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Understanding the mechanism of injury and kinetic forces involved in traumatic injuries

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In brief

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Summary
In this article, the author describes the kinetic forces patients can be subjected to during traumatic incidents or accidents and how these impact on injuries.

Key words
- injuries
- trauma
- wound care

These key words are based on subject headings from the British Nursing Index. This article has been subject to double-blind review.

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Aim and intended learning outcomes

This article aims to highlight the importance of assessing exact mechanisms of injury (MOIs) and the kinetic forces that patients may have been subjected to during traumatic incidents or accidents.

After reading this article you should be able to:

- Interpret the degree and direction of forces that may have affected the patient you are assessing.
- Anticipate common injury patterns associated with any given applied force.
- Formulate a targeted assessment to identify potential life or limb threatening injuries quickly so that appropriate treatment or interventions can be initiated.

Introduction

It is an integral part of the emergency nurse role to question patients about, and examine them for, various aspects of their presenting illness or injury.

Ambulance service colleagues usually ask the same type of questions when they arrive at the scenes of incident or illness, but they often have the advantage of being able to see the environments where injuries or illness have occurred. They therefore have a better appreciation of the MOI and the kinetic forces that patients have been subjected to before initiating treatment.

The amount and direction of the force to which an individual has been subjected can be evident from the scene of the impact, for example the amount of damage done to a vehicle following a crash or the distance fallen and type of surface onto which the individual has fallen.

Emergency nurses need to have the skills and underlying knowledge to elicit information, either from patients or ambulance colleagues, about MOIs and the type, duration and direction of any forces applied to the patients with traumatic injuries so that such patients can be assessed quickly and thoroughly.

A failure to appreciate the type and amount of force to which patients have been subjected can lead to subtle signs and symptoms being overlooked, and potential life or limb threatening injuries going undetected at the earliest opportunity.

TIME OUT 1

Reflect on a patient with an acute traumatic injury you have nursed recently. What questions did you ask the patient, or ambulance colleagues, to establish the degree and type of forces that caused the patient's injuries?

Many protocols used in emergency departments have trigger factors that involve MOI and, as such, the presence or absence of given forces can influence the initial and subsequent management of patients, for example the speed of impact in road traffic accidents (RTAs) or the types of weapon used in assaults or shootings.

Consideration of these forces can also affect other areas of management, such as treatment regimes, patient education, X-ray criteria and even if patients are safe for discharge.

TIME OUT 2

Which protocols in your department use MOI as a trigger factor?

Laws of motion

To understand the MOI, it is necessary to have a basic understanding of some of the laws of motion.

The first is that a body in motion remains in motion, at the same velocity, until acted upon by an outside force. This is known as Newton's first law of motion.

A person in a vehicle travelling forward at 60mph, for example, will continue to travel at this velocity when the vehicle stops suddenly until he strikes an object, such as the steering wheel or seat belt, that stops his forward momentum.

The speed of the vehicle is a major contributing factor in mortality. A pedestrian struck by a vehicle travelling at 20mph has a 5 per cent chance of sustaining fatal injuries. In comparison, someone struck by a vehicle travelling at 50mph has an 85 per cent chance of being killed (Moulton and Yates 1999).

Nurses must also understand that energy cannot be destroyed but can be changed into different forms, such as the heat emitted by impact or friction. That is, motion is transformed into thermal energy – heat – by the resistance offered to it. This is consistent with the first law of thermodynamics (McNeil 1982).

Consider the driver of the vehicle travelling at 50mph that hits a wall or other stationary object. He will be subjected to four separate impacts or transfers of forces:

- The vehicle collides with an object, possibly another vehicle. It decelerates, and the air bags or crumple zone are activated to dissipate the energy of the driver's velocity.
- The driver hits the internal structures of the vehicle, decelerates further, and is subject to compression forces.
- The driver's internal organs continue moving forward despite his body stopping, and may undergo shearing forces.
- The driver recoils, with a velocity that is possibly enhanced by the position of the seatbelt, and experiences rebound injuries.

The above example shows that the energy of movement – kinetic energy – is subsequently transferred into other forms of energy such as compression, cavitation or shearing forces

According to the formula of moving objects, kinetic energy (KE) = $1/2\ MV^2$, where M is mass and V is velocity. This shows that the velocity of an object has a much greater effect on its kinetic energy than its mass.

This means that it is the velocity at which an object strikes a person, rather than the object's mass, that determines the severity of that person's injuries. For example, a bullet weighs no more than few grams but can cause catastrophic injuries if fired from a high velocity rifle.

TIME OUT 3

What injuries would you anticipate in a patient described in this stand by call? 'Twenty-eight year old male driver of a car. Head on collision with a tree. Indications at scene suggest he was travelling in excess of 50 mph on impact. Significant damage to the front of vehicle, which was a small sports car the driver had built himself. Driver was trapped for ten minutes but has now been freed by the fire service. His Glasgow Coma Score is 11'.

Injury patterns and their relation to MOI and kinetic forces

Certain injury patterns can be matched to the specific forces involved in certain MOIs. They can be placed into two broad categories: blunt or penetrating. In blunt injuries, the skin surface remains intact; in penetrating injuries, the skin surface is broken (Emergency Nursing Association 2000).

Road traffic accidents are the biggest single cause of traumatic death in the UK (Coyne 2001), and patients who have been involved in these tend to present at A&E with a combination of blunt and penetrating injuries.

Many modern vehicles are designed with safety devices, such as air bags, seatbelts or crumple zones, to dissipate the effects of force on impact, or to prevent the occupants being subjected to large acceleration or deceleration (A/D) forces.

These safety devices prevent certain injuries, but can also increase the likelihood of others. Examples include hyperflexion and extension injuries to the necks of passengers wearing seatbelts (Allen 1999, Steill *et al* 2001), clavicle fractures – again from seat belts – and friction burns from air bags (Eaton 2003).

Nevertheless, people who are unrestrained or who are ejected from vehicles on impact are more likely to sustain severe injuries (Greaves and Porter 1999).

Head on collisions usually create several significant injuries including:

- head and scalp injuries, possibly with altered levels of consciousness
- facial injuries from impact with the steering wheel, dashboard or windscreen
- flexion and extension injuries to the cervical spine injuries (Harrison 2000)
- seatbelt tension injuries, including abdominal visceral injuries or perforation, fractures and burns around the clavicle
- chest injuries, including pneumothorax, pulmonary or cardiac contusion, and rib fractures or flail segment
- abdominal compression injuries from impact with the steering wheel, diaphragm rupture or visceral injuries

Table 1. Common injuries due to A/D forces

Organ or body part	Compression injury	Shearing injury
Head	Skull fractures Brain contusions Intracerebral bleeding	Torn cerebral blood vessels Brain stem contusions
Neck	Compression fractures of the spine	Spinal cord contusion or transection Fractures Dislocations
Thorax	Pulmonary contusion Pneumothorax or haemothorax Rib fractures possibly with flail chest Cardiac contusion	Aortic dissection
Abdomen	Ruptured aortic valve Diaphragmatic herniation Damage to organs including spleen, kidneys, stomach, liver, pancreas	Mesenteric tears Aortic injury Liver transection
Pelvis	Pelvic fractures Genitourinary injury Ruptured uterus in pregnant patients	

(Institute of Health and Clinical Development 1999)

- upper limb injuries from direct impact associated with vehicle intrusion as a result of the impact
- lower limb injuries, including fractures or dislocations of the femur and patella from impact with the dashboard, or crush injuries associated with engine intrusion into the passenger compartment (Hodgetts *et al* 1997).

In RTAs, lateral impacts or collisions are usually associated with spinal and head injuries (Cooke 2001). The side of the vehicle that has received the impact should be determined as well as the patient's position in the vehicle to indicate injury pattern.

Rear impact usually results in head and neck injuries unless there is major intrusion into the passenger compartment (Emergency Nursing Association 2000).

Pedestrians struck by vehicles have different injury patterns depending on the vehicle's velocity and height, which changes the point of impact.

Acceleration and deceleration forces

The injuries that occur due to A/D forces fall into one of two groups: shearing injuries and compression injuries.

Shearing injuries, such as damage to the arch of the aorta, occur almost exclusively as a result of the A/D forces themselves. By contrast, compression injuries, such as those to the head from hitting the dashboard or windscreen, occur due to impact caused by deceleration.

Shearing forces can cause the liver, heart and other heavy organs to pull away or fold round the ligaments or muscles securing them, and so result in dramatic internal haemorrhage.

Jumping or falling from a height is likely to result in calcanial and other lower limb fractures depending on how the patient landed and what they landed on. If they landed on their feet, the energy transfer can progress up the leg causing hip injury, up the spine causing compression fractures, and to the skull causing a fractured base of skull.

If the force of the fall is broken, the injury pattern can be different if injuries occur at all. This is because impacts with other structures during the fall may cause injuries even though the final deceleration forces to which the patient is subjected are reduced.

Similarly, footballers who invert their ankles while playing are less likely to sustain serious injury to these joints than those who invert them because of a heavy tackle, in which the forces applied to their ankle joint are greater.

Compression injuries that occur due to an impact secondary to the A/D forces can include knee or femur injures, including dislocations in an RTA, or pneumothorax if the chest walls or lungs are forcibly compressed at impact.

Rebound injuries, which occur due to recoil following deceleration, include spinal fractures and contra-coup injuries to the brain.

The common injuries that occur due to A/D forces are outlined in Table 1.

TIME OUT 4

Think about what you have read about kinetic energy and A/D forces. How would you find out from an ambulance crew what forces patients may have been subjected to during an accident? How might this information influence their examination and assessment?

Cavitation and blunt trauma

Think about a bowling ball striking skittles. The skittles together form a single entity, analogous to a human body, but when they are hit by the ball the transfer of energy knocks them out of position. The same occurs to the internal organs when an object strikes the body. This effect is referred to as cavitation.

The cavitation is permanent or temporary depending on the amount of force that has been applied to the body, and on the elasticity of the tissues involved and their ability to recoil (Institute of Health and Clinical Development 1999).

Permanent cavitation occurs when a tract or hole is made through tissue and it remains even

after the energy has been removed or dissipated. Temporary cavitation is not so easily recognised because the structures involved may have returned to their original location once the energy has been dissipated.

Cavitation can be obvious, but is not always so. For example, if the skull is struck by a bat, it is fairly likely that there will be a depressed fracture that is easily detectable.

But if the abdomen is struck, cavitation is less obvious because of the underlying structure's ability to recoil. The results however, which may include organ damage or life threatening haemorrhage, can be just as serious.

Emergency nurses must therefore be aware of the degree of cavitation that is likely to occur following blunt injury and the consequent damage to related organs and other structures.

Cavitation and penetrating trauma

If a patient is shot by a low velocity bullet from a hand gun, the energy transfer, and therefore the degree of cavitation, will be much less than that due to a high velocity round from the same distance.

However, in both cases there will be a permanent cavitation – a hole – and significant other structural damage due to the temporary cavitation that occurs (Fig. 1), particularly in cases involving the use of high velocity rounds.

Nurses should consider the likely damage from temporary cavitation in any wound caused by projectiles, including glass fragments from a shattered windscreen or debris from an explosion.

The entry wound from a bullet or other projectile can be relatively small but the energy transfer from the projectile to the underlying tissues will result in temporary cavitation that may become permanent. The greater the energy transfer the greater the cavitation, and the greater the likelihood of it becoming permanent.

Cavitation can damage organs, structures and tissues even if it is only temporary, and can, if untreated, lead to significant tissue destruction and sepsis.

The amount of kinetic energy projectiles contain, and the paths they take once they enter bodies, influence whether or not they produce exit wounds. As projectiles travel through tissue, their paths, or tracts, can be deflected by hard structures such as bone.

Meanwhile, the 'yaw' and 'tumble' movement of projectiles also influence the degree of cavitation, particularly in gunshot injuries. In these circumstances, the 'yaw' results from the rotational forces applied to the projectile as it is ejected from a weapon, while the 'tumble' is the change in rotation as it hits the body and starts somersaulting rather than spinning along its long axis.

Exit wounds tend to be larger than entry wounds because the structures and debris projectiles collect as they pass through the body are forced out through the skin.

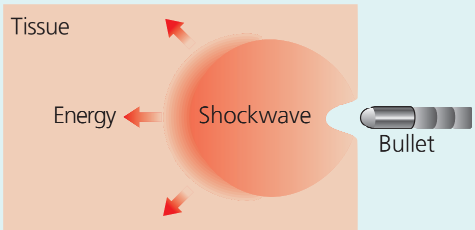
Cavitation, either permanent or temporary, does not only occur following gunshot or other wounds caused by high velocity projectiles. Simple puncture wounds can also exhibit some degree of permanent or temporary cavitation.

The extent and degree of cavitation associated with stab or other puncture wounds, for example, can be considerable, and in such cases, underlying organs, tendons and blood vessels should be examined for structural damage.

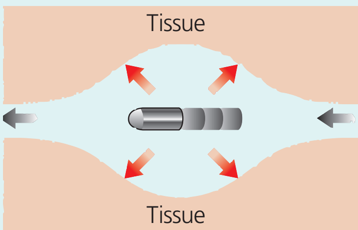
TIME OUT 5

Consider which structures may be damaged in the following scenario. A patient has an entry wound in the lateral aspect of his thigh after a tin can exploded in a bonfire. What questions would you ask and what signs would you look for to confirm or exclude injury?

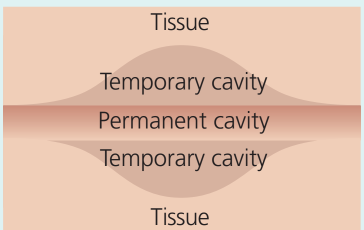
Fig. 1. Cavitation after bullet penetration



Step 1. High velocity bullet penetrating tissue at velocity of about 120m/s. Shockwave ahead of bullet



Step 2. Bullet passing through showing temporary cavity at maximum size



Step 3. Damage areas

(National Association of Emergency Medical Technicians 2002)

Table 2. Structured approach to gathering information about MOI and the forces involved

Pre-incident

What events led up to the accident or injury? For example, did the patient trip, or become light headed and then fall? Did they hit something on the road that caused them to crash? Did they develop chest pain while driving? How fast were they going at the time of the accident?

Principle: take nothing for granted. Events that precede an impact and the kinetic forces involved can compound the patient's problems and complicate investigations, treatment or discharge.

Incident

What exactly happened during the incident? Was the person hit from the side by another vehicle? If so, which side? Did the air bags deploy? Was the person running when they inverted their ankle? Or did they jump to head a ball and land awkwardly?

Principle: understanding the direction, duration and degree of energy that has, or may have, been transferred to the patient can help anticipate the nature and extent of possible injuries.

Post-incident

What did the person do or feel immediately after the accident? Were they aware of developing neck pain immediately or has it come on over a period of time? Did the person carry on playing football? Or did they soak in a hot bath to ease the knee pain but the pain is now worse?

Principle: use clues from the history taking to target the assessment. Attention to symptoms should complement the assessment of signs and key history factors.

Targeted history taking

According to Norman McSwaine, one of the pioneers of the advanced trauma life support and pre-hospital trauma life support courses: 'A complete and accurate history and proper interpretation can identify 90 per cent of the injuries before the actual physical examination is performed' (NAEMT 2002) in most circumstances.

Most emergency nurses are experienced in taking histories from patients and handovers from ambulance colleagues, but it is frequently done in an unstructured way.

A structured approach, similar to the one in Table 2, can be useful to gather appropriate information about the MOI and the forces involved.

The system outlined in Table 2 gives practitioners vital information about the exact nature and extent of the forces applied to patients, as well as other key indicators of likely injuries. This allows them to initiate appropriate interventions, or to anticipate injuries.

Nurses should also remember however to take an AMPLE history (Table 3). This ensures that other key areas of information are considered when deciding what interventions or investigations should be instigated, and what treatment is needed immediately.

Table 3. An AMPLE history

Questions to ask all patients

A: Allergies, age and alcohol?

M: Medications

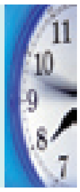
P: Past, pertinent medical history

L: Last meal, low temperature?

E: Events before accident or illness. Is epinephrine (adrenaline) masking other injuries?

TIME OUT 6

Now that you have finished reading the article, you might like to write a practice profile. Guidelines to help you are on page 35



Conclusion

Every day, emergency nurses encounter patients who have been subjected to varying degrees of force or energy exchange.

Understanding the direction and extent of the forces that patients have been subjected to, and a working knowledge of the structures that might have been injured as a result, allow practitioners to make targeted assessments to identify any life or limb threatening injuries.

Alternatively, nurses can use this information to initiate appropriate diagnostic or treatment interventions to ease patient suffering and minimise their length of stay in the emergency department.

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