DEFINITION

Ballistics is the science that deals with the motion, behaviour and effects of projectiles.

A **ballistic wound** is a wound created by a projectile.
Most common cartridges and projectiles found in a war zone. In addition to military rifles and explosives, shotgun and pistols are widespread too.
<table>
<thead>
<tr>
<th></th>
<th>Kinetic energy</th>
<th>Practical range</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assault rifles</strong></td>
<td>HIGH</td>
<td>300/400m</td>
<td>Non fragmentable except at short range</td>
</tr>
<tr>
<td><strong>Shotgun</strong></td>
<td>LOW</td>
<td>50m</td>
<td>Wad found in wounds at close range; multiple pellets</td>
</tr>
<tr>
<td><strong>Pistols</strong></td>
<td>LOW</td>
<td>50m</td>
<td>Widespread use in civilian violence</td>
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<td><strong>Fragments</strong></td>
<td>INITIAL VERY HIGH</td>
<td>Variable, lethal zone up to 50m</td>
<td>High wounding capacity due to irregular shape and sharp edge, especially for vessels and nerves; IEDs</td>
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</table>
TYPICAL FULL METAL JACKET MILITARY AMMUNITION

Metal casing

Lead core

Cannelure

Boat-tail shape

Rifling marks

7.62x39 former Yugoslavia
TWO BASIC COMPONENTS OF A FULL METAL JACKET BULLET

- Lead core
- Metal casing
THE WAD IS FOUND VERY OFTEN DEEP IN THE WOUND IN CLOSE RANGE SHOTS.

BOTH PLASTIC AND FABRIC WADS ARE NOT VISIBLE ON X-RAY IMAGES.
INTERNAL: what happens inside the barrel, acceleration, interaction with the rifling...

TRANSITIONAL: brief moment at muzzle level, when pressure behind the bullet drops down, sonic considerations...

EXTERNAL: flightpath of the bullet in the air, motion, no other forces acting on the bullet than gravity and air resistance producing drag

TERMINAL: what happens when bullet hit the target, motion and behaviour within the target, wounding mechanism
TERMINAL BALLISTICS

INTERACTION OF BULLET WITH TARGET

WOUNDING MECHANISM
BASIC PRINCIPLE OF TERMINAL BALLISTIC

THE DAMAGE, CREATED BY A FLYING BULLET HITTING BODY TISSUES, IS THE RESULT OF KINETIC ENERGY ( $E = \frac{1}{2}MC^2$ ) TRANSFERRED FROM THE BULLET TO THE TISSUES
WOUND PROFILES

Wound profiles allow a good visualization of bullet behavior in a homogeneous medium.

They do NOT represent exactly what happens in human tissues but they help understand important wounding mechanisms and provide a good comparative analysis of different bullet terminal ballistics.
WOUND PROFILES

TISSUE SIMULANTS

GELATINE ("elastic")

GLYCERINE SOAP ("plastic")

Bone and vessels simulants can be added
WOUND PROFILES

Wound profiles are obtained by shooting through a GLYCERINE SOAP block. The block is cut along its longitudinal axis. The "profile" of the cavity left after the bullet’s passage represents the temporary cavity and **ITS VOLUME** - THE AMOUNT OF ENERGY TRANSFERRED (Martell’s Law).
WHEN TUMBLING STARTS, TRANSFER OF ENERGY INCREASES ABRUPTLY
2 KALASHNIKOV BULLETS

AK-47
7,62x39

AK-74
5,45x39
A bullet may hit an obstacle before reaching its intended target. It is then destabilized and will hit the target in a particular way.

This is called the “ricochet” effect and is demonstrated by having the bullet just grazing a wooden stick before the target, which is hit with the bullet travelling sideways and creating a WP compatible with an immediate and very large transfer of energy.
WOUND PROFILE OF A RICOCHET EFFECT
Cruising

Direct action of the bullet

Permanent cavity

Stretching

Tissues are stretched radially and outwardly with respect to the bullet path

Temporary cavity
DEFINITION OF AN EXPLOSION

PHYSICAL PHENOMENON DURING WHICH GASES ARE PRODUCED AT VERY HIGH PRESSURE AND TEMPERATURE OVER AN EXTREMELY SHORT PERIOD OF TIME
• Blast injuries
  – Three initial phases
    • Primary
    • Secondary
    • Tertiary
  – Two subsequent phases
    • Quarternary
    • Quinary
• Primary phase
  – Pressure wave moves at up to 10,000 (3048 m/sec)
    • Dismemberment
    • Pulmonary contusion
    • Pneumothorax
    • Air emboli
    • Tympanic rupture
  – Pulmonary manifestations may be immediate or delayed
• Tertiary phase (blunt force injuries)
  – Contact with ground/stationary object
  – Crushed by structural collapse
• Secondary and tertiary injuries are more obvious, but primary injuries can be more severe
• Quarternary phase
  – Heat and fumes

• Quinary (bomb-related injuries)
  – Dirty bombs (bacteria, radiation, chemicals)
  – Fragments of human (suicide bomber) remains can be embedded in victims
• Head
  – External injury should increase suspicion of brain trauma
  – Compression may lead to scalp laceration/hematoma and/or skull fracture
  – Shearing injuries result from continued forward motion of the brain after the skull comes to a stop
• Neck
  – Compression
    • Range of motion exceeded
    • Axial loading
  – Shear
    • In a lateral impact to the torso, the torso accelerates away from the head, stretching the soft tissues and vertebral column (distraction injury)
• Thorax
  – Compression
    • May exceed tensile strength of ribs
    • Pulmonary overpressure injuries
    • Compression of organs
      – Pulmonary contusion
      – Cardiac contusion
  – Shear
    • Aortic transection
    • Traumatic aortic aneurysm
• Abdomen
  – Compression
    • Damage to solid organs
    • Overpressure
      – Ruptured diaphragm
      – Hollow organs
      – Retrograde aortic flow ruptures aortic semilunar valve
  – Shearing
    • Occurs at points of attachment/fixation of organs
      – Kidneys, liver, spleen, intestines, (full) bladder
Landmines

Banned from use, production, stockpiling and transfer by the OTTAWA TREATY (1997), landmines are still found and used globally.

Many states have NOT signed the Treaty (China, US, Russia, South and North Korea...)

Designed to be used against human targets, they do not always kill but more often are intended to maim.

Landmines remain operational long after the cessation of “hostilities” and civilians represent the vast majority of casualties.
LANDMINES

PMN (Black Widow) **ANTIPERSONNEL** MINE; 249 grams of TNT explosive
Designed to kill, cause casualties some distance from the explosion

PFM 1/1S (Green Parrot or Butterfly) **SCATTERABLE** MINELET;
40 grams of liquid explosive; designed to maim
CLAYMORE FRAGMENTATION MINE
Or M18
628 grams of C4 explosive
700 steel spheres
Lethal up to 50 m
Dangerous up to 250 m

OZM 4 BOUNDING MINE
185 grams of TNT + prop.
Fragm. from cast iron shell
Lethal up to 15 m
Wounding mechanism of landmines - THE UMBRELLA EFFECT

When the skin has returned to position, the extent of proximal damage is hidden

From R. Coupland
Proximally the damage, especially to soleus, is always much more than what is visible.

Be prepared to “climb up” during DBR, muscle necrosis can be found proximally (yellow dotted line) to wound edges even underneath intact skin.
Wounding mechanism of landmines - THE UMBRELLA EFFECT

Damage to deep structures can be found proximally to wound edges under intact skin.

At initial DBR the surgeon must start planning skin flaps appropriate for amputation (that will be done at DPC time, five days later).

Notice contra-lateral lower limb is practically unharmed.
Wounding mechanism of landmines - THE BOUNDING MINE

R femur fracture
Multiple STWs
Intact feet
Deep L arm STWs
r. Femoral art. lesion
Wounding mechanism of landmines – THE MAIMING MINELETS

LOW EXPLOSIVE CONTENT. OFTEN MAIMING CHILDREN MANIPULATING THE DEVICE
TERRORIST ATTACKS - SUICIDE BOMBERS

Targeted at large human gatherings

number of victims ➔ MASCAL

Extremely variable effectiveness

Suicide bombers ➔ BIO-SHRAPNELS
IEDs  Improvised Explosive Devices

- Most common device used in recent years in Afghanistan
- Custom made using existing explosive from military ordnances or by producing from scratch the explosive with available materials
  - Over 65% of ISAF forces casualties are attributable to IEDs
- Extremely variable effectiveness, but considered very dangerous for civilian population due to their widespread use
- Can be used as booby-traps or be activated remotely by electronic devices including cell phones
IEDs  Improvised Explosive Devices

Young boy, typical victim of an IED in Helmand Province

Note the severity of soft tissue injuries

Often, fabric, wood, metal pieces, nails, bolts, nuts...are found deeply embedded in the wounds and require meticulous surgical technique for proper management and very often, repeated DBRs
Treat the wound, not the weapon
BALLISTIC WOUNDS KEYPOINTS

• Aspect of the wound is variable
• The amount of damage is variable
• Severe damage of deep tissue can occur with small entry wounds
• Tissue damage occur at a distance (radially) from the bullet path
• Shell injuries are often multiple
• Large entry wounds with severe initial damage are often the result of ricochet or the use of expanding bullets
MISSILE INJURY (MINE FRAGMENT)

COMMINUTION

ENTRY

EXIT
ALL WAR WOUNDS ARE HIGHLY CONTAMINATED
Abdomen
Limbs
The goal of war surgery is to avoid infection

1. Debridement
2. Irrigation
3. Antibiotics
BEFORE SURGERY

Washing patient and wound area with Water & Soap
Water is poured from above and flows in a basin. The water in the basin should not be re-used.

Soft brush or gauze may be used with soap.

Assistant holds limb in physiological position.

Optimal wound area washing is better done with patient under anesthesia.
WATER & SOAP

**WATER**
- TAP WATER
- POTABLE WATER
- BOILED AND COOLED WATER
  
  Water that is considered safe for drinking can be used to wash wounds.

**SOAP**
- NEUTRAL SOAP (CASTILE SOAP TYPE) IS BETTER
DEBRIDEMENT

SHARP EXCISION OF ALL DEAD, NECROTIC OR NON-VIABLE TISSUE FROM THE WOUND

PROPER DEBRIDEMENT REQUIRES SURGICAL EXPERIENCE
Along with debridement, **IRRIGATION** is a main staple of initial surgical war wound management.
IRRIGATION

keypoints

- Normal saline solution is the best fluid for irrigation
- No additives, whatsoever, should be used
- No high pressure pulsatile lavage devices should be used
- Large volumes of fluid must be used
IODINE, Povidone-Iodine, Hydrogen Peroxide and organically based antibacterial preparations have all been shown to impair wound healing due to injury to wound neutrophils and macrophages, and thus should not be used.

From Chap.9 Wound healing in “Schwartz’s Principles of Surgery, 9° Ed.”
**TIMING AND VOLUME**

<table>
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<th>The 6 hours threshold is often found in the literature as being an absolute watershed between low infection rates and high ones</th>
<th>It is based on the formation time of biofilm by bacteria as a shield from host defences and antibiotics</th>
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<td>Studies show increase of infection rate in open fractures with delays in surgery over 6 hrs</td>
<td>The main factor in infection rate appears to be the initial severity of the injury, not the time elapsed before surgery</td>
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**IN PRACTICAL TERMS**

**DEBRIEMENT & IRRIGATION SHOULD BE DONE A.S.A.P.**
AND FINALLY.....

LEAVE THE WOUND OPEN
POST OP DAY 5