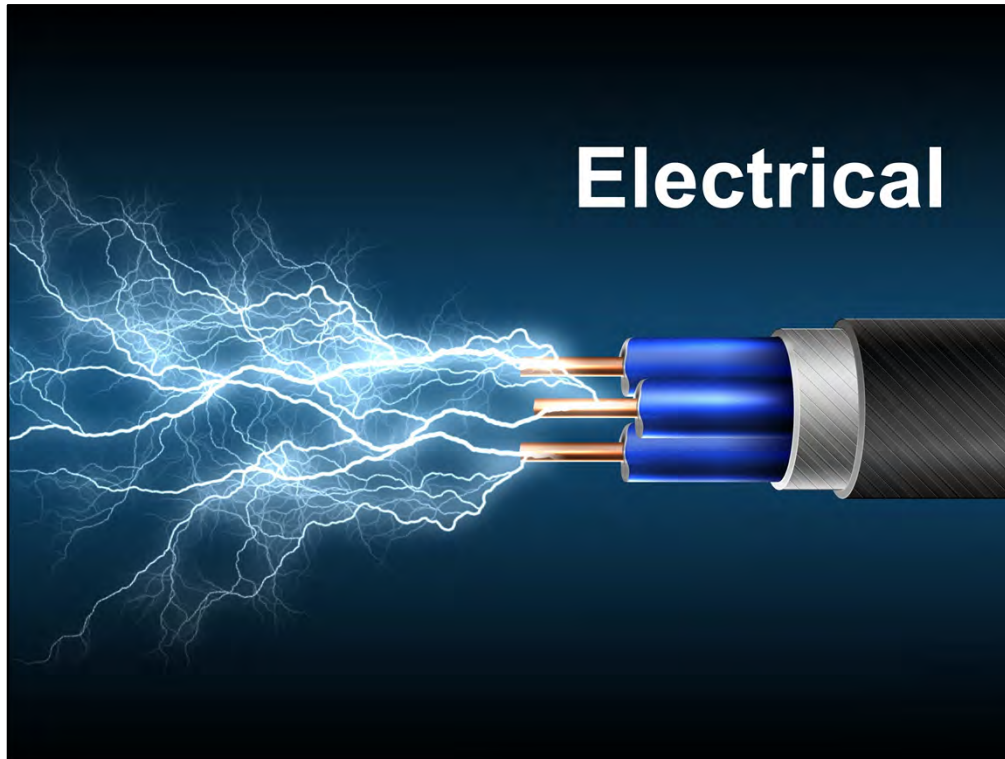
Quaternary – refers to other mechanisms of injury that cause injury. These may be related to flash burns, chemical burns, inhalation injuries, etc.



Another energy form is thermal. Excessive thermal energy may result in a person becoming overheated (hyperthermia), but more commonly known to cause burns.



(pause briefly on this slide)



Electrical energy can result in electrocution, cardiac dysrhythmia, and tissue damage (burns).



Excessive chemical energy beyond human tissue tolerance produces another type of trauma -- poisoning. Some mechanical trauma patients may also have been exposed to hazardous materials, resulting in a mixed mechanism of injury.



Chemical energy transfer is what we normally think of as a “poisoning”, and this is a type of trauma, although most overdoses or poisonings may not be usually thought of as “trauma”.




Very rarely, is trauma from ionizing radiation.

So, let's consider some basic principles that are important in our review of traumatic injury.

Understanding Physics

- Newton's First Law of Motion
(Law of Inertia)
- Newton's Second Law of Motion
- Newton's Third Law of Motion
(Law of Conservation of Energy)
- Kinetic energy





The logo for STN (Society of Trauma Nurses) is located in the bottom right corner of the slide. It consists of the letters 'STN' in a bold, stylized font, with the full name 'SOCIETY OF TRAUMA NURSES' written in smaller text below it.

We are not going to get into the details of all the physics principles nor much about the mathematics of these physical principles. But we will briefly describe each of Newton's Three Laws of Motion and some simple physics concepts that relate to the transfer of energy. Knowing a minimal amount of information can help us understand and predict the type, pattern, and severity of injuries that may result from different types of incidents.

Newton's laws of motion are three physical laws that describe the relationship between the forces acting on a body and its motion due to those forces. Each builds upon the next.

Newton's First Law

- Objects tend to stay at rest or in motion unless acted upon by some force
- Velocity is constant



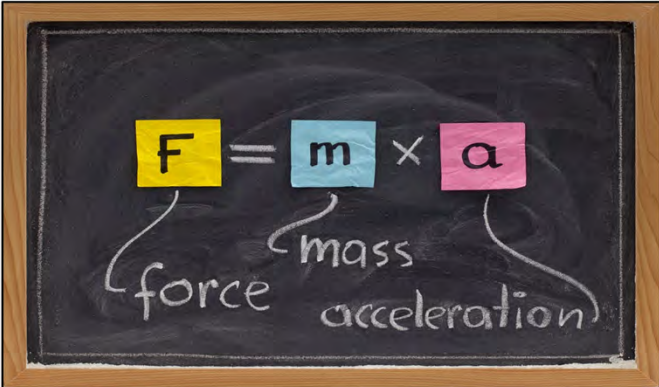
The object is stationary and will remain in this one spot and *continues* to do whatever it happens to be doing...just sitting there...unless a force is exerted upon it.

If the object is moving continuously, such as the space probe in outer space, it will continue to move unless an outside force is exerted upon it. A force is necessary to change the velocity of a body, e.g., acceleration, but no force is needed to maintain its velocity. The concept of inertia was actually discovered by Gallileo, and thus Newton gave credit when he otherwise titled his first law as the "*Law of Inertia.*"

Velocity is a vector quantity which expresses both the object's speed and the direction of its motion.


Newton's Second Law

Defines the relationship between acceleration, force, and mass



F = **m** × **a**

force mass acceleration




Very simple concept: It takes more force to move a heavy object than it does to move a light object.

Newton's second law requires modification if the effects of special relativity are to be considered, however, this is above and beyond the scope of this lecture.

Newton's Third Law

- For every action (force), there is an equal and opposite reaction.
- Energy cannot be created or destroyed
- Energy can only change from one form to another

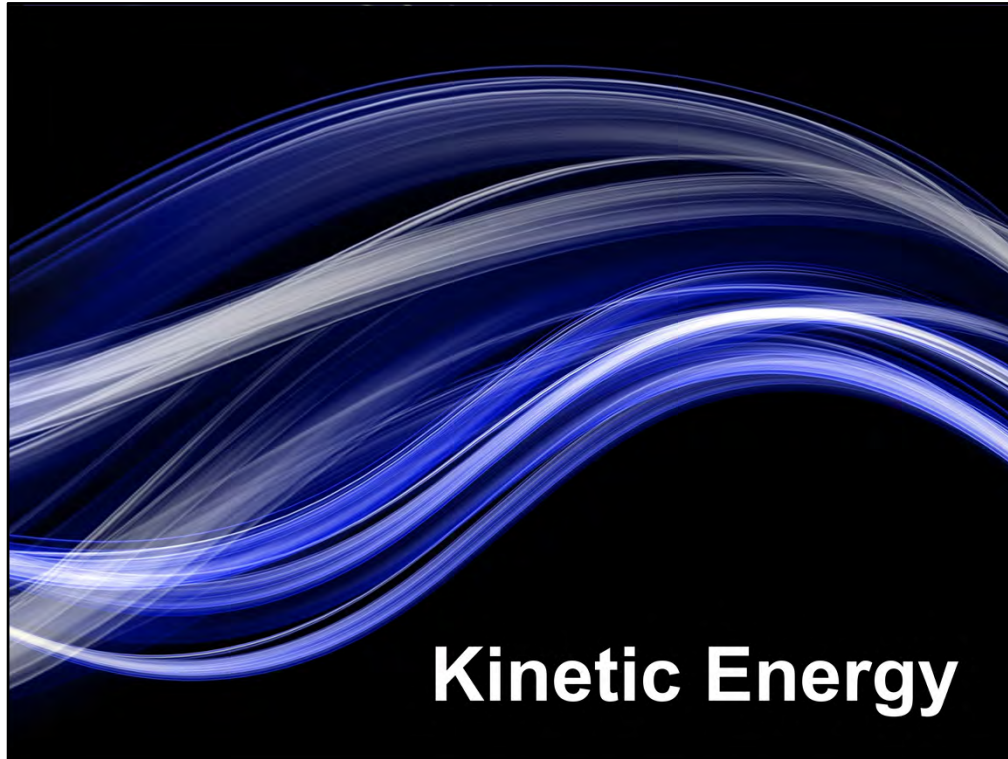


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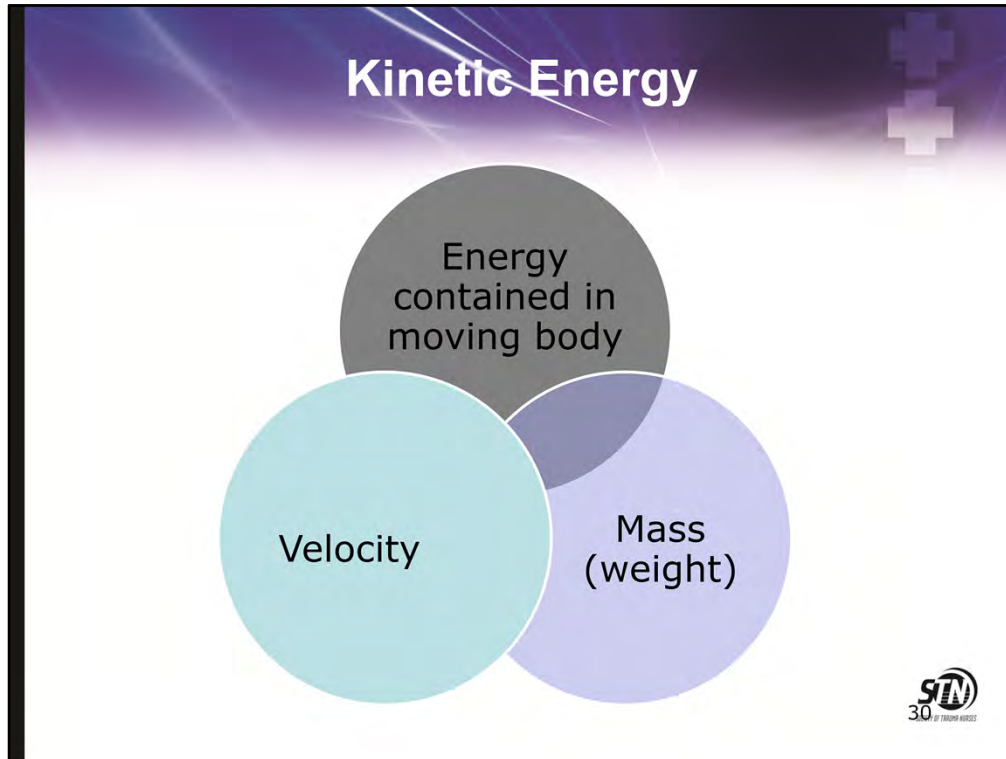
The law of conservation of energy (AKA Newton's third law) is that **energy cannot be created or destroyed, but it can be transferred or transformed from one form to another**. Energy in a system may be transformed so that it resides in a different state.

Simply put: Pushing on an object causes that object to push back against you, the exact same amount, but in the opposite direction.

Example of change in form: Suppose you push an empty plate across a table. The plate has kinetic energy but its motion decreases as it slides across the table as the energy is lost. In truth, the kinetic energy is not lost, but it just changes form due to the friction. Although we can go into more detail about the energy produced, the purpose is for you to recognize outside forces exist.



But most trauma care providers deal with tissue damage as a result of objects in motion. The excessive transfer of kinetic energy to the human body, beyond its normal tolerance, results in the damage we know as “trauma”. This is what we will focus on in this presentation.



Remember kinetic energy applies to energy that is in motion.

Kinetic energy = $\frac{1}{2}$ mass of an object X (velocity)²

Injury doubles when weight doubles but quadruples when velocity doubles!!

Example

- Head on collision
- The kinetic energy of two moving bodies that collide are combined.



Two vehicles traveling at 55 mph will have a significant impact as the force is equal to one traveling at 110 mph as opposed to colliding with a stationary object such as a tree or telephone pole.

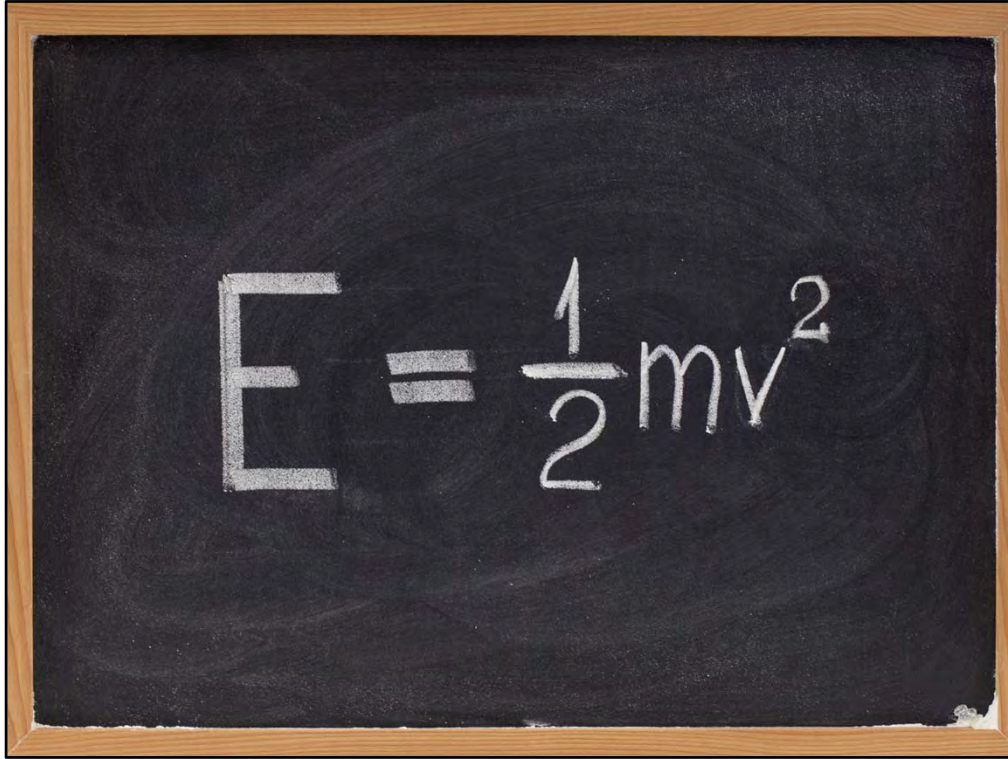


Kinetic energy in a moving object is never lost, but may be transferred to another object.



When the energy is transferred to another object, it will be accelerated. If this energy transfer is to a human body and is above the level the body can tolerate, tissue damage will result.

The cue ball dissipates energy to the remaining pool balls and they in turn spread the energy throughout.

A photograph of a black chalkboard with a wooden frame. The equation $E = \frac{1}{2}mv^2$ is written in white chalk on the board. The 'E' is on the left, followed by an equals sign, then a fraction with '1' over '2', then 'm', 'v', and a superscript '2'.

A useful way of looking at this is by this formula, where kinetic energy is a product of mass and velocity squared.

Note that the velocity (speed) element of the equation is squared. This means that speed contributes to the total energy much more than does mass.

Units of measure: kg, meters /second, and Joules

1 joules = a tennis ball moving at 14 mph

1000 joules = 1 kJ (kilojoule)

EXAMPLE:

180 lbs person moving at 30 mph

80 kg person at 13.41 meters per second

$$\mathbf{KE = \frac{1}{2} m v^2}$$

$$\mathbf{KE = 80 (13.41 \times 13.41) / 2}$$

$$\mathbf{KE = 7.193 \text{ kJ}}$$

Physicists usually use these units of measure: kilograms for mass, meters per second for velocity, and “joules” as the unit of measure of the total amount of kinetic energy.

In this example, an 80 kg (180 pound) person is moving at 30 miles per hour (13.41 meters per second). Putting these values into the Kinetic Energy equation, results in about 7 kilojoules.

EXAMPLE:

180 lb person moving at 30 mph

**80 kg person at 13.41 meters per
second**

$$\mathbf{KE = \frac{1}{2} m v^2}$$


$$\mathbf{KE = 80 (13.41 \times 13.41) / 2}$$

$$\mathbf{KE = 7.193 \text{ kJ}}$$

(pause briefly on this slide, let them read it, do not say anything)

Speed 30 → 42 mph

<u>EXAMPLE:</u>	<u>EXAMPLE:</u>
<ul style="list-style-type: none">• 180 lb person moving at 30 mph• 80 kg person at 13.41 meters per second• KE = $\frac{1}{2} m v^2$• KE = 80 (13.41 x 13.41) / 2• KE = 7.193 kJ	<ul style="list-style-type: none">• 180 lb person moving at 42 mph• 80 kg person at 18.774 meters per second• KE = $\frac{1}{2} m v^2$• KE = 80 (18.774x18.774) / 2• KE = 14.098kJ



If we increased the speed from 30 mph to 42 mph, and did the math, we would find that the total amount of kinetic energy resulting is DOUBLE. 7 kilojoules at 30 mph and 14 kilojoules at 42 mph.

A practical use of this is to realize that a car crash at 42 mph would result in twice the likely trauma or tissue damage as a crash at 30 mph.

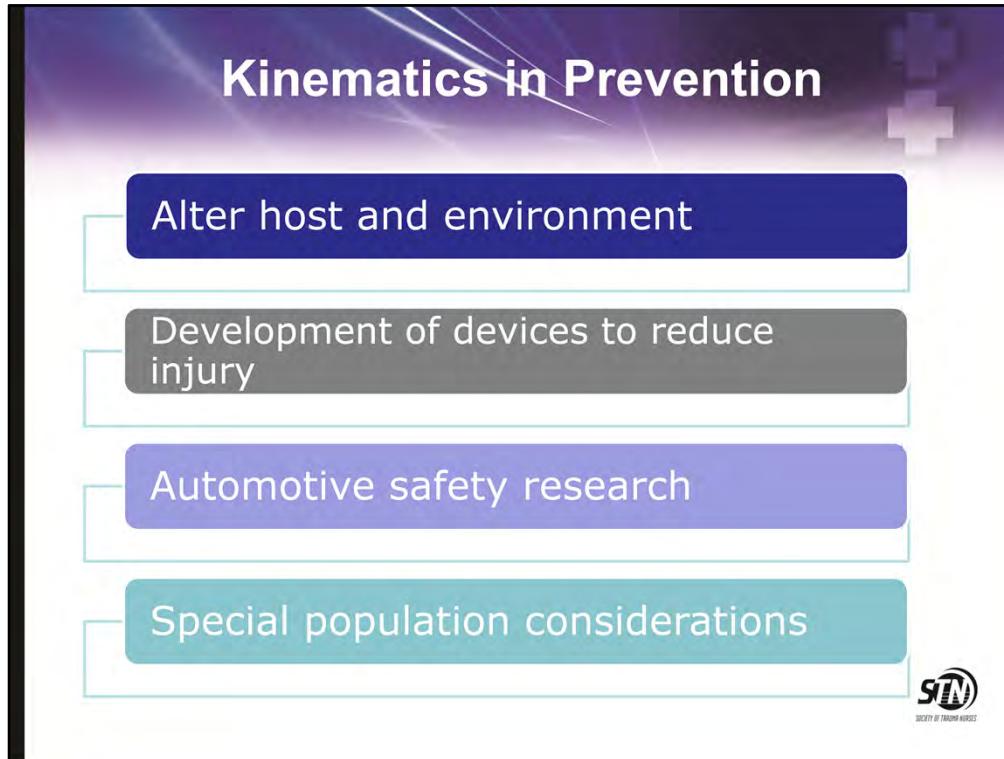
<u>30 mph</u>	<u>42 mph</u>
7.193 kJ	14.098 kJ
Increase speed from 30 to 43 mph, doubles KE	

A bit of increased speed can have a major effect on the total kinetic energy involved, and on the severity of the trauma that results.

Injury doubles when weight doubles but quadruples when velocity doubles



But, especially in motor vehicle crashes, one needs to remember the “velocity” that is squared is the total velocity of both cars. Two cars hitting head-on at 15 mph each results in a “DELTA V” of 30 mph.



William Haddon – ideas which became the cornerstone of injury prevention.

Many strategies involve altering the host and environment.

Injury Prevention Concepts:

Automotive

- Decrease force transmitted to passenger compartment. Vehicles are now made to “crumple” upon impact.
- As a result, the momentum changes and will occur over a longer period of time.
- Engine/transmission design now directs this downward as opposed to into the passenger compartment.
- Restraint systems allow the passenger to maintain velocity equal to that of the car and more evenly distributes energy loads over a greater surface.
- Can still cause injury, especially if worn improperly
- Lap belt - Compression injuries of bowel (rupture), pelvic fractures, mesentery tears/laceration, L spine fractures
- Shoulder harness – intimal tears or thrombosis of great vessels of neck and thorax; fracture/dislocation of cervical spine
- Even with proper use may cause clavicular and rib fractures; perforation of hollow viscus secondary to compression mechanism
- May still generate kinetic energy during the crash which in turn can be dissipated through airbag deployment
- Airbags may cause injury
- 100 deaths reported over a five-year period as a result of improper restraint and/or passenger location
- Corneal abrasions, facial lacs, facial burns

Helmet use by bicyclists and motorcyclists absorb some the energy during impact and thus, it is not transmitted to the brain.

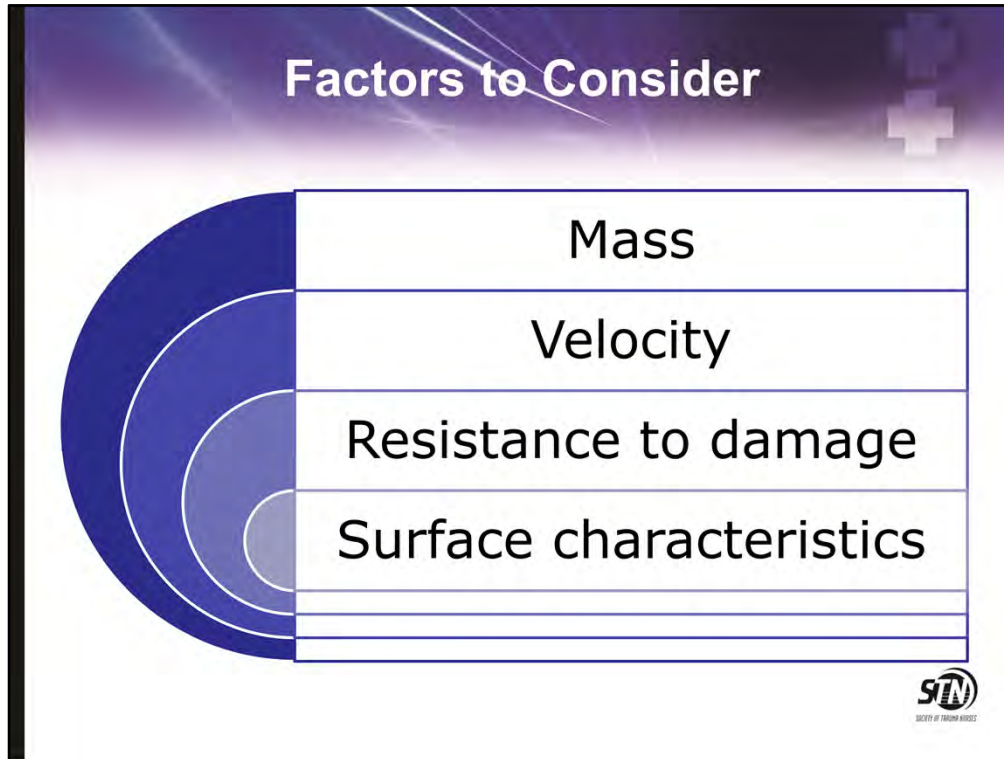
Special populations: pediatric, pregnant, and elderly considerations will be reviewed under their respective sections and are familiar to all.



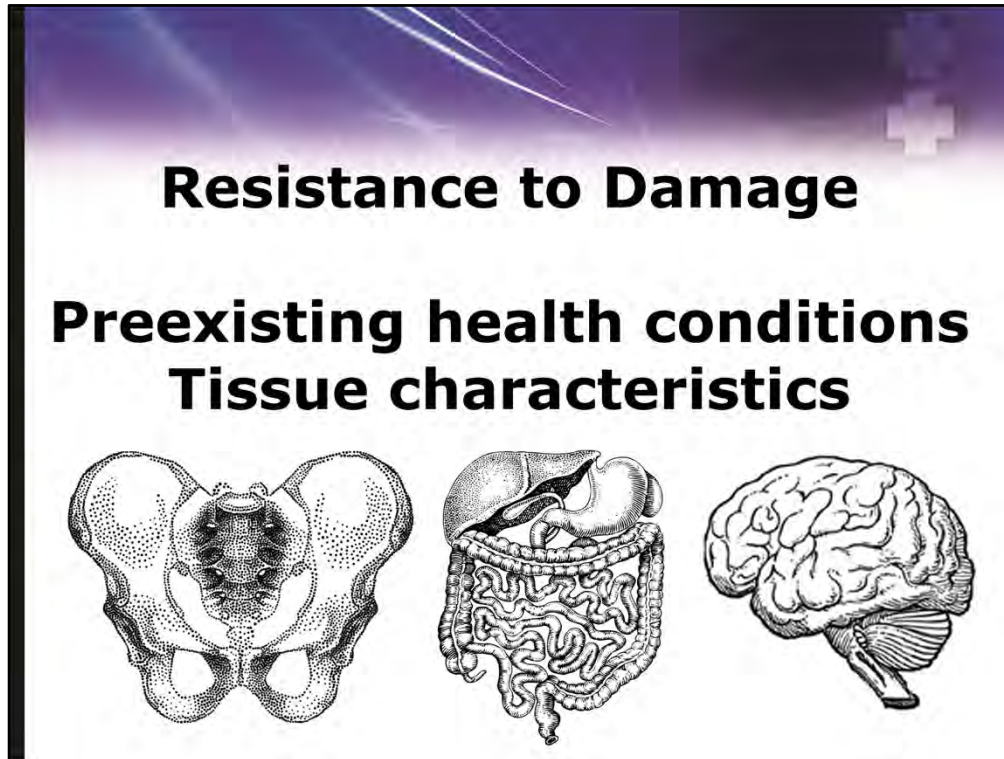
Trauma providers categorize trauma (from motion) into two types: blunt and penetrating. Although Burn is another categorization, that will be covered in another lecture.

Penetrating injuries includes stab wounds, impalements, and gunshot wounds.

We will focus on blunt first, as it is often the more common type of trauma seen.



Several factors in addition to mass and velocity are involved in the actual amount of tissue damage done. These include resistance to damage and surface characteristics.



Various tissue types have various degrees of resistance to damage. For instance, the pelvis or the femur is much more difficult to damage than other more-vulnerable tissues, such as the gut or the brain.

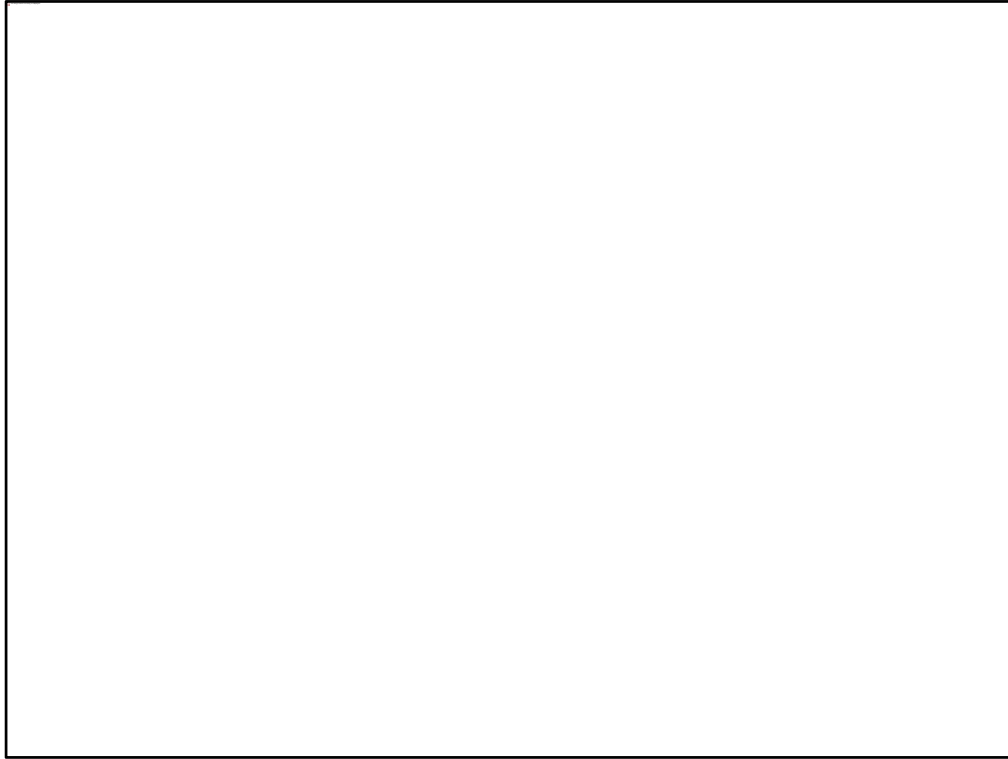
In addition, the overall health of the victim, before the trauma event, may affect resistance to damage. A young healthy athlete can tolerate more kinetic energy transfer than can an 83-year-old man. A high-school boy may be able to jump off of the roof of a house with no trauma, but an elderly man will most certainly be injured.



Tearing or shearing forces result when part of the tissue is moving in one direction, and forces applied to another part of the tissue push it into another direction. If the tissue has low tensile strength, shear injury results, as in skin lacerations, aorta tear, or diffuse axonal shear injury to the brain.

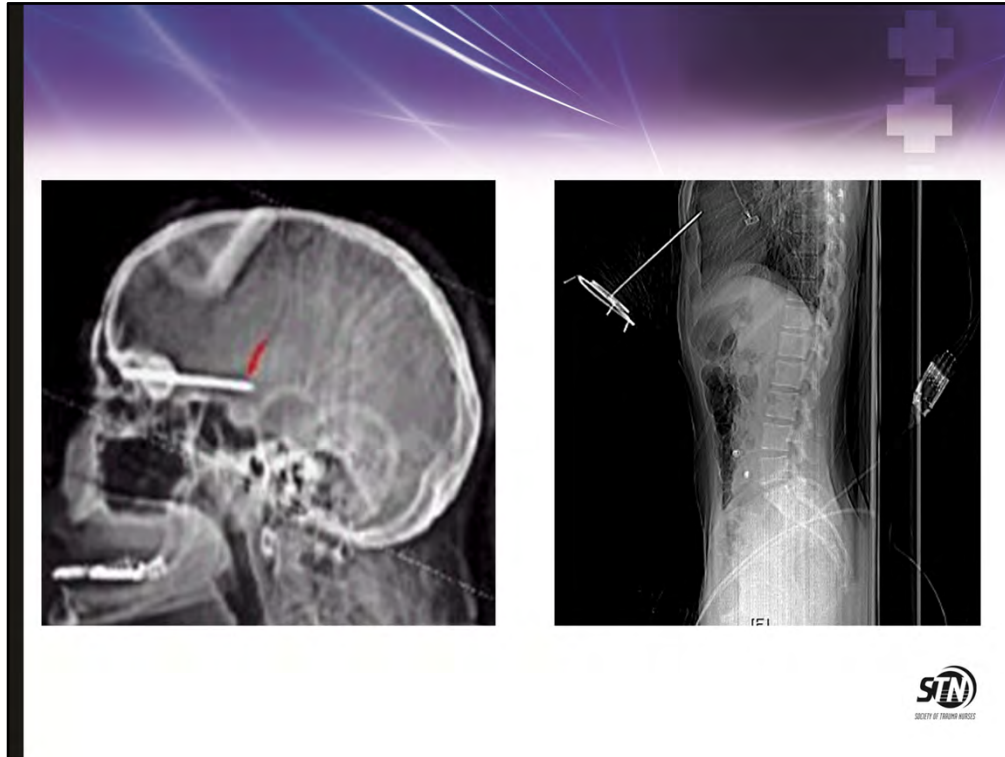


The surface area to which a given force is applied predicts the extent of damage. Here, a 3-pound hammer hits a thumb at a given speed. The faster the speed, the greater the force, and the greater the injury.



And here, an ice pick stabs a thumb. This force is applied to only a very small surface area of tissue, meaning that more energy is transferred to a smaller amount of tissue.


Very small surface areas, such as with ice picks, and knives, and bullets will typically result in penetration or impalement.



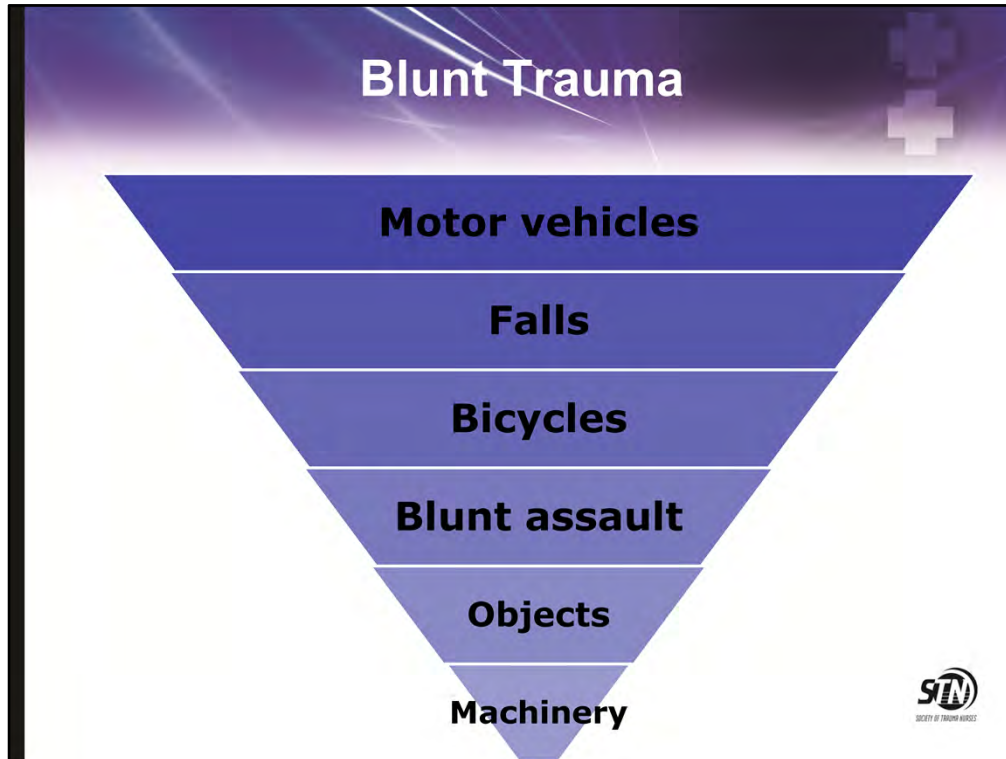
In contrast, an ice pick to the brain and “ticket holder” (if you look closely, you will see paper tickets at the base) to the chest (close proximity to the heart) can have huge implications with resulting serious injury despite having a small “wound.”

Acceleration and Deceleration

- Acceleration
 - Rate at which body in motion increases its speed.
- Deceleration
 - Rate at which a body in motion decreases its speed.



Two key concepts related to collisions (or any type of trauma involving a sudden “stop” such as a fall) include acceleration and deceleration injuries. Obviously, a faster rate of speed results in more force exerted.





Most serious trauma in the United States is from motor vehicle crashes. The same is true in many countries world-wide, and is predicted to soon be the leading cause of trauma across the globe. Motor vehicle trauma is rapidly increasing in China, India, and many parts of Africa.

During falls, bicycle crashes, blunt assaults, the body impacts with various objects. Injuries including machinery are more common in some areas of the country. These are the most-common types of BLUNT trauma, in addition to motor vehicle crashes.

Let's start with a review of the predominating mechanism, MVC.

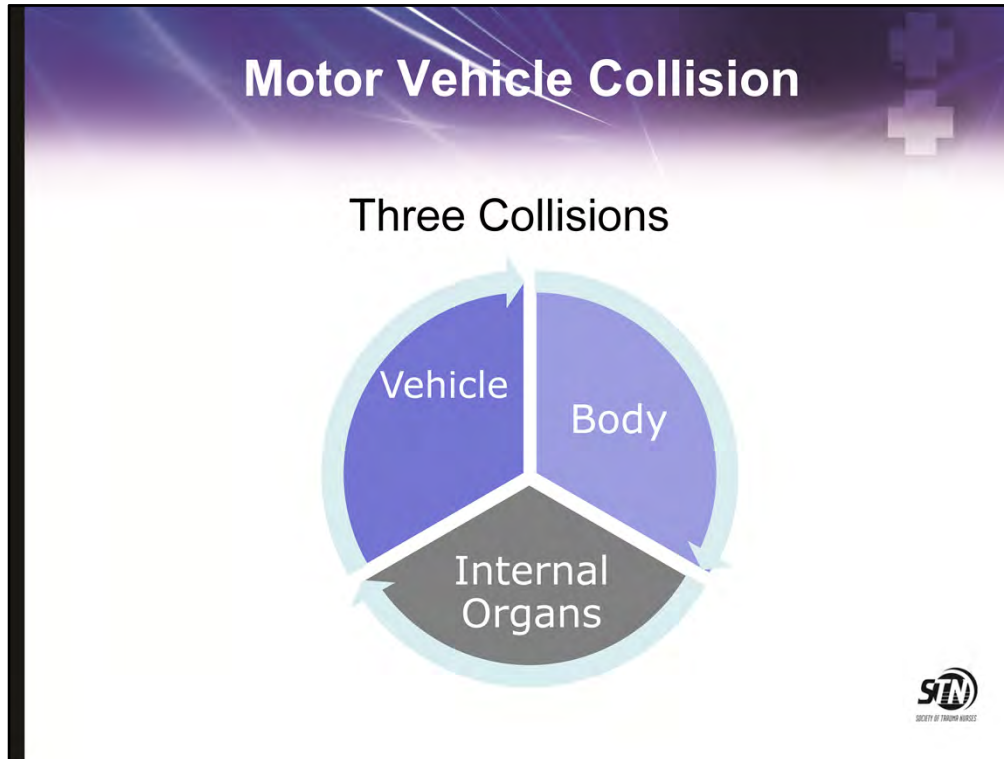
Types of MVC

- Frontal
- Rear-end
- Lateral
- Rotational
- Rollovers



These are the main categories describing the types of motor vehicle crashes.

Image is a classic “t-bone” crash.



One must remember that there are three collisions for every crash. The three collisions include the initial impact of the vehicle into the object (a car, a brick wall, a tree, etc). Then the body collides within the framework on the car, inside the car, or perhaps is ejected. The third collision involves the body's own collision of various organs, shearing and tearing of tissue, etc.



Cars may strike head-on. The “Delta V” is the combined speeds of the two cars. There is often a high energy transfer, and lots of tissue damage with a high severity of injury. Occupants are typically thrown forward – that is, they continue moving forward at the original speed, while the car decelerates dramatically over a very short time period (just milli-seconds of “ride down time”).



The victim (driver) usually goes “up and over” (over the steering wheel), resulting in chest/abdomen impact to the steering wheel, and face impact to the windshield. This results in numerous chest and abdomen injuries, and head / face injuries, with neck hyper-extension. Injuries may include blunt myocardial injury, pneumo-hemothorax, diaphragm rupture, liver laceration, facial fractures, diffuse axonal shear injury of the brain, skull fractures, cerebral contusions/hemorrhages, and cervical spine fractures possibly with spinal cord damage.

Or the driver may go “down and under”, end up under the steering wheel and dashboard, with leg fractures, hip dislocation, possibly with face impact to the steering wheel with face fractures and brain injuries.



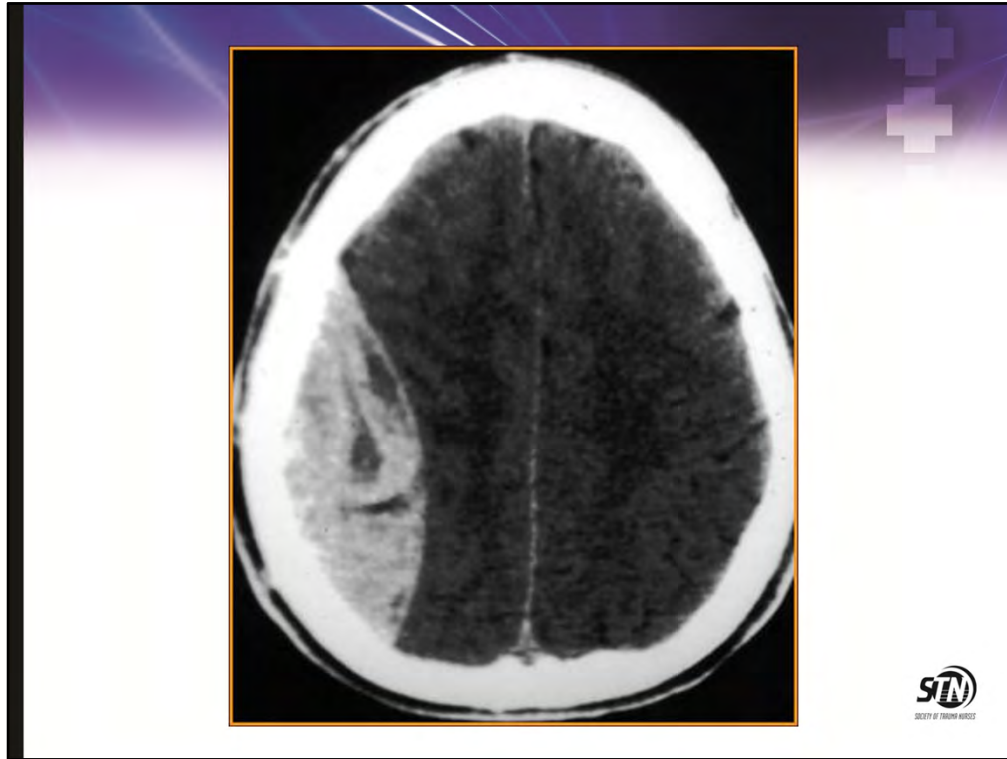
- Rollovers result in force vectors from all directions as the car rolls and the person inside bounces around.
- Patterns of injury are less predictable except that severity is expected to be high.
- Effective restraint systems may mitigate this severity.
- Without restraints, the victim is at very high risk for ejection from the vehicle with a resultant “five times” increase in expected severity and risk of poor outcomes.



- Lateral, or T-Bone, crashes often happen at road intersections, sometimes as a result of red-light-running.
- There is less car metal between the victim being hit from the side, and this means more rapid energy transfer due to a shorter “ride-down” time.
- The trauma is correspondingly greater. Patient moves toward point of impact. Increased potential for “shearing” injuries
- Injuries are predictably to the side of the body closest to the impact.
- A driver hit on the driver side would often have left clavicle fracture, left rib fractures, pneumothorax on the left, spleen injury, pelvis fracture on the left side, and left-sided brain injuries.

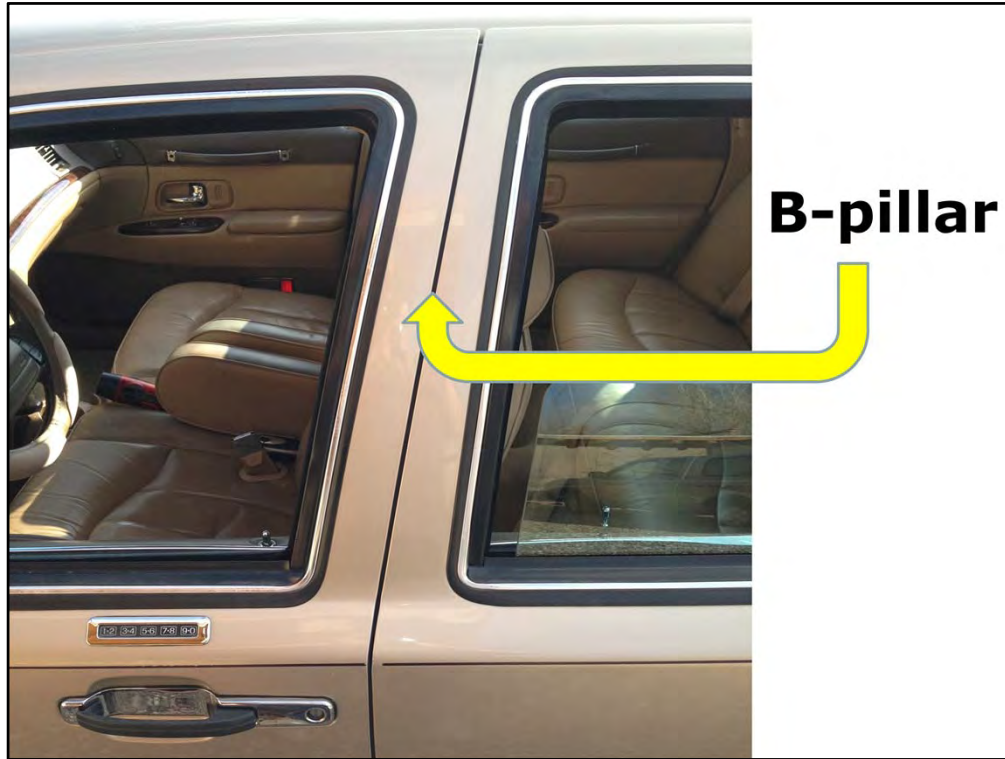


The head usually strikes the B-pillar post in a T-Bone type crash.



...with serious brain injury resulting.

Image is significant epidural hematoma.



The area between the front and back doors.



(show this slide only briefly, without comment)



Rear-end collisions are often less damaging due to more ride-down time as the rear end of the car collapses and energy is absorbed (speed is reduced), before the kinetic energy reaches the driver being rear-ended.

Also the seatback provides some protection. When it does, the driver is accelerated forward, throwing the head back. This may result in neck hyper-extension, with whiplash or worse.



Rear-end crash and neck hyper-extension. Can result in cervical spine injuries as well as coup contrecoup injuries.

It is important to adjust the head rest to the appropriate height to minimize chances of injury.

Image is classic MOI with rear end collision.



When there is a mis-match of mass between the two vehicles, such as with a compact car and a very large truck, the mass of the larger vehicle means that most of the kinetic energy is transferred to the small vehicle.



The train always wins.



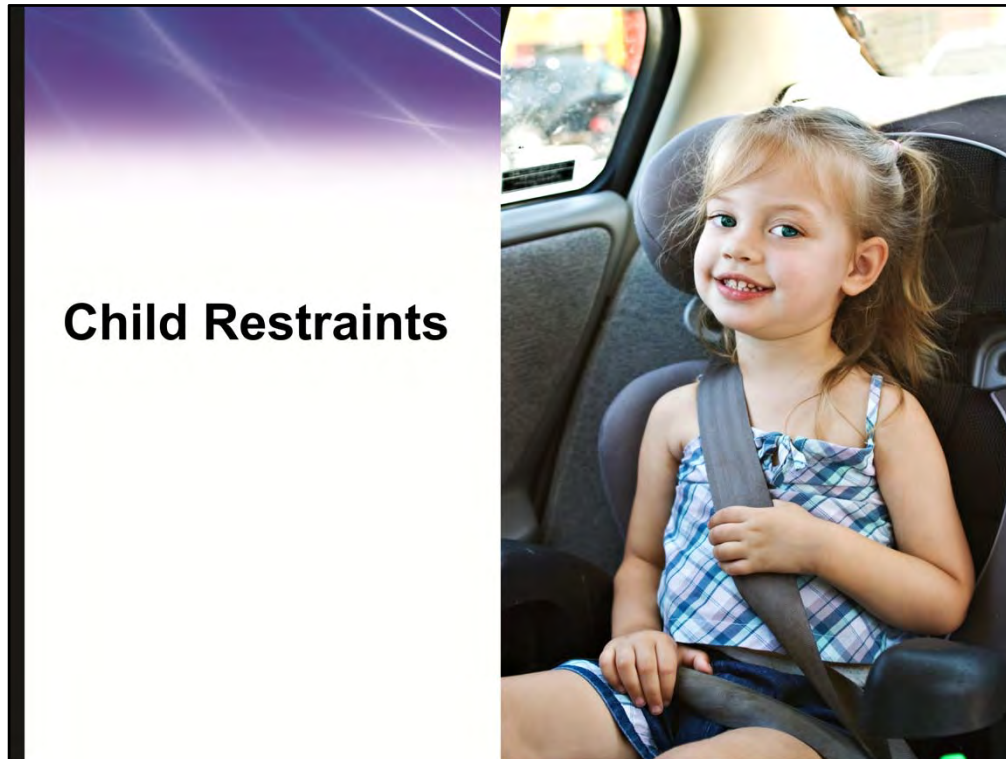
Protective devices mitigate injury severity as previously noted. Seatbelt and shoulder strap restraints prevent the person from being thrown forward into the steering wheel, dash, and windshield. They also prevent tumbling around in the car during a rollover, and ejection from the car.



Airbags soften the impact, and increase “ride-down” time, resulting in less injury. Airbags are now often found not only in the front, but along the side and in other locations.



Curved surfaces, fewer protruding knobs, and padded surfaces also reduce injury. Shown here is the driver's knee adjacent to a padded dash. Note the controls are flush to the surface and will result in less injury.



Child restraint systems, properly used, are highly effective at reducing injury severity.



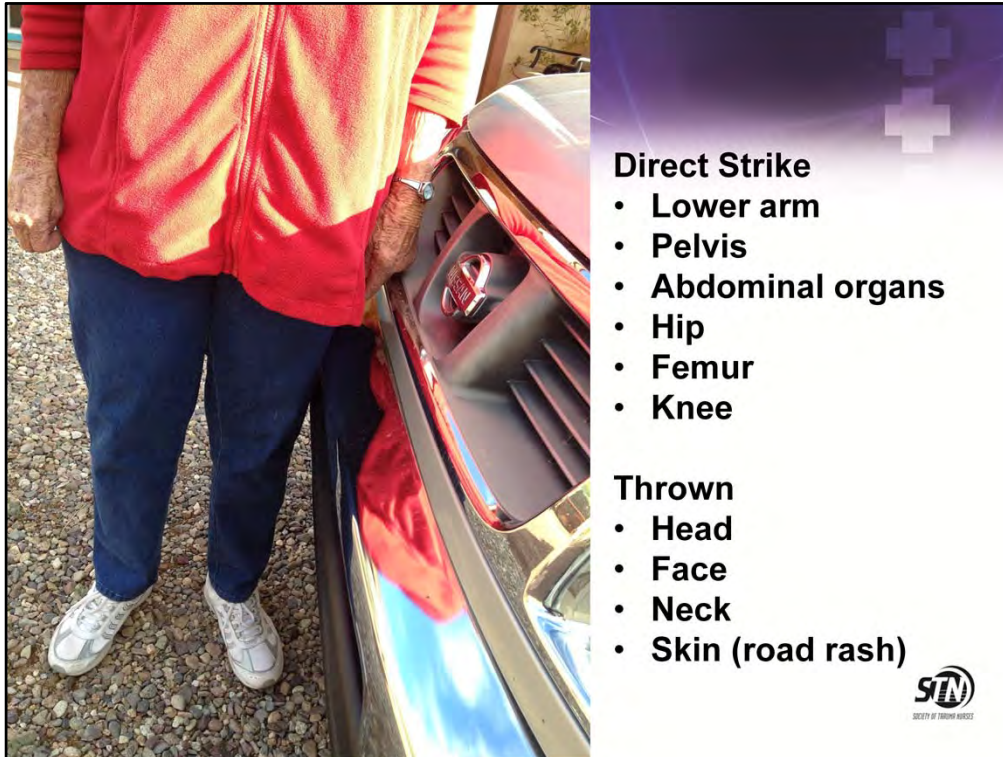
Always keep in mind that the severity of the injuries resulting from a car crash are also related to the resistance or tolerance of the human body to the energy transfer. Older drivers are in less-robust physical condition, and more susceptible to injury, so greater severity results from less-severe crashes. A person on anti-coagulant medication may bleed more from less-severe injuries, producing a worse outcome.



Pregnancy or other pre-existing conditions can influence the pattern of injury, or of the ultimate effect of the injuries.



Speed is often high, and mass mis-match is dramatic; the person is often thrown a great distance, resulting in high-severity injuries.



(Let student read slide, without comment.) Pause.

Note that a bigger vehicle, or a smaller person (short adult or pediatric) will align differently. For instance, a small child versus a larger SUV will have direct strike into chest. This is known as Waddell's Triad and will be reviewed in the Pediatric section.



- Another kind of motor-vehicle crash is that involving the ATV, all-terrain-vehicle, or “quad”.
- The wheel-base is narrow, the center-of-gravity is high, and this results in the vehicle tipping over easily.
- Riding double increases the center-of-gravity height and increases roll-over risk.
- The vehicle may weigh over 500 pounds and may roll over onto the person.
- Speeding, racing, jumping, and other stunts increase crash risk.
- Many pediatric-aged ATV drivers are injured.



Motorcyclists are particularly vulnerable when hit by a car. Here the cyclist is struck head-on and is thrown up onto the car, impacting the windshield, and is often thrown on over the top of the car and onto the pavement.



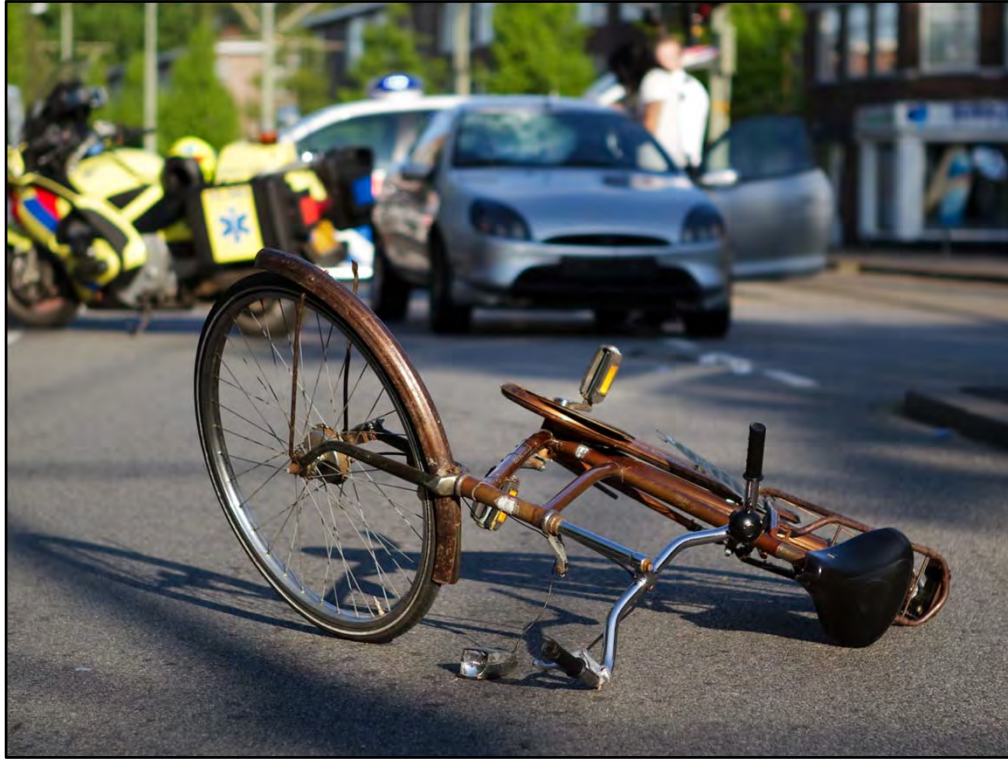
Car drivers may not see motorcyclists, striking them broadside or T-bone style. Another common type of motorcycle crash includes “laying the bike down” and sliding on the pavement.

Motorcyclist legs impacting car bumpers or highway guardrails produce devastating damage.

Obviously, cyclists without helmets stand a greater risk of significant brain injury.



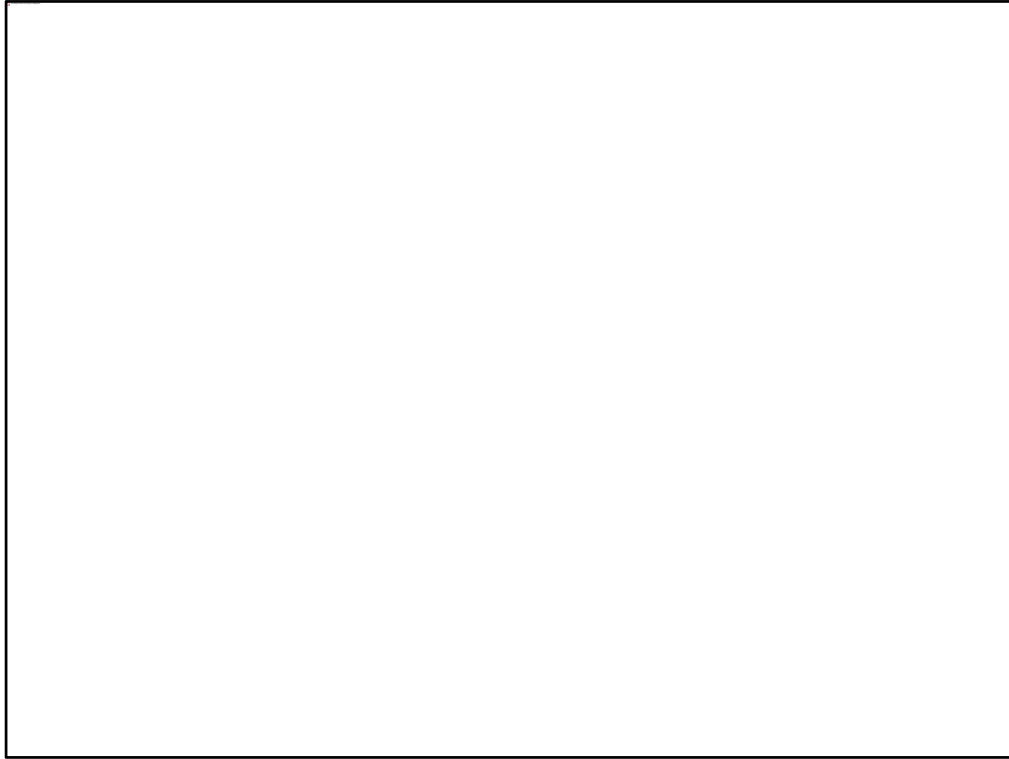
Bicyclists falling often suffer skin and orthopedic injury, but sometimes serious brain and other injuries as well.



Bicycles versus cars is another one of those mass mis-match situations. The bicyclist always loses.

Crash risk is increased because bikes are often ridden in vehicle traffic, and the car driver often does not see the bicyclist.


To reiterate, cyclists without helmets stand a greater risk of significant brain injury.




Helmets are highly effective at reducing brain injury. But completely separating the cars and the bicycles is the most-effective prevention strategy.

Feet-First Falls

- Compression fractures
- Calcaneus fractures
- Fractures of the wrist
- Injury to internal organs
- Injuries to head, back, and pelvis



<http://manyfor.com/lucky/a-wooden-ladder-fall-down.html>




The impact travels up the spinal column and may result in compression fractures. CTLS films are important in all falls of a significant height.

If landing on the feet, bilateral calcaneus fractures are often seen. Forward falls may cause fractures of the wrist as hands are extended to break the impact of the fall. Look for head, neck, back, and pelvis injuries if thrown backwards

Greater than 20 feet may cause internal organ injuries but this can also happen at shorter heights.

Head-First Falls

- Brain injury
- Hyperextension of the head/neck
- Compression of the cervical spine
- Chest, lower spine and pelvic injuries are also common



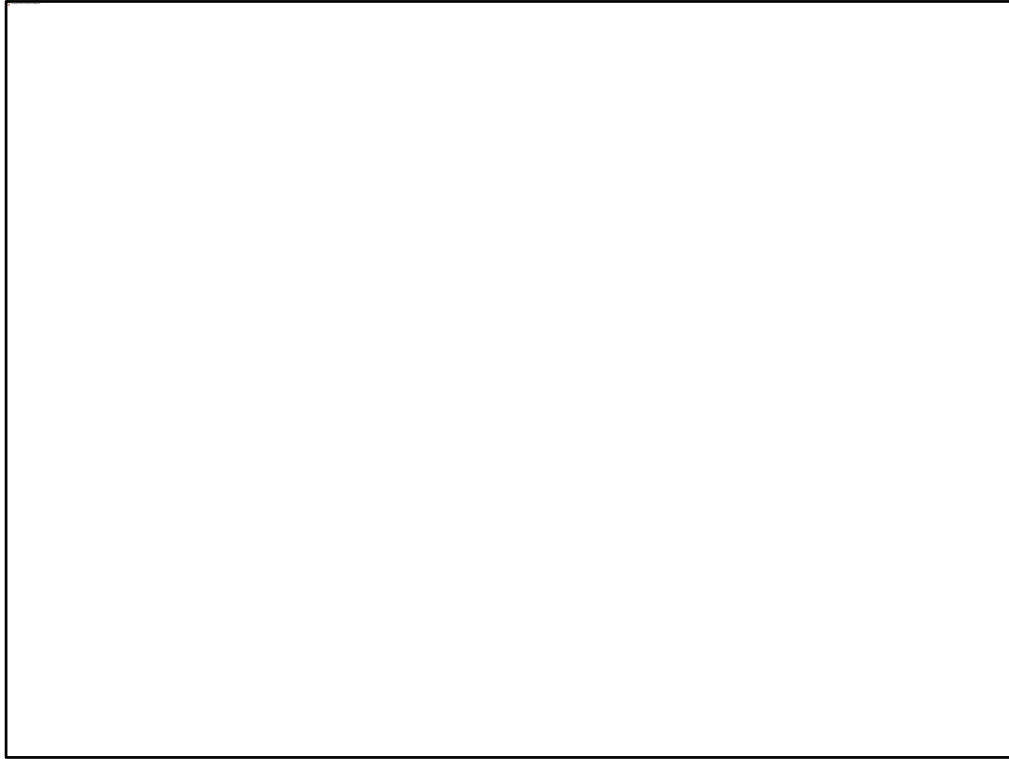
<http://manyfor.com/lucky/a-wooden-ladder-fall-down.html>

Most obvious is the injury to the head.

Depending on the position of impact, hyperextension injuries may occur.

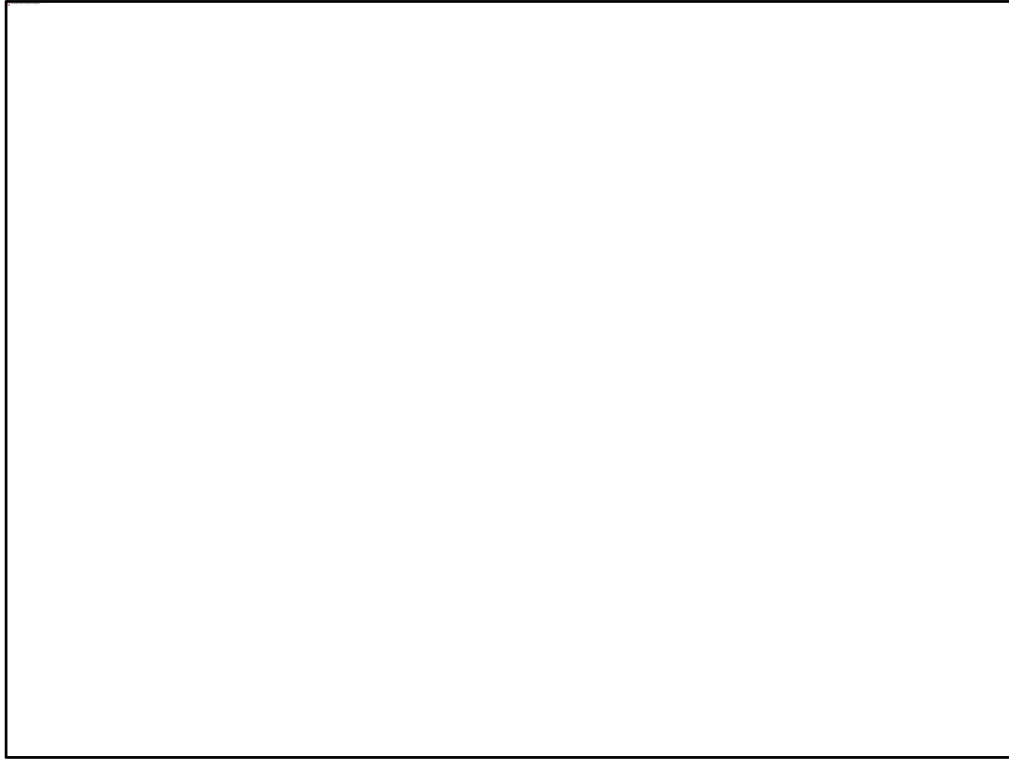
As a result of axial loading, compression of the cervical spine may occur.

Multiple injuries can result depending on height of fall, force of fall, and type of surface breaking the fall.

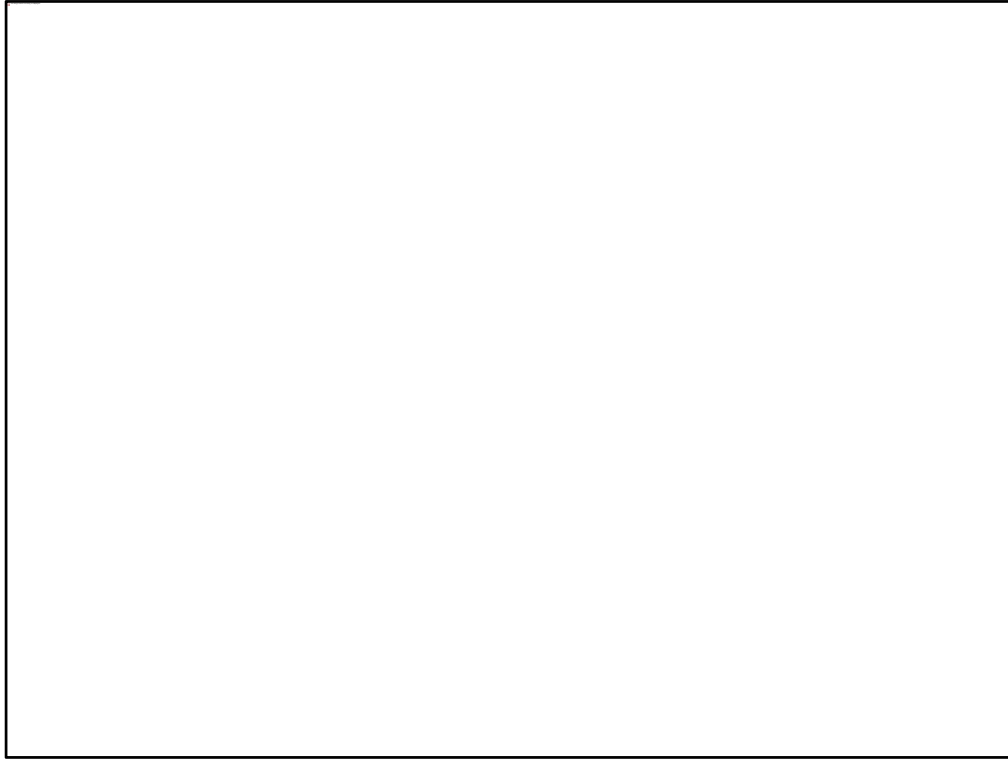


The surface upon which someone falls does matter.

There will be greater tissue damage when falling onto rocks, than...

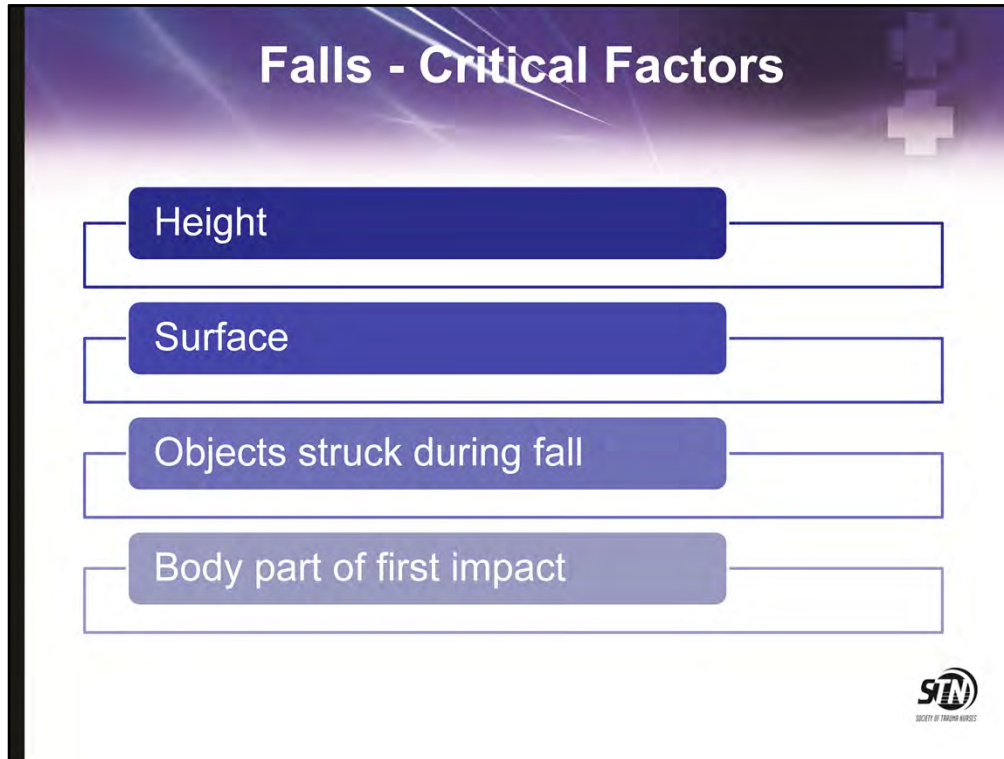


...when falling onto soft sand.



This picture illustrates all of these factors:

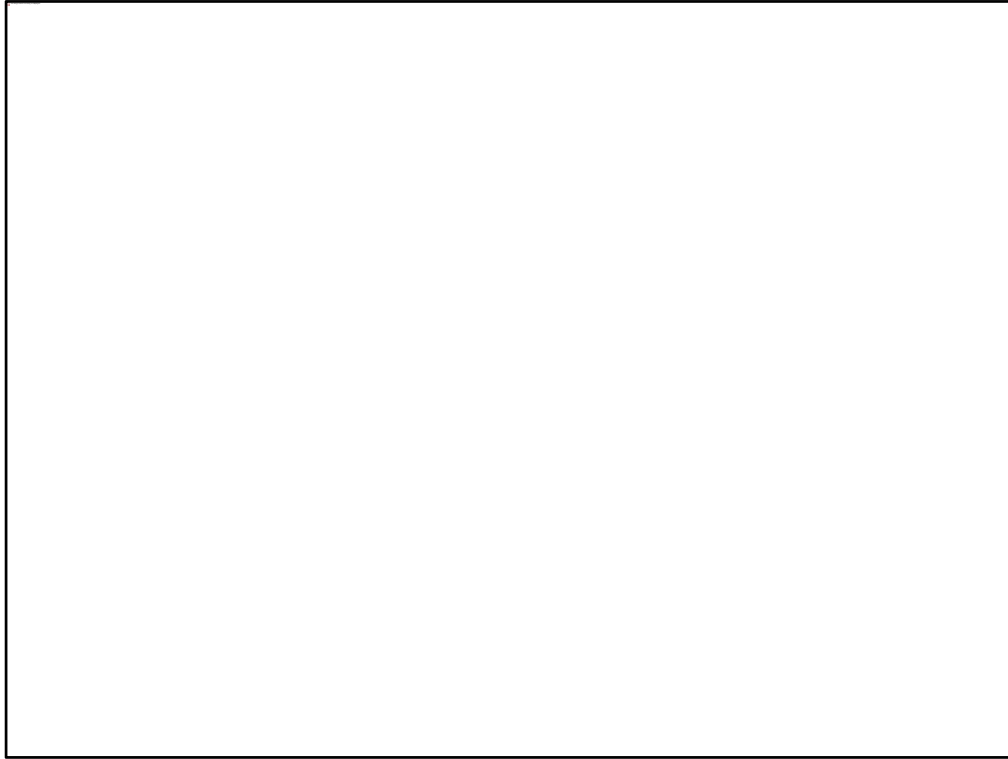
- An older person is in less-robust physical shape than a younger person – bones fracture more easily and brain bleeds are more common, especially if one is on anticoagulants.
- The height of the ladder is related to the gravitational “velocity” achieved ($KE = \frac{1}{2} m v^2$)
- The weight of the man = the mass
- The surface onto which he falls matters
- All of these factors can predict the extent of injury



- Increased height causes increased injury
- The type of impact surface increases injury
- Consider what objects the victim may have struck during the fall
- Typically the body part that impacts first sustains the bulk of injury

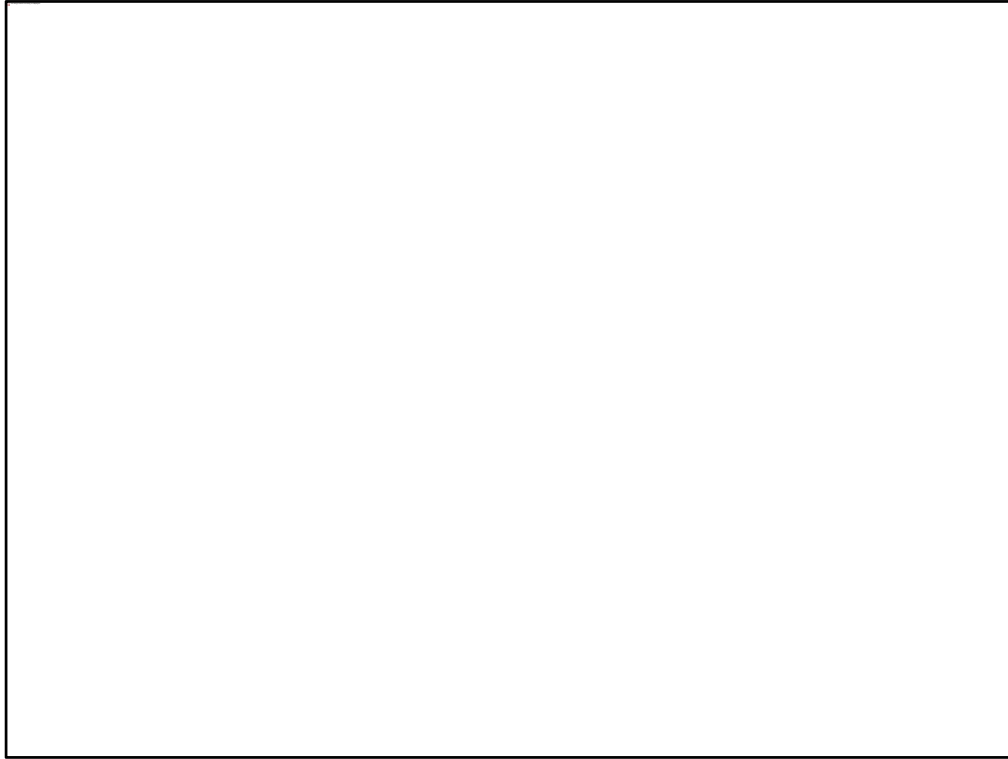
Have a high index of suspicion and consider the path of energy through body and what other organs/systems could be impacted

Finally, consider any “conditions” that may have been the cause of the fall, e.g. syncopal episode, etc.



Three height measures all trauma personnel should know:

- 20 feet is the height listed in the CDC's trauma triage guidelines, for which the victim should be taken to a trauma center (probability of serious injury is high)
- 20 feet = 2 stories
- The same trauma triage guidelines list "two times the patient's height" as the height of a fall for a pediatric victim, to take that victim to the trauma center.
- 35 feet = height of fall at which $\frac{1}{2}$ of humans die (like an LD50 in toxicology, "lethal dose 50%")



With blunt assault, injury patterns and severity are often less predictable.
One cannot always “see” the extent of the damage.
The concept of “cavitation” may also apply here.

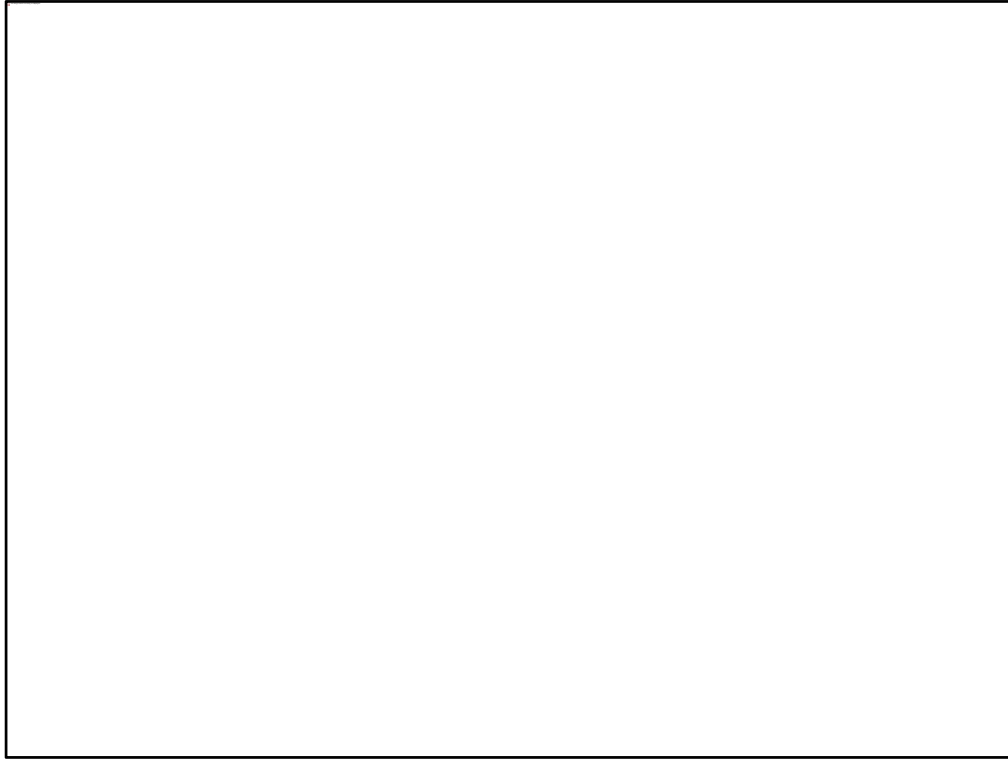


Penetrating trauma

Stab wounds are low-velocity wounds, but with the energy transfer focused on a small body surface area, like the earlier picture of the ice pick. The location of penetration determines how severe.

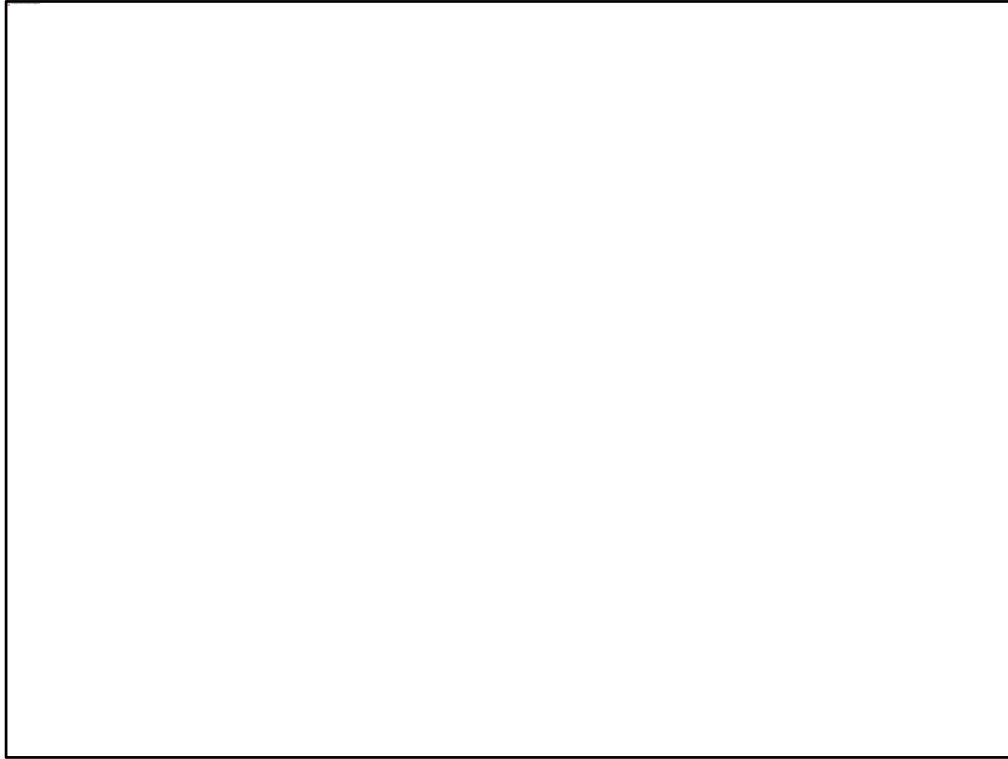
Which underlying organs may be damaged is a bit easier to predict, especially if the length of the knife is known. There is also the speculation that a male assailant tends to stab with an upward thrust and female assailants, a downward motion.

Remember that more than one cavity may be penetrated by a single wound. Consider the chest and abdominal stab wounds. Chest wounds from the nipples to the costochondral margin may injure abdominal contents due to the diaphragmatic movement.



Results from forceful collision between object patient.
Should not be removed until under controlled conditions as in the OR, as this may lose the vascular control and result in exsanguinating hemorrhage.
Concern exists for infection secondary to bacterial and foreign body contamination

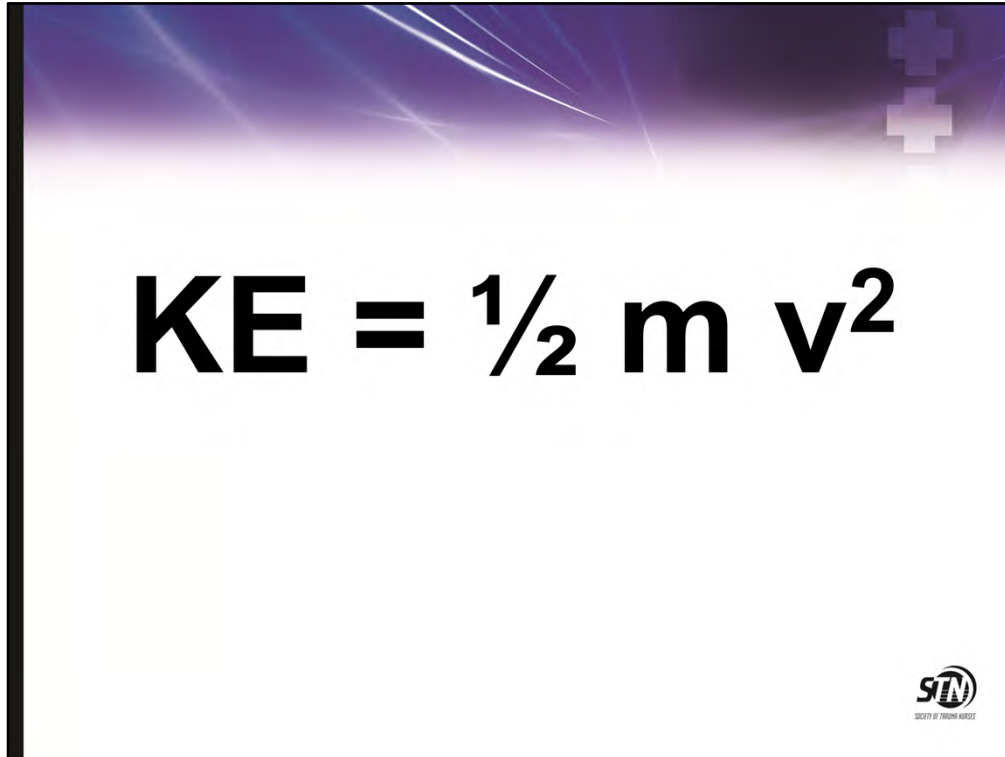
Image is a piece of solid thick wire that entered through ear and penetrated through muscles and into bone of skull.



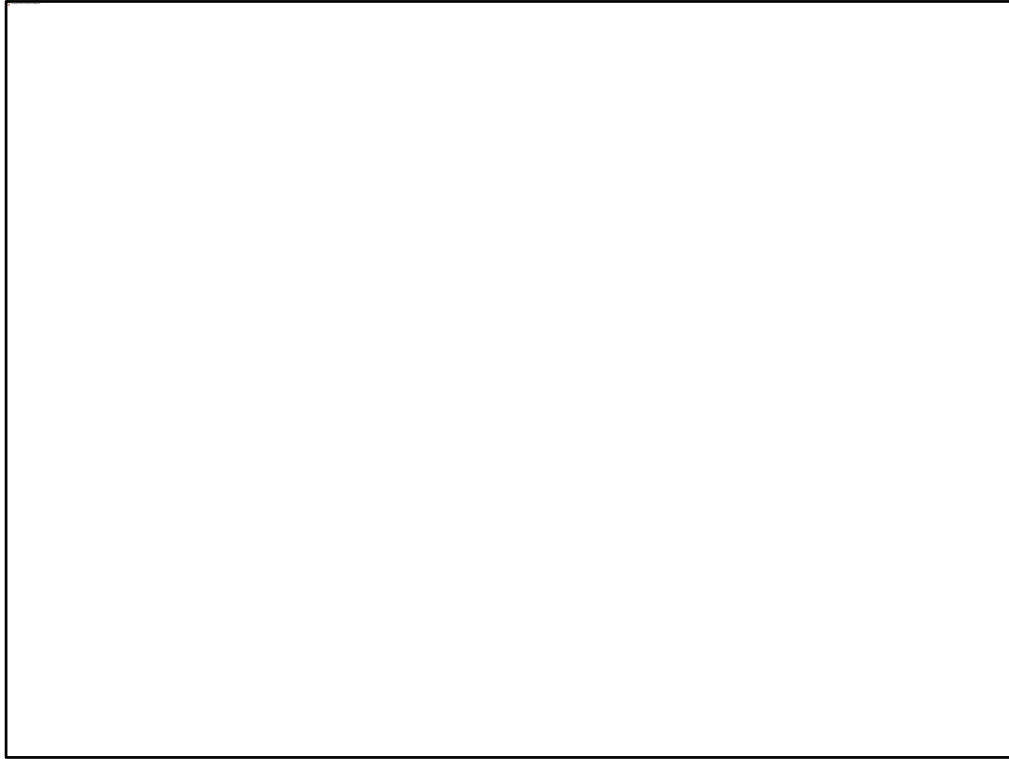
(This last section could be expanded upon and presented at a different time than the earlier blunt mechanisms.)

By definition, ballistics, is the study of firearms and projectiles. Distinction is made between low- and high-velocity weapons.

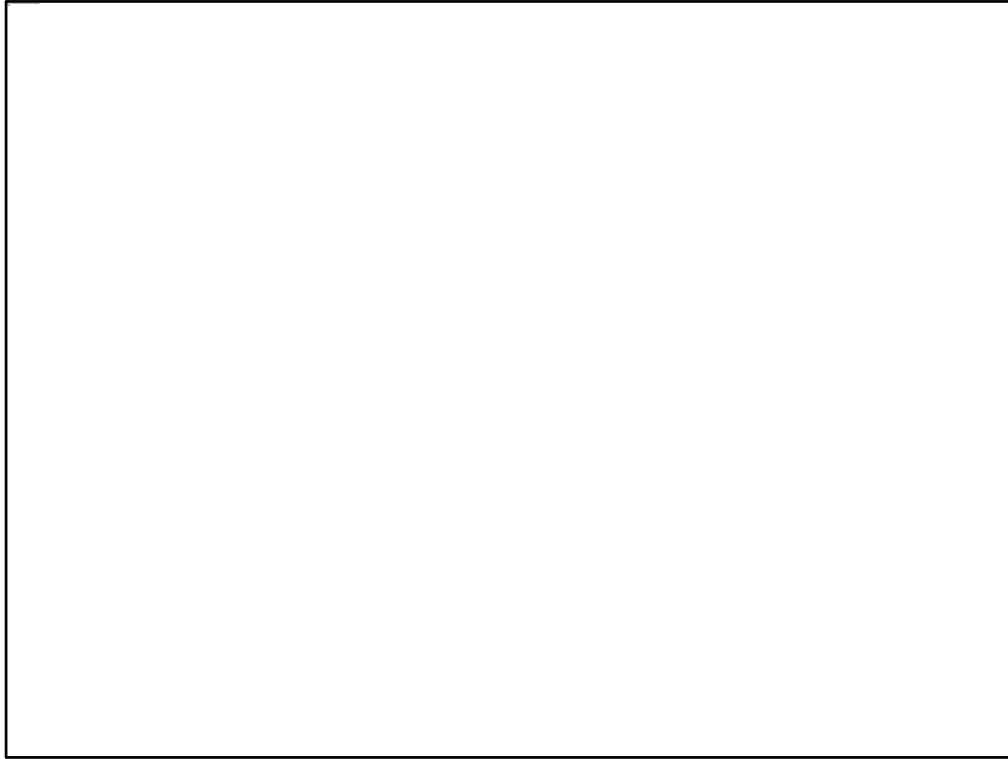
Kinetic energy is dissipated in four ways: heat, energy moving the tissue outward, energy that forms a primary path by direct crushing of the tissue, and energy which deforms the projectile.



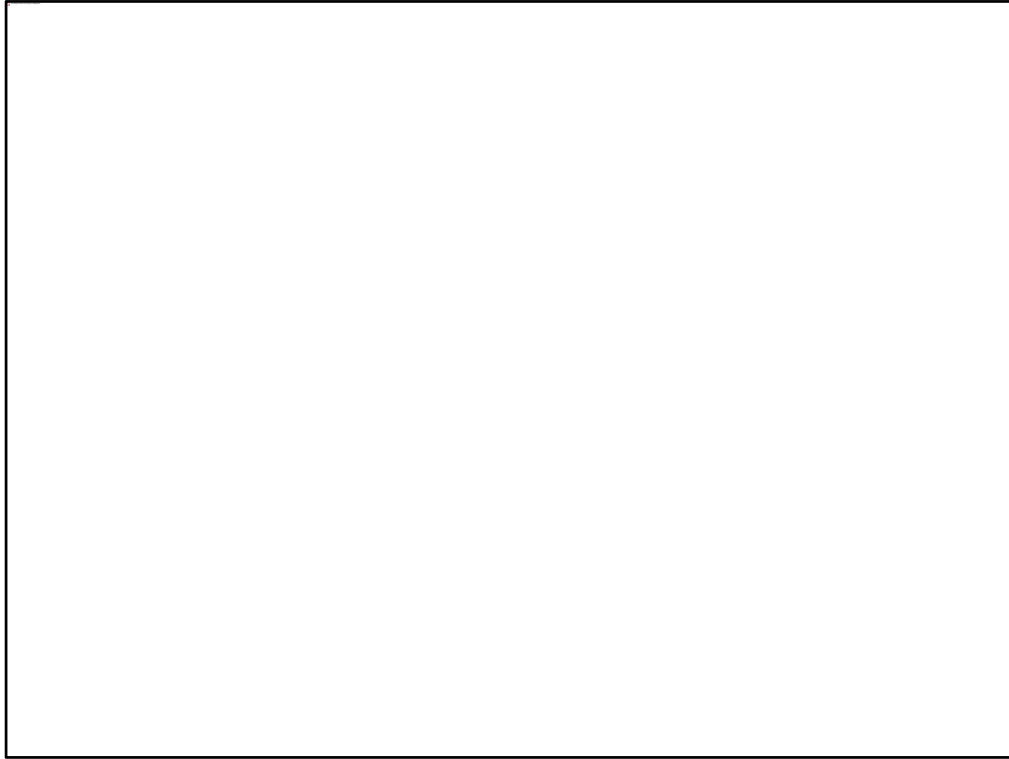
With guns, the Kinetic Energy formula is the same. Mass is important, but bullet speed is more important. The speed of the bullet is related to the amount of powder load in the cartridge.



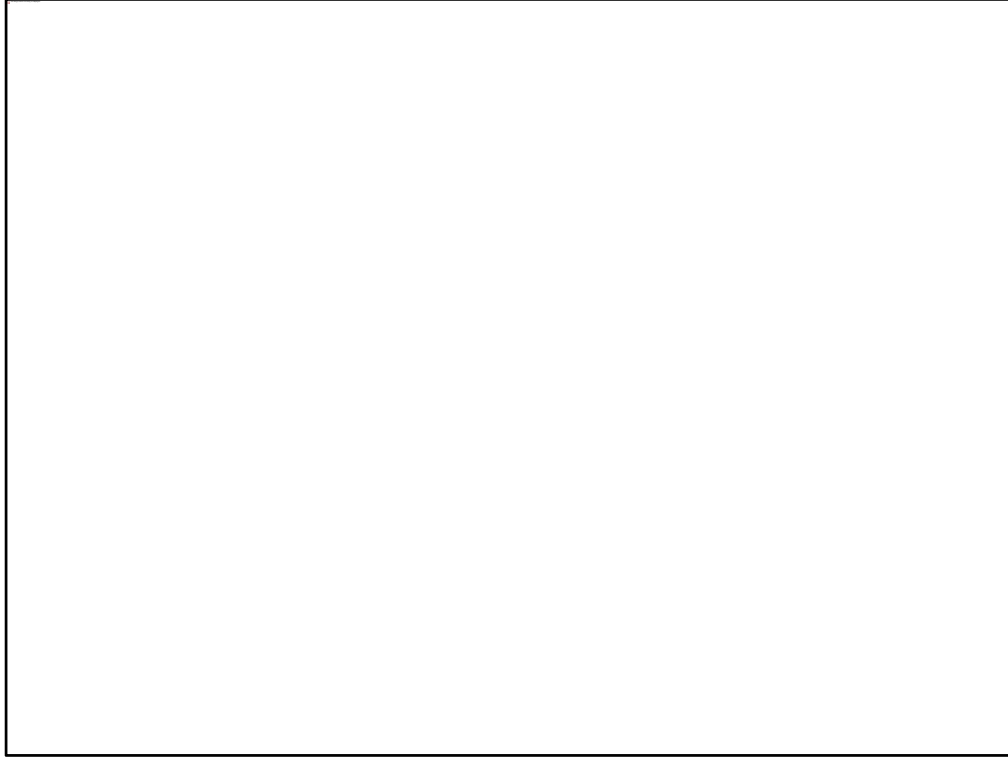
The caliber is the bullet diameter. This is usually related to the mass of the bullet.



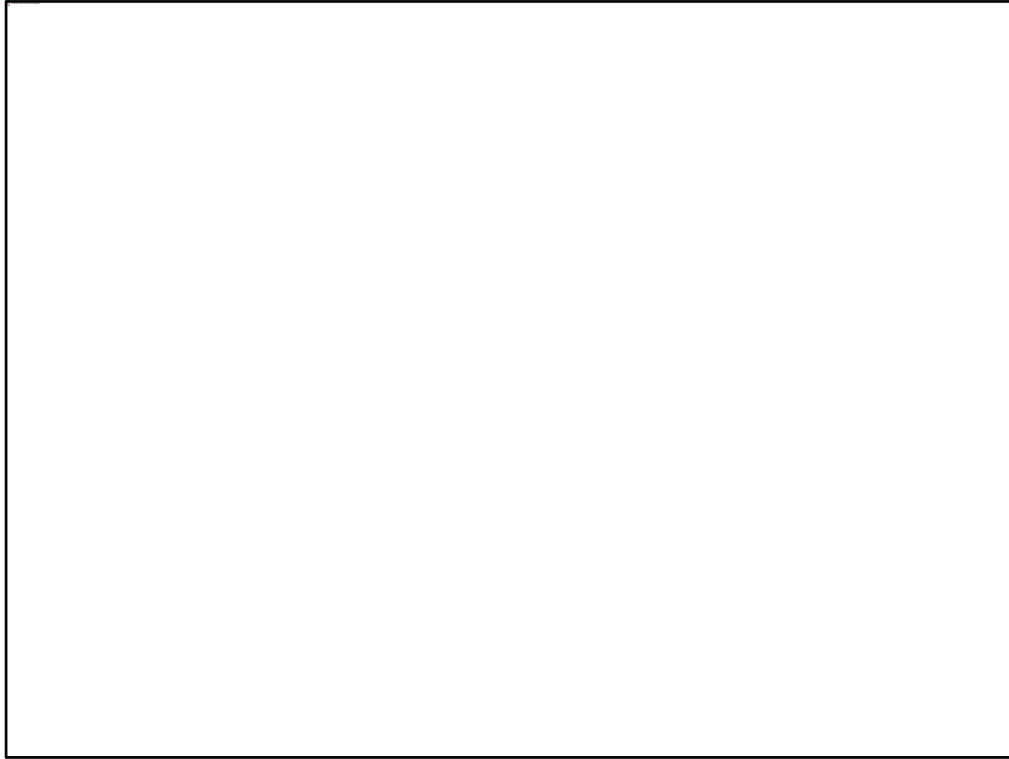
A high-power weapon, such as this hunting rifle, results in a higher muzzle velocity (bullet speed), and produces much more damage. Remember that velocity is squared in the kinetic energy formula. Knowing what type of weapon the victim was shot with, helps to predict the severity of trauma.



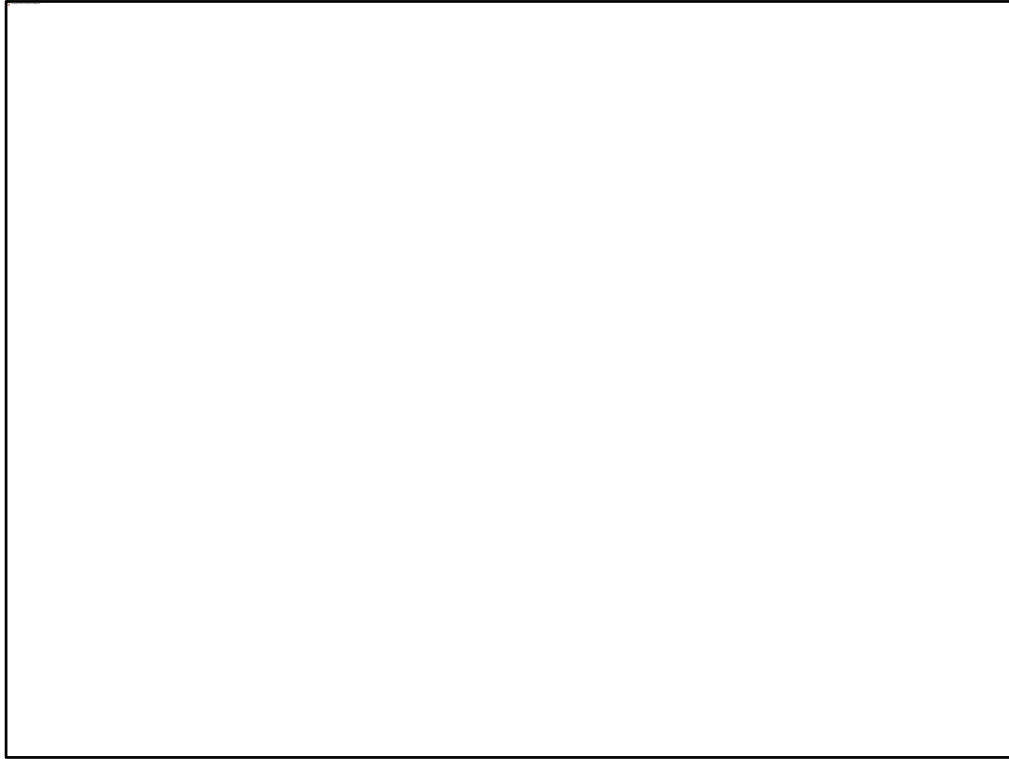
A 45, or 9mm, 38, or 357 magnum handgun may be a “medium” powered weapon.



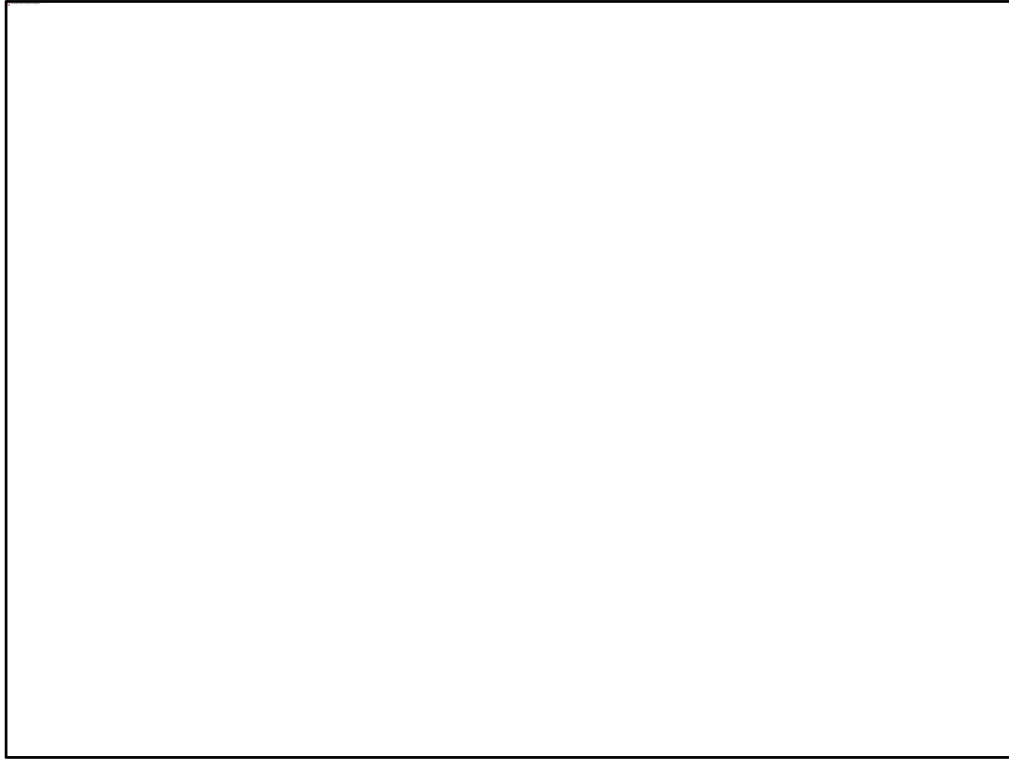
This low-powered 22 caliber pistol on the left, has a small-mass bullet, and with a smaller powder load, generates a relatively slow bullet speed, thus the amount of kinetic energy generated is lower.



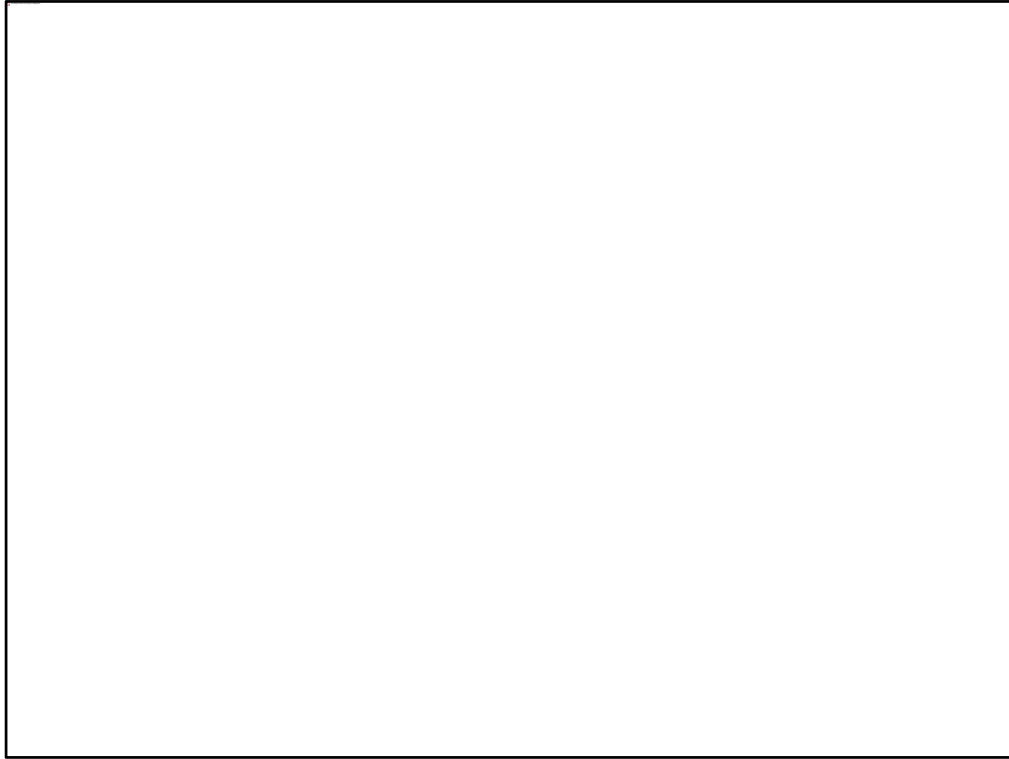
Big bullet, lots of powder, high speed, lots of energy equals lots of damage.



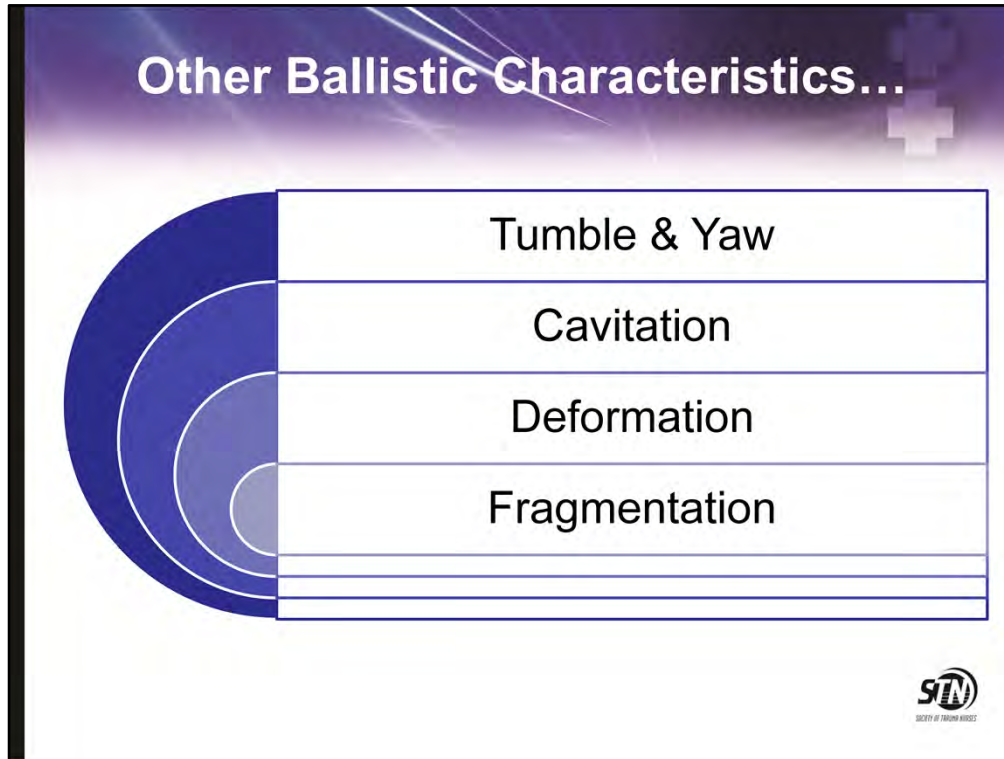
Smaller bullet, lower speed, less damage.



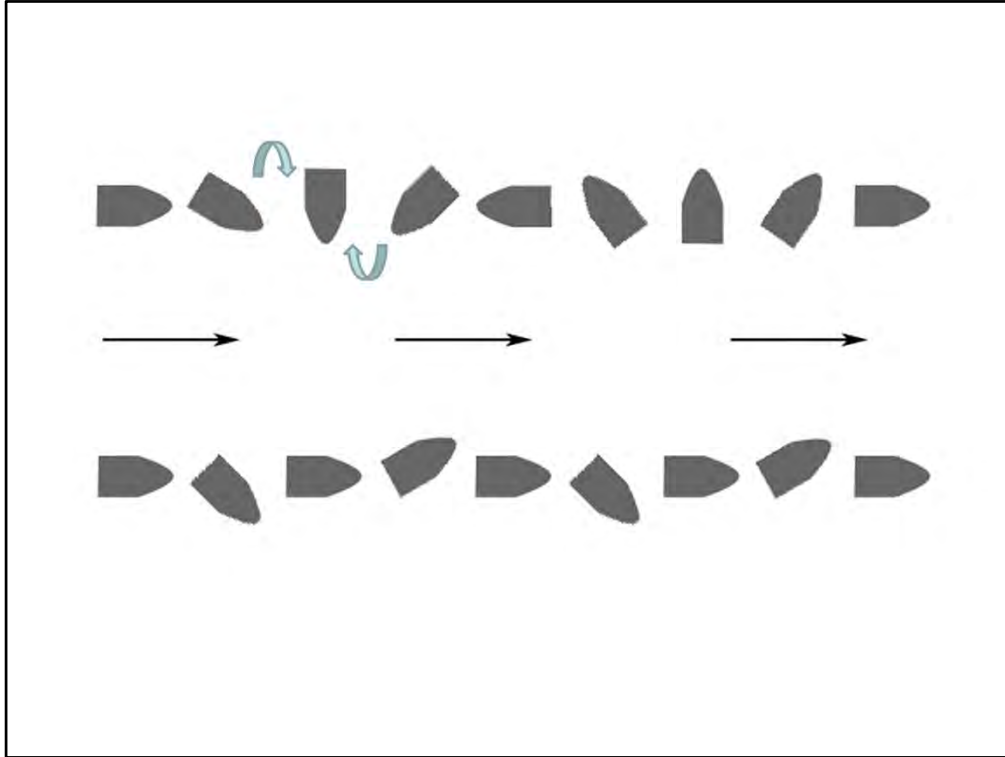
Pause here for a moment. No need to say anything.



Pause briefly. No need to say anything.

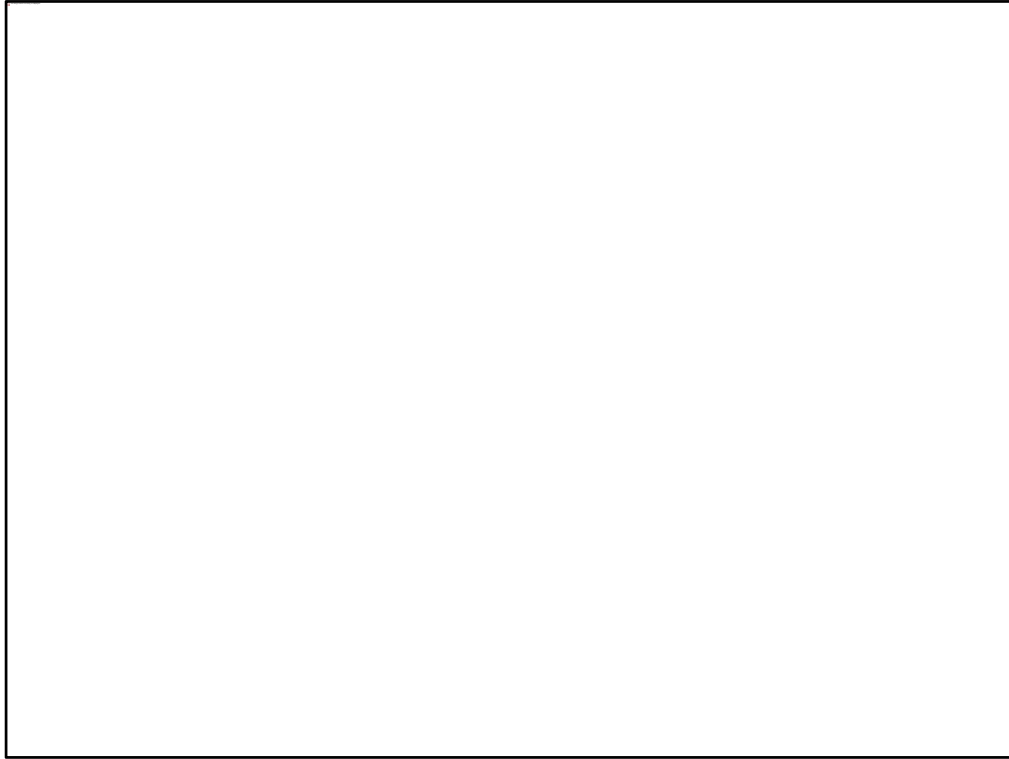


Velocity is key, however, more significant in regard to the amount of tissue damage is the energy transfer. The energy transfer depends on the bullet's characteristics, including deformation, fragmentation, mass, stability, path and tissue.

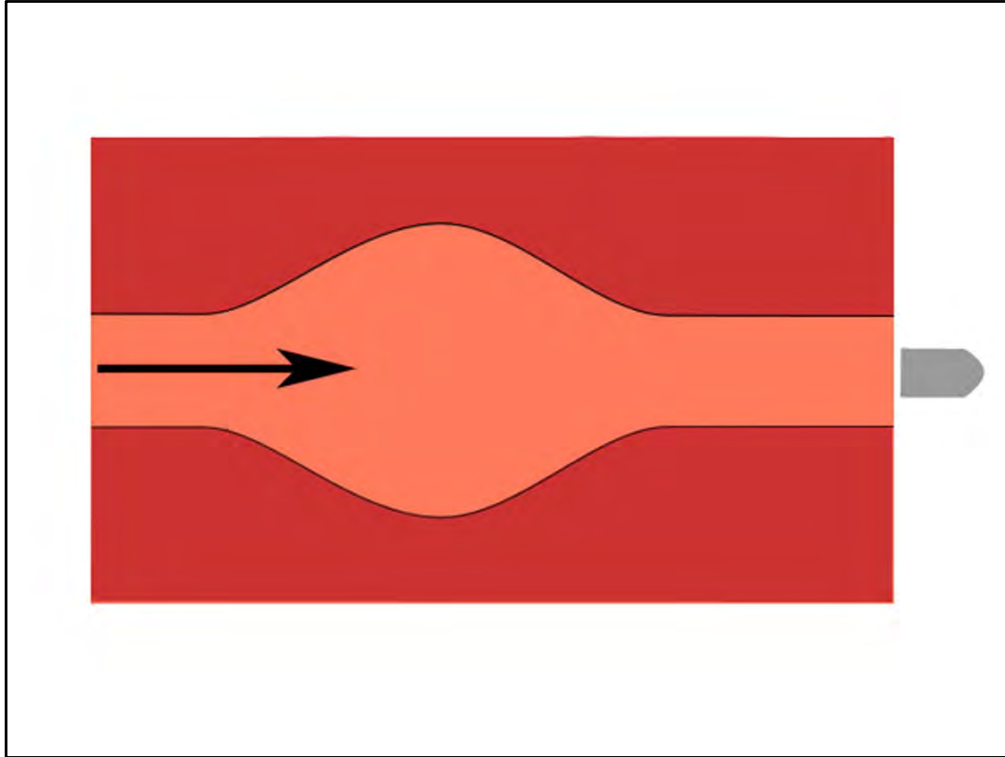


“Tumble” is end-over-end motion of the bullet as it moves along. In tissue, this increases damage.

“Yaw” is a side-to-side motion, and likewise increases tissue damage.



Some bullets are designed to fragment, such as “hollow-point” bullets. This causes bullet fragments to take different paths in the body, and therefore increases damage.



“Cavitation” is caused by a blast wave of energy moving in all directions out from the bullet as it moves through tissue. This greatly increases the diameter of the tissue damage caused by the bullet.

There are two cavities produced, the temporary and the permanent. The temporary cavity is the momentary stretch of tissue as it moves away from the path of the bullet. It increases in size with increased velocity. The permanent cavity is caused by the compressive stress of the projectile itself.



Bullet fragmentation increases tissue damage. A bullet striking a bone cause accelerate bone fragments to the speed of the bullet, and these fragments also cause more destruction.






Some bullets are designed to deform when striking tissue. Copper clad bullets deform very little, while un-clad and “wad-cutter” bullets deform a lot. Deformation can increase path diameter through tissue and increase damage. But a deformed bullet is also less likely to pass all the way through the body, exit, and hit someone else.

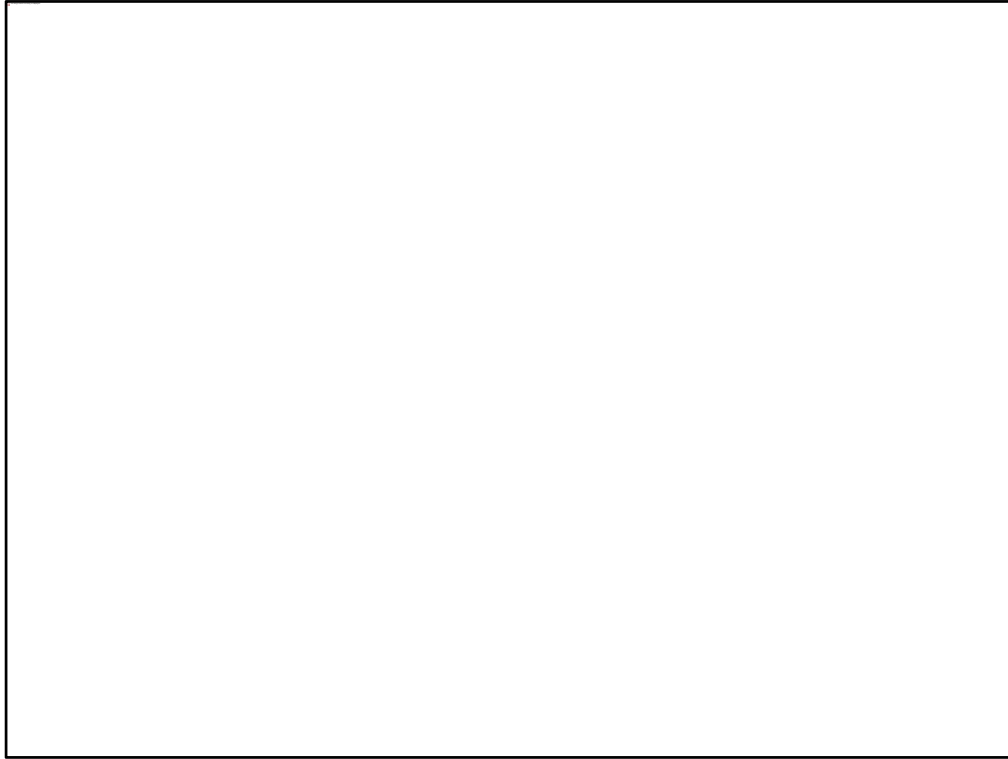
Hollow-point Bullets a.k.a. hollow-nose

- Contain a hollow in the tip
- Hollow-tip bullets are designed to “mushroom” upon impact - to cause more tissue damage – used for hunting.
- They can be partially jacketed (soft-point) or fully jacketed
- If they are partial jacket, they are called soft-point hollow nose bullets

Soft-point hollow nose Full metal jacket hollow nose

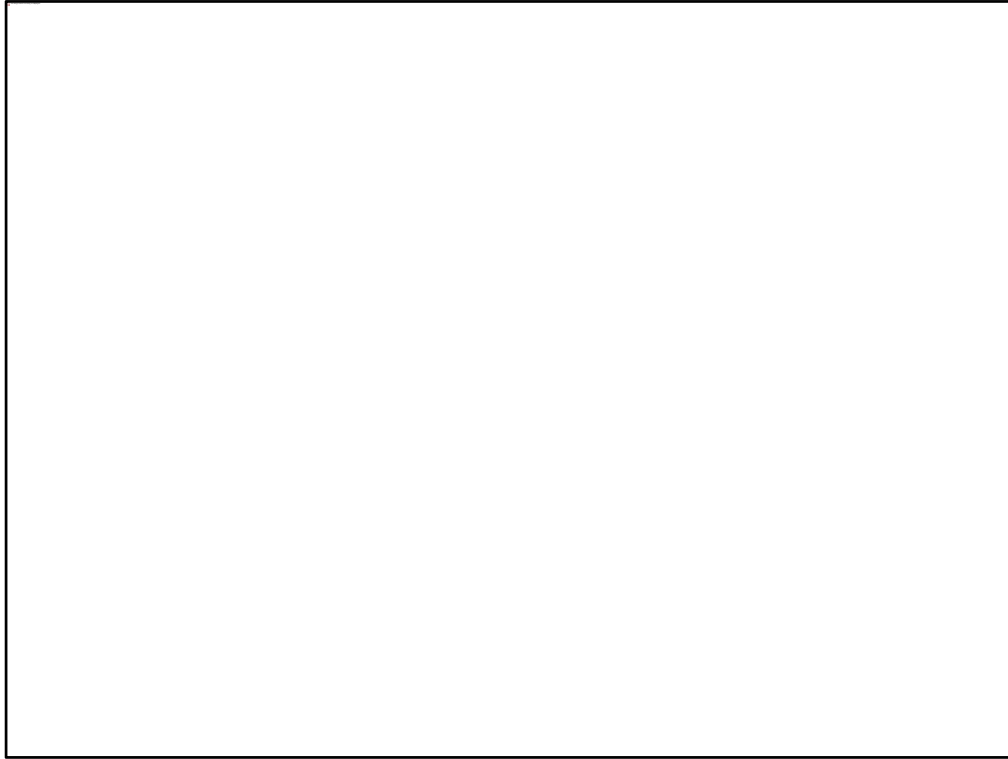


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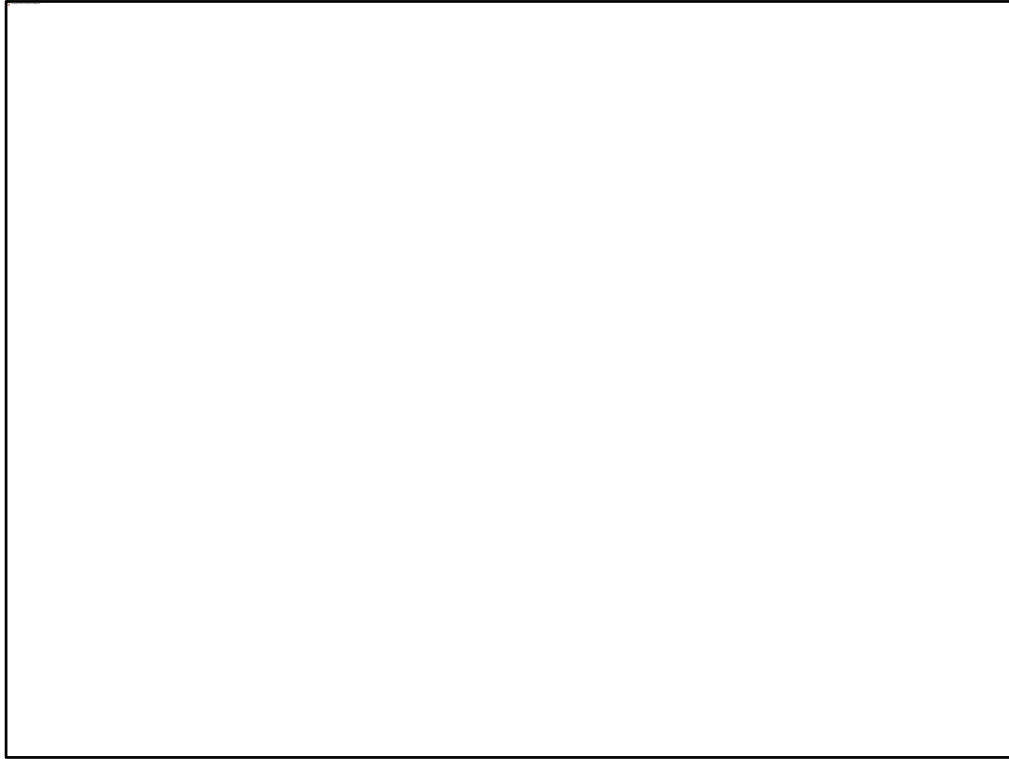


Sometimes the path of the bullet through the body can be predicted, if it is known how many shots were fired (for example, one shot), and if there are two wounds, then you know the path of the bullet is likely a straight line between the two wounds. In this example, there would be no bullet visible on x-ray.

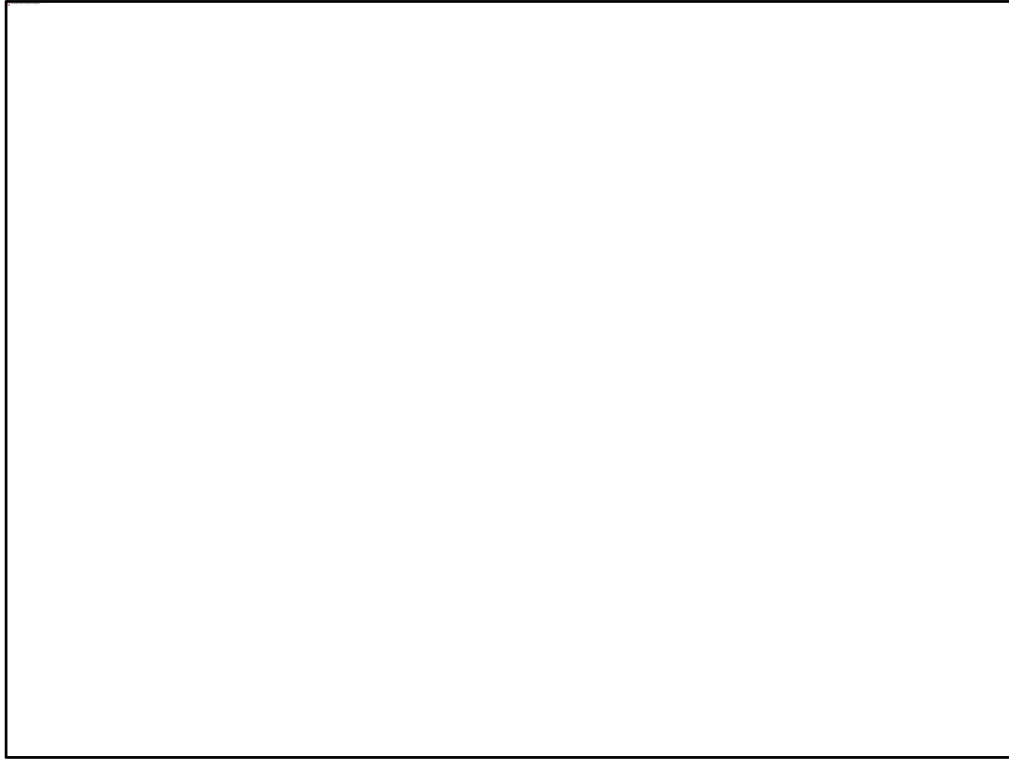
One thing to remember is that the “entrance” and “exit” wounds should not be labeled as such. One should describe the wound locations and their appearance.



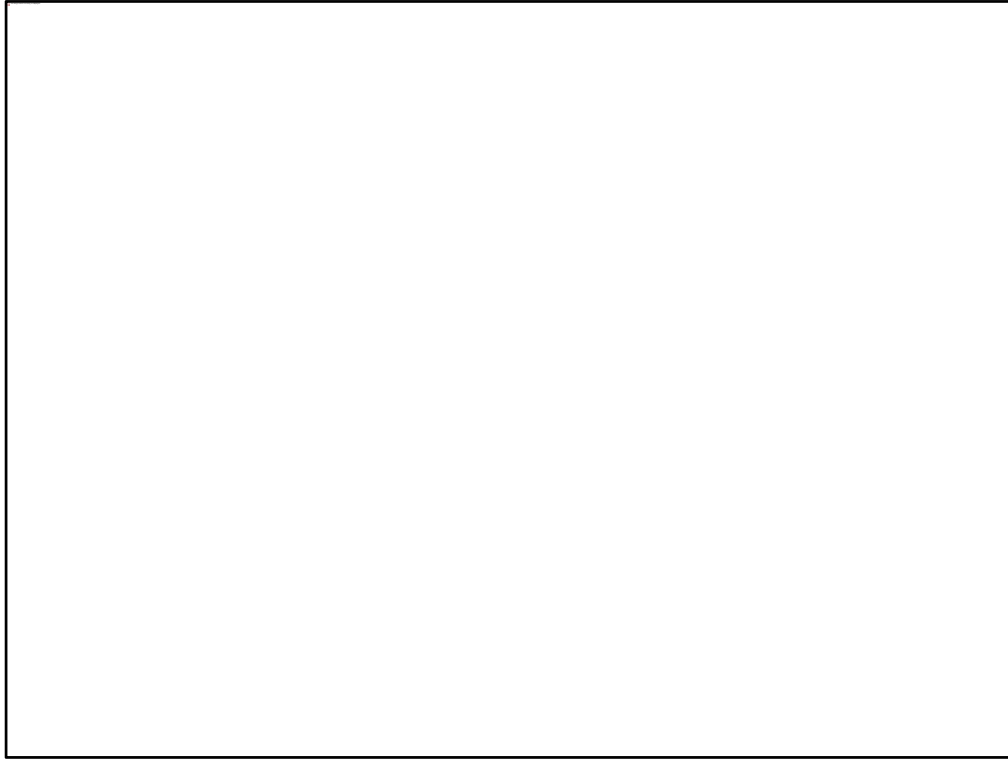
A shotgun shell contains multiple pellets. Some have many small ones (“bird shot”). Some have fewer but larger, more massive, ones (“buck shot”). The pellets spread or diverge from one another the further away from the shotgun barrel they travel. Shots from a greater distance do less damage due to greater spread, and therefore fewer pellets hitting the body. There is also a “wad” (plastic or cardboard) in front of the pellets, and at close range, the wad can also enter the body. Sometimes cloth from the victim’s clothing tears and wraps around the wad and also enters the wound.



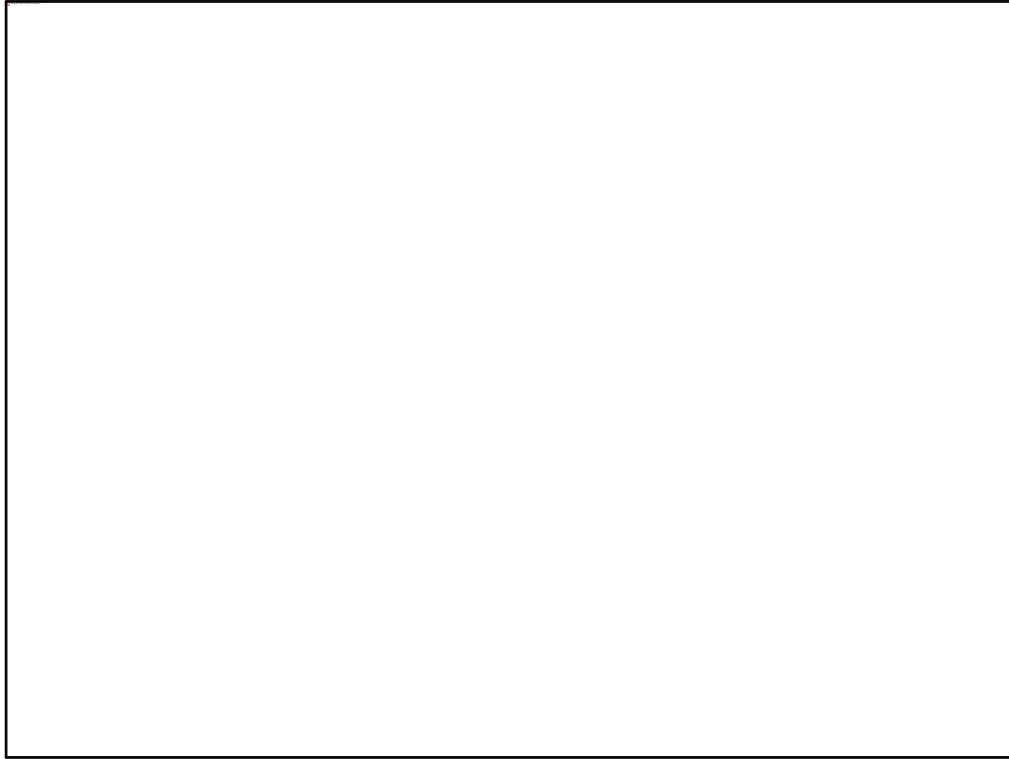
X-ray of multiple bird shot. Depth of penetration is difficult to determine.



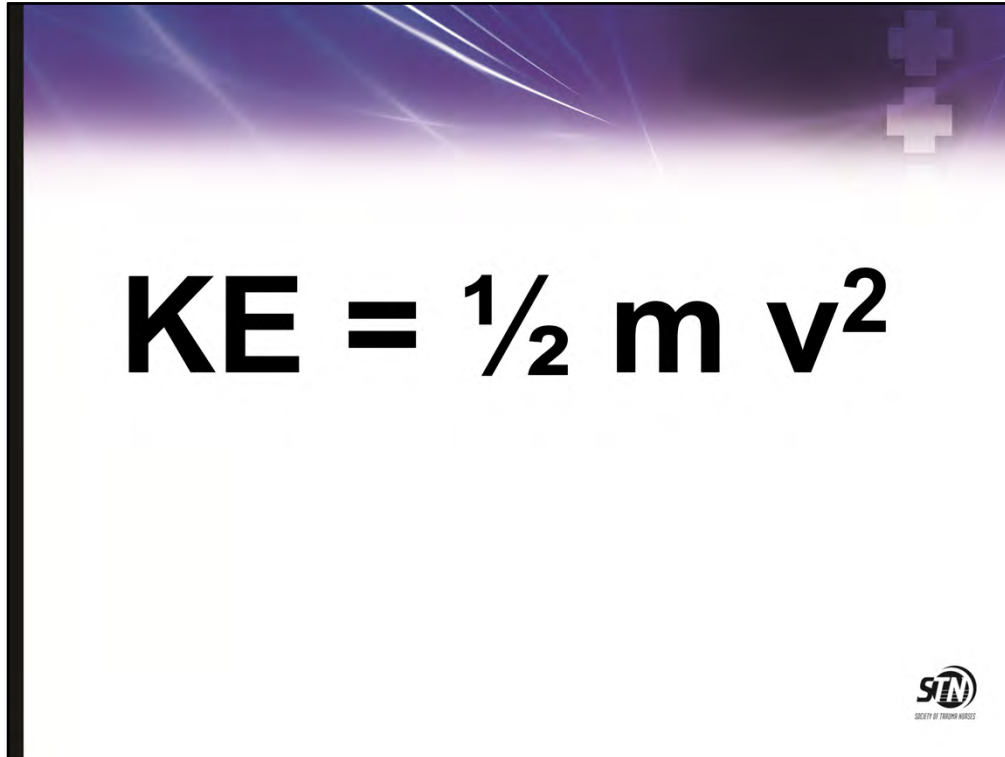
Large tissue damage from high-powered shotgun blast at close range.



Air-powered pellet and BB guns generate much slower speeds, and the projectiles are less massive, as in this typical pellet from a pellet gun. Nevertheless, the body can be penetrated and vital organs can be damaged, so the danger should not be underestimated.




This is an air-powered BB gun designed to look like a real handgun.


$$KE = \frac{1}{2} m v^2$$

With guns, the Kinetic Energy formula is the same. Mass is important, but bullet speed is more important. The speed of the bullet is related to the amount of powder load in the bullet.

Entrance vs. Exit Wounds

- Exit wounds are not always larger
- Avoid labeling wounds entrance or exit
- Include anatomic location, shape, size and any additional finding such as powder burns
- Preserve evidence
 - Cut around not through bullet holes in clothing
 - Handle any bullet carefully
 - Preserve chain of custody



Contrary to popular opinion, exit wounds are not always larger than entrance wounds. Lower energy missiles tend to have similar sized entrance and exit wounds, causing damage to the structures in the direct path. Higher energy missiles are more prone to cavitation causing injury to the surrounding tissues adjacent to the path of the missile, thus, exit wounds are substantially larger.

One should not label the suspected entrance and exit wounds as such to avoid medicolegal implications. Describe and document wounds objectively and accurately. Photograph if possible. It is important to optimize the documentation and evidence collection while caring for the patient.



Summary and Conclusions

Injury patterns and severity
are *predictable*,
based on knowledge about
mechanism of injury,
especially mass and velocity



Velocity is the most important factor in predicting the severity of trauma.