



WOUND BALLISTICS

**AN INTRODUCTION FOR HEALTH,
LEGAL, FORENSIC, MILITARY
AND LAW ENFORCEMENT PROFESSIONALS
(film with additional information)**



ICRC



ICRC

International Committee of the Red Cross
19, Avenue de la Paix
1202 Geneva, Switzerland
T + 41 22 734 60 01 **F** + 41 22 733 20 57
E-mail: shop.gva@icrc.org **www.**[icrc.org](http://www.icrc.org)
© ICRC, June 2008

Cover images:

Marco Kokic/ICRC, Michèle Mercier/ICRC, *British Medical Journal*, EAAF

WOUND BALLISTICS

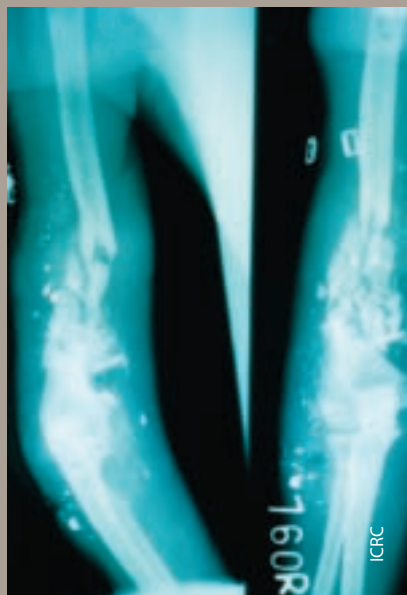
**AN INTRODUCTION FOR HEALTH,
LEGAL, FORENSIC, MILITARY
AND LAW ENFORCEMENT PROFESSIONALS
(film with additional information)**



**A skull found
in a mass grave.**



**The 12.7 mm x 99 mm
cartridges used in the film.**



**An X-ray of an arm
with a bullet wound.**

For more than 150 years, scientists have studied the interaction of bullets and fragments from explosive weapons with human tissue. Such studies have had an effect on how wounded people are treated, the development of international humanitarian law in relation to weapons and, more recently, the investigation of crimes in which firearms have been used. This field of study is known as wound ballistics.

The International Committee of the Red Cross (ICRC) has produced this DVD and brochure on wound ballistics to help a variety of professionals who are in a position to limit the suffering caused by armed conflict or other situations of violence. Health professionals, who treat people wounded by weapons, will benefit from a better understanding of the physical process of wounding. Lawyers need a good grasp of wound ballistics to promote rules limiting the use of force and prohibiting certain bullets. Forensic experts need an understanding of wound ballistics in presenting evidence in court about cause of death. Soldiers and law-enforcement officials have difficult roles and bear weighty responsibilities. To meet these responsibilities, they need to understand the impact of their weapons on the human body.

The brochure provides a brief summary of each chapter featured in the film. It also includes a glossary of terms and a section with answers to your questions. It is meant to augment the film and to enhance the viewer's understanding.

The film looks at the impact of bullets from rifles and handguns as well as fragments of explosive weapons – all at different velocities. It can be viewed in its entirety or by chapter. Two experts present the series of test shots featured in the different chapters. Dr Beat Kneubuehl, of the Institute of Legal Medicine at the University of Bern, Switzerland, is an internationally recognized expert in wound ballistics. Dr Robin Coupland, formerly an ICRC war surgeon, has worked with Dr Kneubuehl for 15 years to develop an instructional demonstration of wound ballistics. Their work is relevant and useful for the professionals for whom this DVD has been made.

CHAPTER LIST OF THE DVD-VIDEO

CHAPTER 1 – 6 min. 12 sec.

Wound ballistics

The introductory chapter explains why the film has been made and who the presenters are and gives an overview of:

- *why it is important for certain professions to study wound ballistics*
- *the physical basis of wound ballistics*
- *how a shot is fired*

CHAPTER 2 – 3 min. 51 sec.

Shot 1

7.62 mm NATO

Bullet: Full metal jacket

Target: Soap

This chapter shows the typical track of a full metal jacket bullet as it moves through a tissue simulant.



CHAPTER 3 – 1 min. 10 sec.

Experimental simulation

Soap and gelatine blocks are internationally validated soft-tissue simulants. This guarantees reproducibility of results. It is possible to observe in which respects simulated wounds are similar to real wounds.



CHAPTER 4 – 1 min. 03 sec.

Shot 2

7.62 mm

Bullet: Semi-jacketed

Target: Soap

A semi-jacketed bullet of the same calibre, mass and velocity as in shot 1 is shot into soap for comparison.



CHAPTER 5 – 2 min. 49 sec.**Bullet construction**

Comparing full metal jacket
and semi-jacketed bullets

The wound track of a full metal jacket bullet is different from that of a semi-jacketed bullet.

**CHAPTER 6** – 3 min. 46 sec.**Shots 3 and 4**

7.62 mm NATO

Bullets: Full metal jacket and semi-jacketed

Target: Gelatine and polyurethane tubes

The same two bullets are shot into gelatine containing two polyurethane tubes to simulate bones.

**CHAPTER 7** – 1 min. 36 sec.**Shot 5**

Reduced propellant

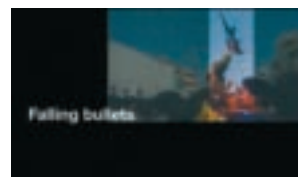
7.62 mm NATO

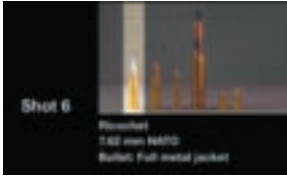
Bullet: Full metal jacket

The same bullet as in shot 1 is fired but at a simulated range of 300 metres. This is done by reducing the propellant.

**CHAPTER 8** – 48 sec.**Falling bullets**

People can be injured by bullets which have been shot into the sky during celebrations.





CHAPTER 9 – 1 min. 56 sec.

Shot 6

Ricochet

7.62 mm NATO

Bullet: Full metal jacket

What if a bullet's flight is disturbed? In a ricochet, a full metal jacket bullet can produce a wound like the one caused by a semi-jacketed bullet.



CHAPTER 10 – 1 min. 51 sec.

Shots 7 and 8

Bullet stability in flight

5.56 mm NATO

Bullet: Full metal jacket

The twist imparted to the bullet in the barrel influences the bullet's stability in flight and this, in turn, affects the wound.



CHAPTER 11 – 2 min. 12 sec.

Shots 9 and 10

12.7 mm x 99 mm

Bullets: Full metal jacket

"Multipurpose"

More powerful bullets designed to penetrate vehicles or light armour can cause enormous wounds if used against people.



CHAPTER 12 – 2 min. 57 sec.

Shots 11 and 12

Simulating fragment wounds

Wounds made by fragments from shells, bombs, grenades and other explosive weapons can be simulated in a laboratory by firing spheres into tissue simulants.



CHAPTER 13 – 1 min. 20 sec.

Shots 13 and 14

9 mm Luger handgun

Bullets: Full metal jacket

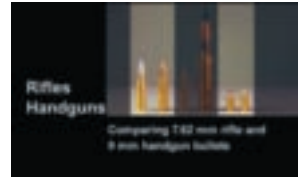
Expanding

The wound track made by a handgun bullet is influenced by the bullet's construction.

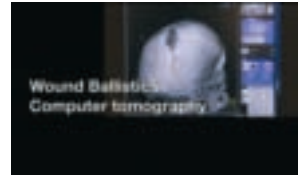
CHAPTER 14 – 59 sec.**Rifles and handguns**

Comparing 7.62 mm rifle and
9 mm handgun bullets

*Whatever the profile of the wound track, handgun
bullets cause smaller wounds than rifle bullets.*

**CHAPTER 15** – 55 sec.**Wound ballistics****Computer tomography**

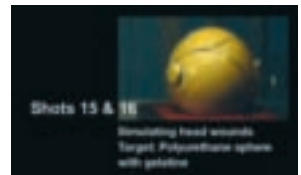
*CT images of real wounds can be compared with
observations made in a wound ballistic laboratory.*

**CHAPTER 16** – 2 min. 43 sec.**Shots 15 and 16**

Simulating head wounds

Target: Polyurethane sphere with gelatine

*Detailed study of head wounds is important for forensic
specialists and surgeons.*



Some technical terms and definitions

Bullet

The projectile, which accelerates down the barrel, exits the muzzle, flies through the air and hits the target.

Calibre

The width in millimetres of the inside of the barrel (and therefore, in most cases, the width of the bullet).

Calibre designation

The calibre and the length of the cartridge case. Calibres have official designations such as those used in this DVD: 7.62 mm NATO; 5.56 mm NATO; 9 mm Luger and 12.7 mm x 99 mm.

Cartridge

The cartridge case, the propellant (gun powder) and the bullet.

Cartridge case

That part of the cartridge which contains the propellant and is ejected from the breach of the gun after it has been fired.

Expanding bullet

A bullet designed to expand and increase its cross sectional area on impact with soft tissue. Most semi-jacketed bullets do this. However, not all bullets which are designed to expand are "semi-jacketed" and not all semi-jacketed bullets expand.

Fragment

Part of an explosive munition which becomes a projectile when the munition detonates. The weapon may be specifically designed to eject fragments, or these may simply be the result of pieces of the munition case being propelled away from the explosion.



Marko Kokic/ICRC

The cartridges used in the film.

Full metal jacket bullet

A bullet whose lead core is completely covered by a hard metal such as steel or nickel. Some full metal jacket bullets have a steel rod in the centre; others may have an air space at the tip beneath the hard metal. They are also referred to as “military bullets”.

Projectile

The bullet or fragment that passes through tissue. (This should not be confused with the military use of the term, which would also include a munition such as a shell or a mortar as it travels through air and which may then injure by dispersing fragments.)

Semi-jacketed bullet

A bullet whose lead core is exposed at the tip. A number of other names are used, such as “dum-dum bullet”, “soft-point bullet” and “soft-nose bullet”.

Twist

The spiral grooves on the inside of the barrel of a gun which impart spin on the bullet, so giving it stability in flight.

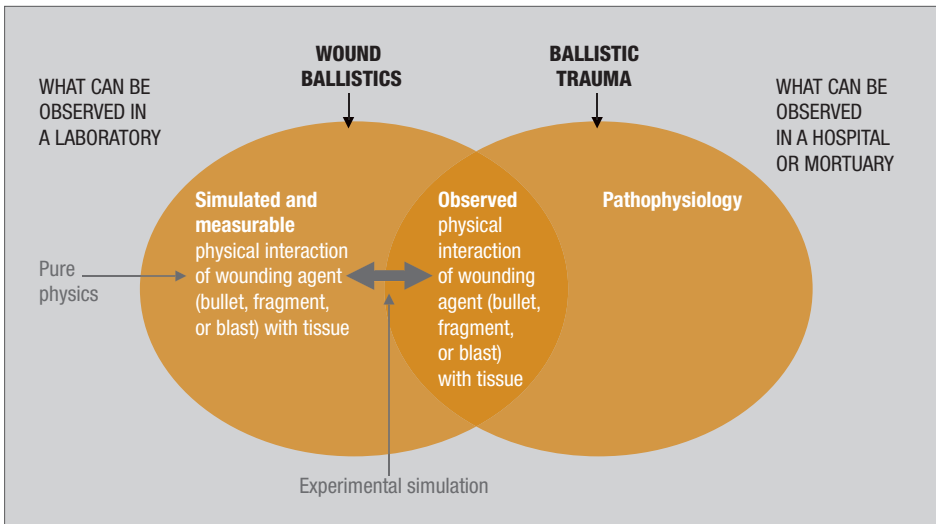
Twist length

The distance for one turn of the spiral groove. “Low twist” indicates a long twist length.

Answers to your questions

What is wound ballistics?

In broad terms, wound ballistics is the study of the interaction of wounding agents (such as bullets and fragments from explosive weapons) with tissue. The laboratory aspect of wound ballistics is the simulated and measurable physical interaction of wounding agents with tissue. Ballistic trauma, which overlaps with wound ballistics, includes the pathophysiological reaction of the body to the physical process. Therefore, ballistic trauma includes blood loss, shock, wound infection and death.



What is experimental simulation?

Experimental simulation is the process of comparing the simulated and measurable physical interaction of wounding agents as they pass through tissue with observations of real wounds seen in mortuaries or hospitals. This process serves to validate the laboratory simulation.

What materials can be used to simulate soft tissue and bone for wound ballistics experiments?

Glycerine soap and 10% or 20% gelatine are standard soft tissue simulants used in many wound ballistic laboratories. They have the same density as soft tissue. They differ in their elasticity and transparency. The width of the cavity at any point along the track corresponds to the energy deposited at that point.

THE ADVANTAGES OF SOAP ARE:

- the cavity created by the passage of the bullet or fragment (the wound track) remains, making it possible to measure how much energy is deposited for every centimetre of the track
- long shelf life
- easy to handle
- can be recycled after use

THE DISADVANTAGES OF SOAP ARE:

- opaque
- requires factory production
- expensive

THE ADVANTAGES OF GELATINE ARE:

- elasticity resembles real tissue
- transparent, which permits cine-photography of the projectiles moving through the block
- cheap

THE DISADVANTAGES OF GELATINE ARE:

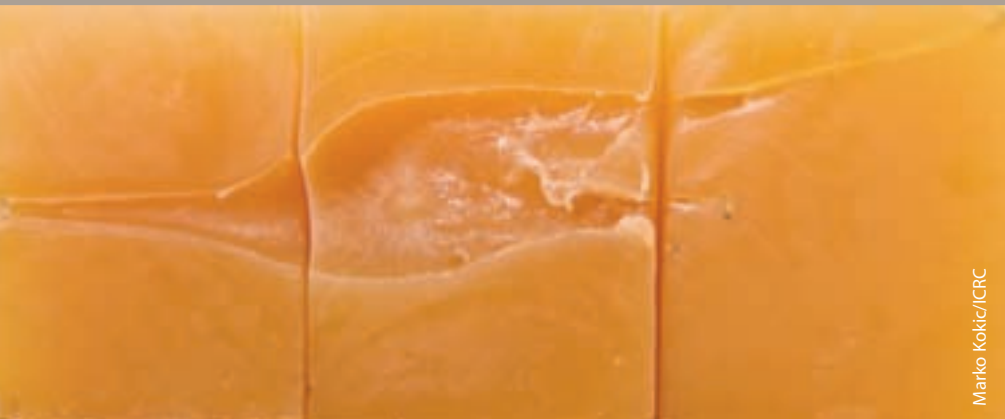
- the temporary cavity collapses and so energy deposit along the track cannot be measured easily
- short storage time (in refrigeration)



Marko Kokic/CRC

The tracks of two different 9 mm handgun bullets shot into a soap block.

The track of a 7.62 mm full metal jacket rifle bullet shot into a soap block.



The track of a 7.62 mm semi-jacketed rifle bullet shot into a soap block.

Polyurethane tubes filled with and set in gelatine permit simulation of wounds to long bones. A layer of latex simulates the periosteum. The polyurethane has the same density and rigidity as real bone and is the same material used for training orthopaedic surgeons in fracture-fixation techniques.

How does a bullet or a fragment from an explosive weapon make a wound?

When a bullet or a fragment passes through tissue, it does physical work on the tissue. This causes the tissue to accelerate away from the front of the projectile; as a result, the tissue is lacerated and variably crushed. The depth of laceration and the degree of crush is determined by the amount of kinetic energy available to do this work.

The amount of available kinetic energy is arrived at by this equation: $E \text{ (joules)} = mv^2/2$ (where m = mass in kg and v = velocity in m/s). Because of the “ v^2 ”, this equation demonstrates how in principle an incremental increase in velocity creates greater kinetic energy than the same incremental increase in mass of the bullet or fragment. The area of contact between the bullet or fragment and the tissue determines the rate at which the energy is transferred and so, in turn, where and at which point along the wound track the work is done. The more energy deposited at any point along the bullet’s track, the wider the wound at that point. (This is indicated in shot 1: a full metal jacket rifle bullet deposits little of its energy as it penetrates tip first; as it turns sideways, it increases its area of contact and so the energy deposited per centimetre of track increases.)

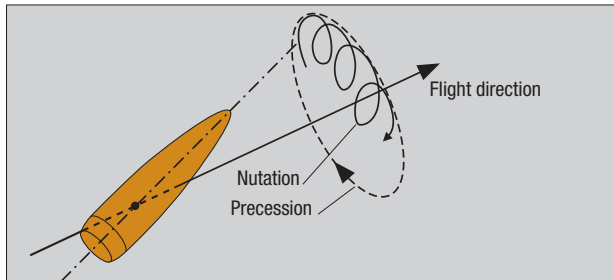
What is a “wound profile”?

The “wound profile” is a useful conceptual tool for giving a visual impression of the length, shape and dimensions of the whole track of the bullet or fragment. This can be deduced from real wounds or tracks in gelatine, but can be simulated and measured most easily in soap. In this DVD the wound profiles of different shots are exposed by cutting along the whole length of tracks made in soap by bullets and fragments.

Why do bullets deform on impact?

Whilst a bullet in motion does work on the tissue, the tissue also does work on the bullet. The amount of work done depends on the amount of kinetic energy carried by the bullet. This means that all bullets, if given sufficient velocity, can deform in soft tissue. As shown in shot 1 of this DVD, a full metal jacket bullet can be compressed and can break when it turns sideways along the track. This deformation is different from the deformation of a bullet specifically designed to expand such as a semi-jacketed bullet (as seen in shot 2 of the DVD.)

Why is the stability of a bullet in flight important?



Any bullet in flight rotates around its long axis between 1500 and 6000 times per second. This gives the bullet stability in flight. However, other movements such as precession and nutation also influence the bullet's stability (see chapter 10 in the DVD). A bullet has high stability if the angle of precession is close to the direction of flight. In general terms a bullet is stable for the first metre after exiting from the barrel. It rapidly adopts a flight with low stability in which the angle of precession is great in relation to the direction of flight. It then becomes increasingly stable in flight. On impact, a stable, non-expanding bullet has a long narrow track initially. A bullet with lower stability turns rapidly after impact, passes through the tissue sideways and so deposits its energy early in the track. As demonstrated in shot 3, with longer range and at lower velocity (and therefore with less energy), the stability of the bullet increases. This explains why bullet wounds sustained at long range do not have as much tissue damage as those sustained at close range.

Incorrect barrel twist or a very worn barrel can reduce the stability of the bullet's motion in flight.

Why can spheres be used to simulate fragment wounds?

Fragments resulting from the detonation of an explosive weapon may consist of heavy or light materials. The length and width of a track formed by a fragment are, as with a bullet, primarily determined by its mass and its velocity. The shape of the fragment makes little if any difference. The track is always circular in cross section because a fragment always presents its widest surface area on travelling through tissue and the tissue is evenly accelerated away from the most forward point of this surface area. A useful parallel is that whatever the shape or size of a stone thrown into water, the resulting ripples always form a circle.

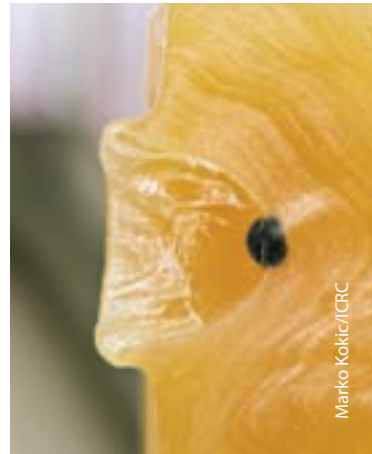
What is international humanitarian law?

International humanitarian law is a set of rules which seek, for humanitarian reasons, to limit the effects of armed conflict. The law protects persons who are not, or are no longer, participating in the hostilities. It places restrictions or prohibitions on the use of certain weapons and methods of warfare.

For example, this body of law obliges parties to an armed conflict to care for the wounded and sick and to protect medical personnel. They must also ensure that the dignity of prisoners of war and civilian internees is preserved.

While conducting hostilities, parties to a conflict are required to distinguish at all times between combatants and civilians and to refrain from attacking civilians and civilian objects. To this end they must not use weapons or methods of warfare that have indiscriminate effects, such as weapons that cannot be targeted at specific military objectives.

International humanitarian law also prohibits the use of certain weapons. These are weapons that, by virtue of their design, cause particularly severe injuries against combatants. Such weapons are prohibited on the basis of the general prohibition

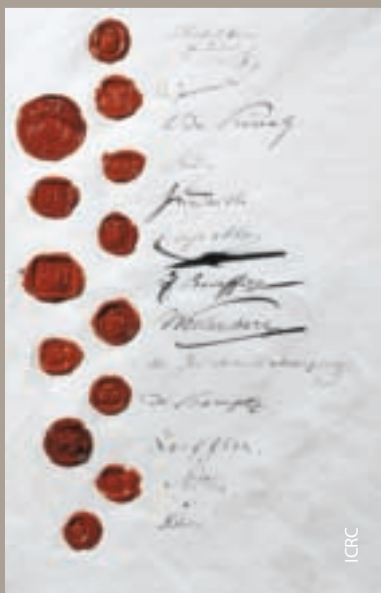


Marko Kocic/CRC

The wide track of a rubber sphere shot into a soap block at high velocity.



ICRC



ICRC

International humanitarian law treaties date back to the nineteenth century.



Marko Kokic/ICRC

Robin Coupland and Beat Kneubuehl show the tracks made by two different 12.7 mm x 99 mm bullets shot into soap blocks.

to use weapons and methods of warfare which cause “superfluous injury or unnecessary suffering”.

International humanitarian law applies to all parties which engage in armed conflict. Such conflicts may be international (between at least two States) or non-international (when the conflict takes place, for example, within a country between the armed forces of a State and an organized armed group, or between non-State organized armed groups). This body of law applies irrespective of who started the hostilities and irrespective of the causes of the conflict.

International humanitarian law is the primary tool available to the international community for protecting the safety and dignity of people in wartime. The law seeks to preserve a measure of humanity, with the guiding principle that even in war there are limits.

Which elements of international humanitarian law are pertinent to wound ballistics?

One of the earliest international humanitarian law treaties dealt with the design-dependent effects of bullets: in the St Petersburg Declaration of 1868, States responded to the development of bullets designed to explode within the human body by renouncing “the use, in time of war, of explosive projectiles under 400 grammes weight.” The preamble to this Declaration affirms that the only legitimate objective of war is to weaken the military forces of the enemy. It therefore stated that in war it is “sufficient to disable the greatest possible number of men”. This objective would be exceeded by the use of weapons which “uselessly aggravate the sufferings of disabled men, or render their death inevitable.”

Even though bullet technology and military practice have evolved, making some aspects of this prohibition (e.g. the anti-matériel use of exploding projectiles under 400 grams) obsolete, the preamble of this instrument is of lasting value and is the basis of the prohibition on weapons which cause “superfluous injury or unnecessary suffering”. Furthermore,

States still generally refrain from the anti-personnel use of bullets which explode within the human body.

In 1899, States adopted the Hague Declaration Concerning Expanding Bullets. This was “inspired by the sentiments which found expression” in the St Petersburg Declaration. The Declaration prohibited “the use of bullets which expand or flatten easily in the human body, such as bullets with a hard envelope which does not entirely cover the core or is pierced with incisions”. The severe wounds caused by such bullets, also called semi-jacketed bullets, are illustrated in this film. The prohibition on the use of such bullets is widely respected in armed conflicts and virtually all State armed forces equip their soldiers only with full metal jacket bullets.

In 1977, the principle originally contained in the St Petersburg Declaration of 1868 was confirmed with the adoption of Article 35(2) of Protocol I additional to the 1949 Geneva Conventions. This provision prohibits the use in international armed conflict of “weapons, projectiles and material and methods of warfare of a nature to cause superfluous injury or unnecessary suffering”. The subsequent prohibitions of the use of anti-personnel landmines, blinding laser weapons and weapons the primary effect of which is to injure by fragments which in the human body escape detection by X-rays have been inspired entirely or in part by this rule.¹

The 2005 ICRC study on customary international humanitarian law concluded that the prohibition on the use of means and methods of warfare of a nature to cause superfluous injury or unnecessary suffering has become a rule of customary international law binding on all parties to both international and non-international armed conflicts, whether or not they are parties to the specific treaties containing this prohibition. This study also stated that the prohibition on the use of bullets which expand or flatten easily in the human body and the prohibition on the anti-personnel use of bullets which explode within the human body have achieved the status of customary international humanitarian law and are applicable both in international and non-international armed conflicts.²

Which elements of human rights law are pertinent to wound ballistics?

Human rights law stipulates that the use of force by law-enforcement officials must be legitimate and proportionate. These rules derive in particular from the right to life and the obligations to respect human dignity and the physical and mental integrity of the individual. Guidance on how the use of firearms can comply with legitimate and proportionate use of force can be found in the general and specific provisions of the United Nations' Basic Principles on the Use of Force and Firearms by Law Enforcement Officials.³

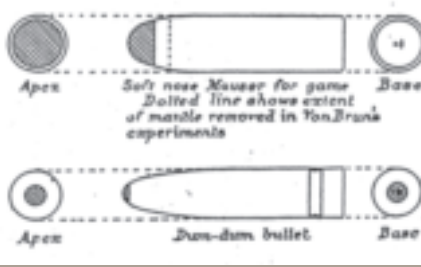
¹ See the 1997 Convention on the Prohibition of Anti-personnel Mines; See the 1980 Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects and that instrument's Protocol I on non-detectable fragments, as well as its Protocol IV on blinding laser weapons.

² Customary International Humanitarian Law, Volume I: Rules, Jean-Marie Henckaerts and Louise Doswald-Beck, Cambridge University Press, 2005, pp. 237-244, 268-274.

³ See UN Basic Principles on the Use of Force and Firearms by Law Enforcement Officials, adopted by the Eighth United Nations Congress on the Prevention of Crime and the Treatment of Offenders, Havana, Cuba 27 August to 7 September 1990, available on http://www.unhchr.ch/html/menu3/b/h_comp43.htm

MISSION

The International Committee of the Red Cross (ICRC) is an impartial, neutral and independent organization whose exclusively humanitarian mission is to protect the lives and dignity of victims of war and internal violence and to provide them with assistance. It directs and coordinates the international relief activities conducted by the Movement in situations of conflict. It also endeavours to prevent suffering by promoting and strengthening humanitarian law and universal humanitarian principles. Established in 1863, the ICRC is at the origin of the International Red Cross and Red Crescent Movement.



This DVD explores the impact on human tissue of bullets from rifles and handguns, as well as fragments from explosive weapons – an area of study known as wound ballistics. Designed for instructional purposes, the film has been made for a range of specialist audiences.

Health professionals, who treat people wounded by weapons, will benefit from a better understanding of the physical process of wounding.

Lawyers need a good grasp of wound ballistics to promote rules limiting the use of force and prohibiting certain bullets.

Forensic experts require an understanding of wound ballistics when presenting evidence in court about cause of death.

The accompanying brochure is intended to further enhance understanding of the film's content. It includes a useful glossary of terms, additional technical information and a summary of pertinent international legal texts.



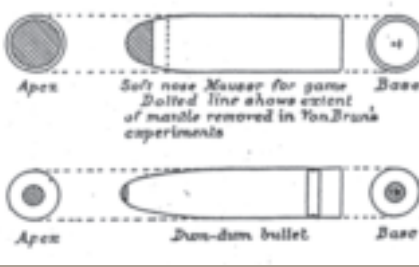
ICRC



40 minutes
English – Français – Deutsch
Brochure available in English only

ISBN 978-2-940396-00-9

0948/002 05.2008 1,000-NTSC



This DVD explores the impact on human tissue of bullets from rifles and handguns, as well as fragments from explosive weapons – an area of study known as wound ballistics. Designed for instructional purposes, the film has been made for a range of specialist audiences.

Health professionals, who treat people wounded by weapons, will benefit from a better understanding of the physical process of wounding.

Lawyers need a good grasp of wound ballistics to promote rules limiting the use of force and prohibiting certain bullets.

Forensic experts require an understanding of wound ballistics when presenting evidence in court about cause of death.

The accompanying brochure is intended to further enhance understanding of the film's content. It includes a useful glossary of terms, additional technical information and a summary of pertinent international legal texts.



ICRC



40 minutes
English – Français – Deutsch
Brochure available in English only

ISBN 978-2-940396-00-9

0948/002 05.2008 2,000-PAL