Gunshot and Blast Wounds

10

Case Study

A police officer was found on his bed in a half-sitting position. His duty pistol was also found on the bed between his legs. A gaping, plate-sized wound could be seen in the right parietal region, a smaller wound approximately 2 cm in diameter in the left. A large volume of cerebral matter had exited the cranium. To the right of the body, fragments of cerebral tissue and small fragments of the cranium were on the ground and partially on the wall up to a distance of around 4 m. A case of suicide involving a single shot entering the left side of the head and exiting on the right side appeared the most likely scenario. However, a police investigation of the domicile was unable to locate and retrieve the projectile.

A forensic autopsy was ordered at which it became apparent that the smaller gunshot wound in the left parietal region could be approximated and showed no central defect or other signs of gunshot entrance. After shaving the hair in the right temporal region at the anterior margin of the larger wound, a muzzle imprint from the gun could be seen in the skin. On dissection, cone-shaped beveling in the bony defect from the inner to the outer table of the left temporal bone was interpreted as a sign of gunshot exit. In the light of autopsy results, the firing direction was amended: entrance gunshot wound to the right temporal region, exit gunshot wound to the left parietal region. With this information, a renewed search of the domicile was undertaken, and the projectile could be located to the left of the body. The projectile was from a cartridge used in police deployment (quick-defense bullet), which was typically deformed.

The particular wound morphology observed in this case was attributed to the use—and misuse with suicidal intent—of the cartridge intended for police deployment: the considerable level of destruction at the gunshot entry site caused the rapid buildup of intracranial pressure to be released via the gunshot entry wound, resulting in extreme "backspatter."

Gunshot wounds are generally treated as an injury entity in their own right; however, it would not be unreasonable to classify them as a special form of blunt trauma. In the present work, the authors propose an alternative classification as "puncture trauma": a bullet or similar object having a minimal surface area but travelling at great speed comes into contact with a body. A similar mechanism to that of a projectile is seen with bird beaks, arrows, or spears. Thus, injuries due to arrows (bow or crossbow), spears, and bird beaks can be classified as "puncture trauma." Bird-beak injuries most commonly affect the scalp and cranial vault in hikers or joggers who inadvertently approach the nests of birds of prey, such as buzzards.

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The effect of a gunshot depends on the energy output and the radial acceleration of tissue. Non-projectile-related tissue injury is additionally caused by blast waves, various particles from the propelling charge, and displaced tissue, particularly bony fragments. Thus, it is reasonable to assume that alarm guns can cause life-threatening injury.

10.1 Firearm Laws

In most countries, the purchase and possession of firearms are subject to obtaining a permit. In Germany, the Weapons Act (*Waffengesetz*, WaffG) regulates the acquisition, storage, handling, maintenance, and trade of weapons. Permission to own a weapon is granted with a weapon owner's license, while permission to carry a weapon is granted in the form of a weapons license in accordance with Art. 10, Para. 4 of the Weapons Act. "Carrying a weapon" in the sense of the Weapons Act refers to having a weapon ready for use, which is permitted only in exceptional cases and certain places. Applicants aged under 25 years need to support their application for a weapon owner's license with a medico-psychological expert appraisal; marksmen who practice sport shooting may possess large-caliber weapons and pistols only from the age of 21 years. Special transport regulations apply to hunting weapons.

However, not only firearms are considered as weapons: Art. 1, Paras. 2 and 3 of the German Weapons Act states the following on the concept of weapons:

> (2) Weapons shall mean
> 1. Guns or equivalent objects and
> 2. Portable objects
> a) which are by nature intended to remove or reduce a human's ability to attack or defend, in particular cutting weapons and thrust weapons;
> b) which, due to their properties, method of operation or how they work, are able to remove or reduce a human's ability to attack or defend, even if not intended for that purpose, and are referred to in this Act
> (3) Handling a weapon or ammunition shall refer to anyone who acquires, possesses, hands over to others, carries, transfers, shoots, manufactures, works on, repairs or trades in weapons or ammunition

According to the Firearms Protocol of the United Nations, which has led the way for weapons laws in numerous countries, it is not permitted to carry cutting and thrusting weapons, knives with fixed blades that can be opened with one hand (folding or pocket knives), or knives with a blade exceeding a length of 12 cm. Carrying a dummy gun in public in Germany is, with exceptions, forbidden, as are Taser guns (long-range electroshock devices). In the wake of several shooting attacks in Germany, the German authorities are now empowered to carry out unannounced inspections on the private premises of weapons owners.

10.2 Types of Firearms and Ammunition

In forensic practice, gunshot wounds are seen in cases of suicide, homicide, and accidents associated with the handling of firearms; injuries are occasionally also seen in the context of examining survivors of gunshot injury. The type of gunshot wound or pattern of evidence is determined by the type of weapon used. Table 10.1 provides a systematic overview of firearm types.

Rifled Barrel. Only shotguns are smooth-barreled. All other firearms produced today have a rifled barrel. Rifling describes spiral, parallel groves along the entire length of the barrel; this rifling imparts a spin to the bullet, thereby stabilizing its trajectory. The surfaces protruding between the grooves are referred to as "fields." The fact that the projectile takes on a highly individual notch pattern, making it possible to attribute it to a particular weapon, is of forensic relevance.

Cartridge Composition. Modern cartridges comprise:

- A case
- The propellant (powder charge)
- A primer
- A bullet
- A cartridge designation

A cartridge's name is made up of its caliber in millimeters (mm) or inches and its case length, perhaps also some additional designation.

Table 10.1 A classification of selected firearms

Types	Subtypes	Particular features
Handgun	Revolver	Essentially single-action weapons: the hammer strikes the firing pin when the trigger is pulled; the hammer needs to be cocked manually before each shot
		Single-action revolver: hammer can only be cocked manually
		Double-action revolver: hammer cocking can also occur when the trigger is pulled; the cylinder turns when the hammer is cocked, either to the left or to the right, depending on the type of weapon; can fire 5–9 shots; empty cartridges remain in the cylinder after discharge
	Pistol	Today nearly all multishot self-loaders: once discharged, recoil of the slide causes ejection of empty cartridges and loading of new cartridges. Manual pullback of slide to load the first cartridge before first shot. Cartridges are contained in a magazine in the butt. Lockable slides are required for pistols with greater muzzle impulses. Single-action pistols are used as sports guns
	Submachine gun	Automatic weapon uses a variety of pistol ammunition. Simple construction (open-bolt blowback operation). Often not adapted to single-shot action. Most famous model: Uzi. Capacity of 30–50 shots depending on the magazine, drum magazine gives up to 100 shots
Long gun (rifle)	Sporting gun	For firing individual bullets, rifled barrel. Hunting rifles are primarily single-shot.
		Military rifles are usually automatic weapons (assault rifles) with gas-operated reloading. Magazine holds 20–30 shots. Single-action, bolt action, and often adjustable to have a burst of fire limited to three shots. Best known assault rifle worldwide: the Russian AK-47 (Kalashnikov)
		Machine guns: designed for rapid-succession firing of rounds, with ammunition usually fed from a belt, up to 250 shots per belt. Heavy, stable mount needed
	Shotgun	Single-shot smoothbore firearm for firing shot. Almost exclusively used as a hunting gun
		Double shotgun: double bore. Combination with a rifle barrel is possible
		Rifle and shotgun barrels: side-by-side = cape guns; over-and-under = combination guns
		Three-barreled guns are referred to as drillings, with common combinations being: two shotgun barrels side by side above one rifle barrel
Blank firing pistols		Replicas of real revolvers or pistols with the same principle of functioning. The barrel mock-up, which must be firmly attached to the frame, is fitted with carbide metal baffles. Shoot blank shells

Numerous special weapons and historical firearms, although relevant in individual cases, are not listed here

Caliber. Caliber is not measured as the outer diameter of a bullet, but as the diameter of a weapon's barrel. The inner diameter of the barrel is determined by its fields. Table 10.2 shows a selection of commonly used cartridges and their dimensions.

Blank Cartridges. Often referred to as "blanks," blank cartridges are essentially built much like normal cartridges, only without a bullet. Instead, the end of the case is either sealed with a plastic plug or crimped.

Blank cartridges are used primarily in blank firing pistols but can in principle be used in any weapon with an appropriate caliber. In addition, cartridges with large propellant charges (mostly 9-mm caliber) are used in nail guns. Blank cartridges are also used in military rifles and machine guns in the context of military maneuvers.

While real blanks are loaded with only propellant, there are also cartridges that contain irritants in powder form; typical examples of such irritants would be CS gas (2-chlorobenzalmalononitrile) or capsaicin (from red chilli peppers and the active component in pepper sprays).

Types of Bullet. A distinction is made between bullets made entirely of the same material, such as lead, and jacketed bullets, which have a uniform core and a case made of a thin layer of another material, e.g., a lead core with a steel or copper jacket. Partially jacketed bullets, which

Table 10.2 The weight, velocity, and kinetic energy of selected projectiles

Cartridge	Mass (g)	Muzzle velocity (m/s)	Kinetic energy (J)
Handguns			
.32 ACP	4.6	276	175
7.62×25	5.6	424	496
9×18 Makarov	6.2	323	321
9-mm Parabellum	8	393	630
.40 S & W	10	347	606
.357 Magnum	10.2	376	725
.47 Magnum	15.6	411	1.320
Small arms			
5.45×39	3.4	910	1.430
.243	6.5	902	2.640
7.62 × 39	8	701	1.970
.270	8.4	933	3.660
7.62×51 (.308)	9.7	838	3.420

Table 10.3 A classification of bullets according to how they behave in the body

Bullet type	Behavior in the body
Nondeforming	Retain shape after penetrating the body, lower energy output, through-and-through wounds more common
Deforming	On penetrating the body, the surface area transferring energy is increased; no loss of material
Fragmenting	Fragment on penetrating the target, high energy output, extensive tissue destruction, so-called dumdum bullets

break up on entering the body and cause particularly extensive injuries, are commonly used for hunting. Bullets can be classified according to how they behave in the body (Table 10.3).

The various types of ammunition were, and still are, developed for widely varying requirements:

Hunting ammunition should kill as quickly as possible, while the primary objective of combat ammunition is to injure, necessitating that one or two other soldiers tend the injured soldier, temporarily making them also unable to fight. Sniper ammunition needs to kill fast and effectively, ideally without causing injury to nearby individuals. Police authorities increasingly use quick-defense ammunition, or "manstoppers," in duty weapons: the actual tip of the full-jacketed hollow-point bullet is made out of a plastic. The bullet expands when it penetrates tissue, resulting in less penetration depth and greater energy output, thereby stopping the subject while ideally causing as little injury as possible.

Shot Shells. Shot shell cases are generally plastic; only the tip containing the primer is made of metal. Then comes the propellant, which is separated from the shot pellets by a wad in order to prevent these elements from mixing. In modern shot shells, this wad has been replaced by a plastic "cup" containing the shot pellets and whose high, hollow base ensures the appropriate distance from the propellant. Shot pellet diameters vary according to the game being hunted. The shot pellets begin to "scatter" after leaving the barrel of the shotgun.

The Primer. The formerly widely used Sinoxid (main components, lead tricinate and barium nitrate) have largely been replaced today by lead-free primers.

The Propellant. The propellant imparts energy for the shot. The oldest known explosive to be used as a propellant is gunpowder (75 % potassium nitrate, 15 % charcoal, 10 % sulfur; produced in powder mills). Nitrocellulose (guncotton) has become prevalent in modern ammunition; this propellant is produced by nitrating cellulose with a nitrating agent (a mixture of concentrated salpetric acid and concentrated sulfuric acid). In di- or polybasic powders, an additional propellant in the form of nitroglycerine is added; burning produces CO_2, CO, H_2O, H_2, and N_2. An equivalent amount of nitrocellulose powder compared to gunpowder produces an approximately threefold greater volume of gas and explosive power.

10.3 Entrance Gunshot Wounds

When a projectile strikes the skin, tissue is carried in the direction of fire. In addition, radial acceleration is caused by the spin of the bullet. A limit velocity of approximately 50 m/s is needed to penetrate the skin.

Prerequisite signs of a gunshot entrance wound include a central tissue defect (wound edges cannot be approximated) and an abrasion ring. In addition, a bullet wipe mark between the central defect and the abrasion ring, as well as a contusion ring around the abrasion ring, may form (Fig. 10.1).

Abrasion Ring. It is assumed that the abrasion ring is produced by temporary depression of the skin and abrasion in the direction of fire. A bullet striking the skin at an orthogonal angle produces an abrasion ring of about 1–2 mm in width.

Fig. 10.1 Gunshot entrance wound. Signs of a gunshot entry wound, defect cannot be approximated, mild abrasion ring, absent bullet wipe (clothing!), and a contusion ring

Bullet Wipe. Oil residues on the bullet are deposited at the margin of the central entrance gunshot wound where they form a black ring. Thus, the extent of bullet wipe, or indeed whether this is visible at all, depends on the amount of dirt in the barrel. If a bullet first passes through clothing, bullet wipe may be visible on the outermost layer of clothing rather than on the gunshot entry wound.

Contusion Ring. A contusion ring develops on the skin in response to the temporary wound cavity. It lies adjacent to the abrasion ring and is bluish red in color, fading on the periphery.

Gunshot Entrance Wound to the Skull. A gunshot entrance wound in the skull region produces a round defect in the outer table with cone-shaped beveling through the diploe widening out to the inner table. Corresponding outward beveling from the inner to outer table can be seen at the gunshot exit point (Fig. 10.2).

Bullet Track and Trajectory. Identifying the bullet track and determining a bullet's trajectory is of major relevance in forensic practice; together with the firing distance (see Sect. 10.5), these provide an important basis on which to reconstruct the angle of fire as well as the firing position. A number of types of shot are described according to the bullet's final localization and the bullet track, as well as other possible characterizing features (Table 10.4).

Temporary Wound Cavity. A temporary wound cavity in the bullet track is formed as

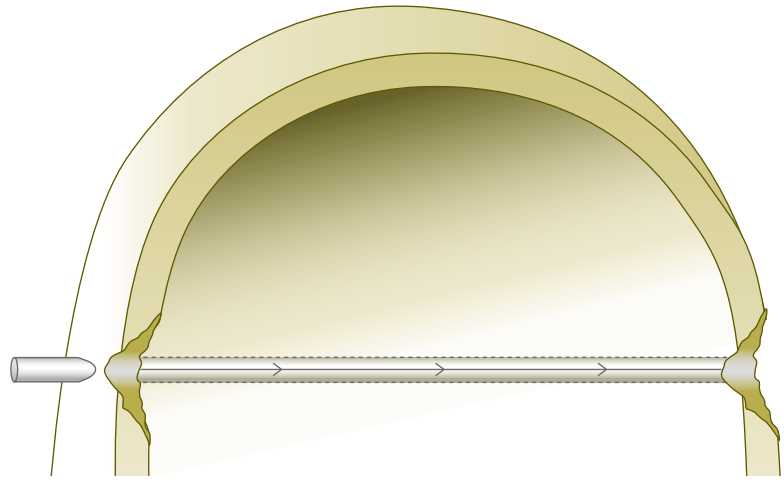

Fig. 10.2 Morphology of gunshot entrance and exit wounds to the skull

Table 10.4 Types of gunshot

Gunshot type	Characteristics
Penetrating	The projectile remains within the body. It can occasionally be felt subcutaneously opposite the entrance site. Possible reasons: bullet has low penetrating force, oblique angle of contact, deceleration due to bone
Perforating (through-and-through)	The projectile has exited the body and can be found externally. In the case of pistol ammunition, usually a of 7.65-mm caliber
Internal ricochet	The bullet changes direction within the body: deflected by tissue of varying densities, e.g., bone
Graze	The projectile grazes the skin. Trough-like skin abrasion, possibly with subcutaneous tissue, additional small oblique radial tears in the skin running in the direction of fire, sometimes difficult to distinguish from a laceration
Tangential	Entrance and exit wounds are located in close proximity. The bullet track travels through skin, subcutaneous tissue, and possibly also deeper soft tissue layers. A distinct oval abrasion ring at the entrance wound oriented away from the direction of fire
Contour	Skull: projectile has only minimal kinetic energy. Inner table contour: projectile follows the contour of the inner table opposite the entrance wound Outer table: projectile penetrates the skull on the opposite side of the entrance wound but not the scalp—projectile moves between the outer table and the scalp
Ricochet	The bullet is deflected from its trajectory by objects it comes in contact with. May cause fatal injury although the shot was actually discharged in another direction, e.g., warning shot. The modified trajectory of the shot (including loss of spin) can produce atypical entrance gunshot wounds lacking: signs of gunshot entrance wound and margins that can be approximated
"Krönlein" shot	Gunshot wound to the skull with a high-velocity bullet. The skull is shattered by the temporary wound cavity with complete evisceration of the brain

kinetic energy is transferred to the contact surface, whereby radial acceleration occurs and deforms the medium in either an elastic or a plastic manner. Both a cavity and a vacuum are thus created behind the bullet. Together, the vacuum and the elastic energy stored in the medium (tissue) cause the temporary cavity to collapse; at high velocities, this can cause organ damage. Since the skull can withstand only minimal expansion, pressure is only able to escape at the entrance or exit gunshot wounds; this process can also involve tissue. Since the entrance wound represents the initial opening, it serves as the primary point of pressure release, producing backspatter, i.e., traces of tissue ejected in the opposite direction to the direction of fire (Fig. 10.3).

Backspatter. The victim's tissue is ejected via the entrance wound in the opposite direction to the direction of fire and, in the case of close-range fire, may be spattered on the firing hand.

High-velocity bullets can cause the skull to shatter, in extreme cases causing complete evisceration of the brain (Fig. 10.4).

Gunshot Wounds to Bone. Due to the expansion of bone tissue and its subsequent collapse, bony defects in the case of perforating gunshot wounds may be smaller than the caliber of the projectile (usually high velocity). On the other hand, if the temporary wound cavity expands or the projectile's trajectory is disrupted, defects may have a larger diameter than the outer diameter of the bullet.

Important: Even in the presence of a circular defect on the outer table in the case of an entrance gunshot wound to the skull, no inferences can be made in relation to the caliber of the weapon used; the actual caliber may be greater or smaller.

10.4 Exit Gunshot Wounds

As a bullet exits, the skin is stretched by the temporary wound cavity and the projectile to the point of rupture; thus, a real "rupture wound" would be seen. Although exit wounds are commonly larger than entrance wounds, this is not always the case.

Fig. 10.3 Backspatter. Tissue fragments have been ejected onto the firing hand; injury to the flexor side of the base of the index finger (gun-slide wound) can also be seen

Fig. 10.4 "Krönlein" shot. Complete evisceration of the brain

Important: Gunshot exit wounds are characterized largely by wound margins that can be approximated, as well as the absence of an abrasion ring or other signs of gunshot entrance (Fig. 10.5).

In the case of a burst fracture due to skull rupture in through-and-through gunshot wounds to the head, it may prove challenging to differentiate the actual exit gunshot wound from other skin lacerations in the scalp and facial skin.

Important: Particularly when bone fragments are carried in the direction of fire, fragments of tissue may be ejected through the gunshot exit wound, producing an irregular, generally noncentral tissue defect.

Pseudo Abrasion Ring (Shoring). Close-fitting clothes at the point of gunshot exit may act as an abutment, producing skin abrasions which, on drying, are remarkable. This lesion is susceptible to misinterpretation as an abrasion ring.

Exit Gunshot Wound in Bone. A perforating, or through-and-through, gunshot wound to the skull produces cone-like beveling from the inner table outwards to the outer table. In the

case of a burst skull, this beveling can be reconstructed by reassembling the bone fragments (Fig. 10.6).

Perforating diaphyseal gunshot wounds to long bones near the longitudinal axis can produce a similar picture to that of skull wounds, with beveling in the direction of fire.

Fig. 10.5 Gunshot exit wound in the upper crown region. Hair in this area has been shaved. Wound margins can be approximated

10.5 Range of Fire

For the purposes of estimating range of fire, morphological wound characteristics are classified into three range of fire categories (Table 10.5):

- Close range (contact wound) (Fig. 10.7)
- Intermediate range
- Distant range

An absolute determination of the range of fire can only be carried out by means of chemical or spectrographic analysis of soot deposition and its density. To this end, an approximately 10 × 10-cm sample of skin with the central defect located in the middle should be taken (stretched over card or cork, marked for orientation, or possibly frozen). If clothing was worn over the entrance gunshot wound, soot deposition can be expected here and clothing should be collected as evidence.

Important: To ensure the reliability of range of fire determination using soot deposition on skin samples or areas of clothing, decedents suspected of having sustained gunshot wounds should not come in contact with water.

Soot deposition found at the margins of an entrance gunshot wound to bone indicates a close-range shot (Fig. 10.8).

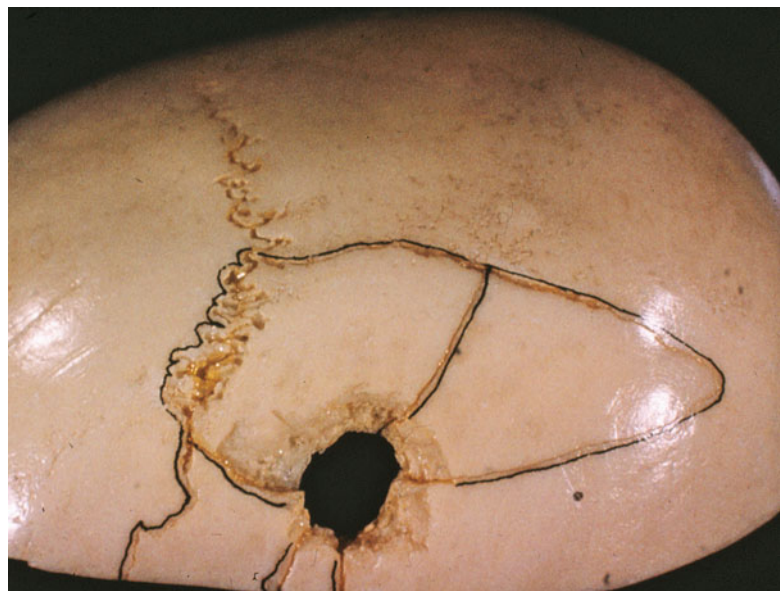

Fig. 10.6 Exit gunshot wound with outward beveling—outer table detachment—and adjacent fractures

Range of fire determinations in Germany are predominantly carried out in police forensic departments. On an international level, many forensic institutes have ballistics departments where investigations of this kind, as well as important research, are carried out. Visualizing traces of soot is made possible using chemical indicators. It is sometimes necessary to fire several test shots against various surfaces and at varying ranges, either with the actual weapon used in the incident under investigation or at least an equivalent weapon, in order to interpret results reliably.

Table 10.5 Categories of range of fire

Category	Morphological criteria at the gunshot entrance site
Close-range (contact) shot (Fig. 10.7)	Soot deposition in and around the wound track, found on the outer table in skull wounds or possibly subperiosteal or on the dura. Stellate laceration in the skin is possible. If a weapon has been pressed tightly against the skin on discharge, an imprint of the muzzle may be visible. CO–myoglobin binding causes salmon-red discoloration of muscles along the bullet track, particularly in the initial segment
Intermediate-range shot	Soot deposition and gunshot residue around the central defect, macroscopically detectable when the muzzle-to-victim distance does not exceed roughly twice the barrel length of the weapon used
Distant-range shot	Signs of close-range fire are absent

The criteria mentioned here are supplementary to signs of gunshot entrance wounds

At the moment of discharge, soot may be deposited to varying degrees on the skin of the firing hand. By comparing hands, typical zones of greater soot deposition can be seen (Fig. 10.9).

Entrance gunshot wound morphology and accompanying findings in relation to the range of fire are shown in Fig. 10.10.

10.6 Special Gunshot Wounds

Special gunshot wounds include wounds not caused by a single projectile fired from a long gun or handgun.

Shotgun Shell Wounds. The shot pellets leave the shotgun barrel together with the plastic "cup" or wad. The pellets begin to disperse beyond the muzzle; the further the pellets move away from the muzzle of the shotgun, the more dispersed the pattern of stippling defects on the skin becomes. At very close range, the plastic cup may perforate the skin, while the still tightly packed shot acts like a

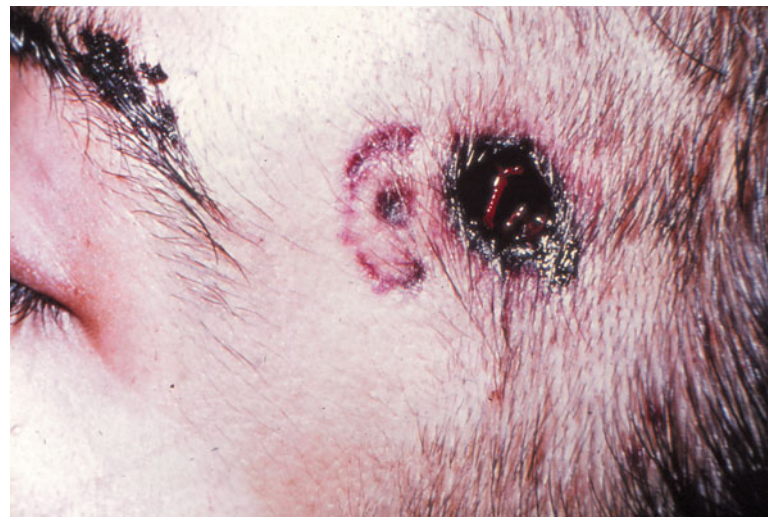

Fig. 10.7 Contact gunshot wound with muzzle imprint and drying in the area of gas escape

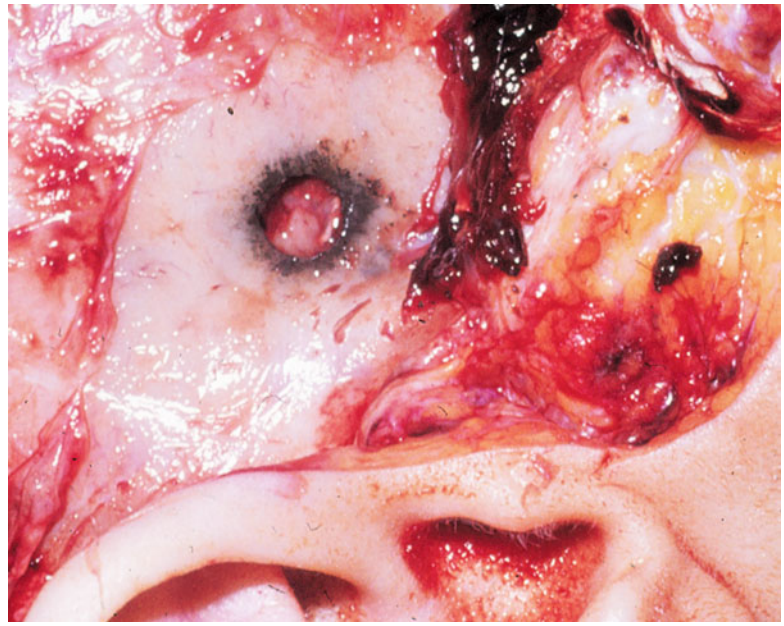

Fig. 10.8 Soot deposition around an entrance gunshot wound to the skull

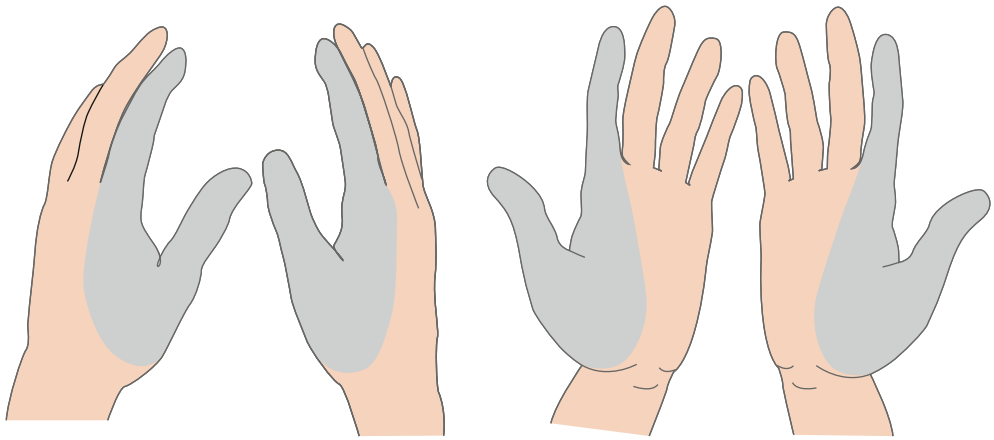

Fig. 10.9 Soot deposition on hands in the determination of the firing hand

single slug. The shot pellets then disperse inside the body according to the so-called billiard effect. In the case of close-range contact wounds from shot ammunition, the expanding muzzle gases are of particular relevance. Depending on localization, soot deposition within the bullet track, internal organ rupture, or skull rupture may result.

Entrance gunshot wounds caused by shotgun shells usually demonstrate a central defect larger than the caliber of the shotgun used, as well as irregular margins (Fig. 10.11). With increasing distance, separate small defects caused by shot around the margins can be seen (Fig. 10.12). Shotgun firing distances in excess of 5 m no longer produce a central defect, but rather extensive stippling defects. The abundant shot pellets can be well visualized using X-ray (Fig. 10.13).

Bolt Gun Wounds. Bolt guns were developed as tools for animal slaughter. A powerful propelling charge is achieved by using a blank cartridge. This drives a metal bolt into the animal's skull. Generally, next to the bolt outlet, there are two opposing openings for the release of excess gas pressure and soot. This constellation produces the typical external wound pattern comprising a central defect and two adjacent rings of soot. A bolt gun pressed against the skull will

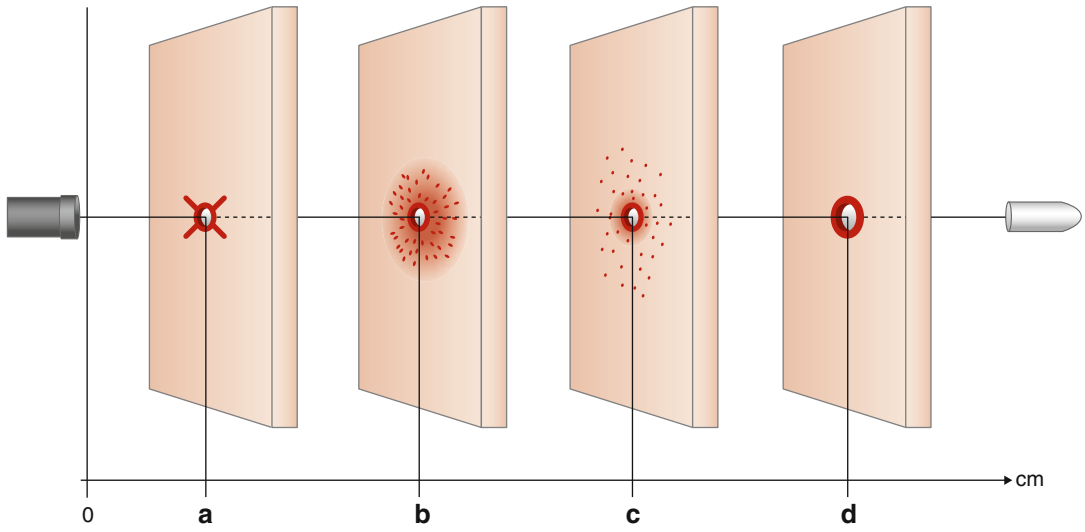

Fig. 10.10 Entrance gunshot wound findings at varying firing ranges. (**a**) Close-range shot. (**b**) Intermediate-range shot fired from a short distance with soot deposition around the entrance wound. (**c**) Intermediate-range shot from a somewhat greater distance with a larger radius of gunshot residue. (**d**) Distant-range shot: no signs of a close-range gunshot entrance wound, bullet wipe, abrasion ring, or contusion ring

Fig. 10.11 Intermediate-range shotgun shot wound. The central defect is greater than the caliber of the shotgun used and has irregular edges

Fig. 10.12 Shotgun shot wound. A large central defect surrounded by smaller shotgun shot wounds in the skin

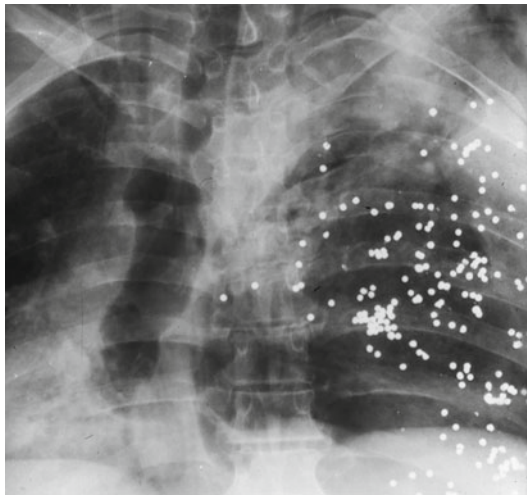

Fig. 10.13 Multiple shot pellets seen on chest X-ray

punch out the scalp and bone, which can then be found embedded in brain tissue at the end of the wound track.

In forensic practice, bolt guns are primarily relevant as a means of committing suicide, being rarely used in homicides. Their use is seen predominantly among occupational groups with access to this type of device, such as butchers and farmers.

Wounds Caused by Blank Firing Pistols. Depending on the type of blank used, the gas blast can produce significant energy flux density. Close- or intermediate-range shots fired from a distance of a few centimeters can cause skin penetration and even internal organ injury. Thin bones may break. Placing the weapon to the head is extremely hazardous, particularly in the area of the temporal bone, which can rupture. Expanding gases and disseminated bone fragments can cause significant brain injury.

Intermediate-range shots striking unclothed skin can cause particles of gunshot residue to scatter, making medical care necessary not solely for cosmetic purposes.

Air Gun Wounds. Air guns (air rifles, air pistols) use mechanically compressed air as a propellant. Individual Diabolo pellets that are inserted at the near end of the barrel are usually used; these pellets are available with a flat, rounded, or conical tip. Depending on the pellet used, the firing range, the point of contact (clothed or unclothed skin), as well as the angle of contact, hematomas, or even skin penetration are seen. Penetration of the orbital cavity or the thin temporal bone can cause fatal brain injury, while other life-threatening injuries may be caused by arrosion of major vessels in the neck area.

Arrow Shot Wounds. Arrows are fired with bows or crossbows by means of a pre-drawn bowstring. These devices are either historic weapons or modern sports devices. Mention should also be made of harpoons, which have an inflatable compressed air cylinder. The harpoon is loaded through the muzzle against the pressure of the compressed air. Modern steel-tipped arrows can be subdivided into two types:

Field Tips. These have a conical blunt shape similar to a truncated cone or round-nose bullet and are used for target shooting in a sporting context. They produce injuries consistent with puncture trauma.

Broadheads. These have two or more razor-like metal blades extending radially from a central shaft, which taper at the tip to form a point. These tips are designed for hunting. Arrows fitted with tips of this kind penetrate the skin with a splitting-like penetration mechanism, producing smooth and often slit-like or possibly radiating linear wound morphology. Rather than being displaced, movable structures such as blood vessels or intestinal loops are cut clean through.

Blast Injuries. These kinds of injuries are typically seen in combat situations or terrorist attacks. The effects of an explosion are categorized into primary, secondary, tertiary, and quaternary injuries (Table 10.6). Explosions produce multiple missile fragments of varying size, as well as a considerable blast wave. Multiple and extensive skin injuries varying in size and form according to the victim's distance from the site of the explosion are characteristic (Fig. 10.14). Thus, multiple missile fragments are often retrieved at autopsy, while internal organs show multiple lacerations and tears; pulmonary lacerations and tears may be caused by the blast wave as well as lacerations of the arterial intima (Fig. 10.15). Amputated extremities and decapitations are also seen.

Table 10.6 Classification of blast injuries

Type	Mechanism of effect	Injury pattern
Primary	Shockwave and overpressure wave: barotrauma	Burst eardrums, pulmonary contusion, gastrointestinal contusion or perforation, mesenteric laceration, liver and spleen rupture
Secondary	Projectile or projectile-like: fragments propelled out of the bomb case or generated in the immediate vicinity	Soft tissue injuries, penetrating injuries with blood loss, pneumothorax, intestinal perforation
Tertiary	Indirect effects of the blast wave: falls, impact trauma, falling or collapsing parts of buildings	Many varied types, particularly blunt, penetrating, and perforating trauma
Quaternary	Miscellaneous: accidental burial, flames, hot flue gases, radioactive elements, biological or chemical toxins	Traumatic amputation, compartment syndrome, crush injuries, burns, inhalation trauma, smoke inhalation, radioactive contamination, biological or chemical intoxication

Fig. 10.14 Blast wounds. Multiple splinter injuries of varying depth, amputated hand, and decapitation

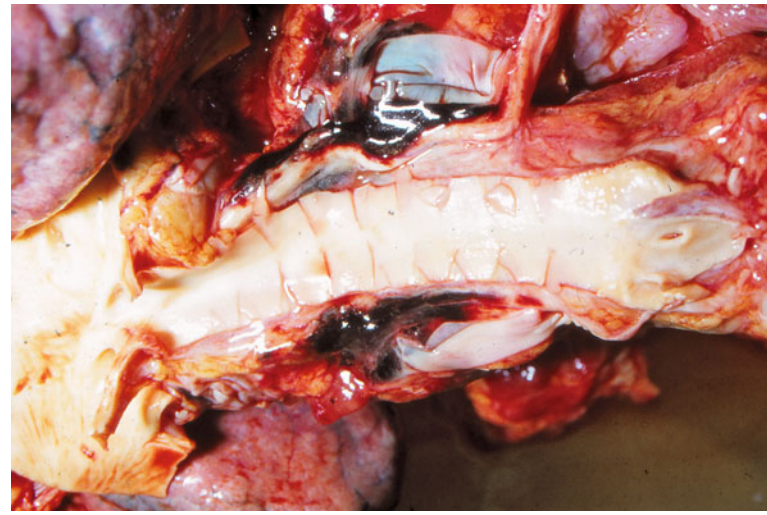

Fig. 10.15 A. carotis communis with intimal lacerations following explosion of a house

10.7 Criminological Aspects of Gunshot Wounds

Suicidal shooting is a widespread phenomenon in Western industrialized nations; naturally, it is seen most commonly in individuals with access to firearms, such as hunters or law enforcement officials. The crucial question to be answered in cases of fatalities involving gunshot wounds is whether injury was self-inflicted or whether another party (or parties) was involved; to this end, Table 10.7 summarizes the most important differential diagnostic criteria.

Much like taking skin samples from around the gunshot entrance wound (range of fire determination), a sample of skin from the suspected firing hand, or even both hands, could be ordered at autopsy for the purposes of detecting or excluding soot deposition. However, quantifying findings is not necessary—detecting soot deposition is sufficient. Therefore, particularly in the case of macroscopically visible soot deposition, invasive measures can be dispensed with and the skin surface simply covered with self-adhesive film for the purposes of collecting soot deposits.

Table 10.7 Differential diagnosis of self-inflicted or third-party involvement in fatal gunshot wounds

Criteria	Self-inflicted	Third-party involvement
Number of gunshot wounds	One	Possibly more than one
Typical localization of the entrance gunshot wound	Temples, mouth	Random
Range of fire	Close-range or close intermediate-range shot	Any range of fire
Angle of fire	Steep angle possible due to the short range of fire	Somewhat flatter to the transverse plane of the victim
Backspatter on the firing hand	May be present	Absent
Soot deposition on the firing hand	Positive	Negative
Gun-slide wounds on the firing hand, typically between the thumb and index finger	Rare	Never
Finding the weapon	In the vicinity of the body	Anywhere and/or cannot be found

The Autopsy Examination Following Gunshot Wounds. Any autopsy examination of gunshot wound victims should establish the number of entrance and exit gunshot wounds, as well as the direction and range of fire. In addition, it should be ascertained which shot or shots were fatal. Before opening the body, X-ray investigations (or ideally a CT scan) of the affected regions should be carried out if penetrating shots are suspected. Imaging all regions for investigation in two planes is important for the purposes of reproducing a spatial orientation (Fig. 10.16). Radiological data available prior to autopsy help in the detection of projectiles and their removal, as well as facilitating the dissection process in general. Investigations to determine range of fire should be completed before the body comes into contact with water. Projectiles lodged in the body should be removed only with plastic forceps in order to avoid compromising ballistic investigations aimed at identifying the weapon.

Causes of Death in Gunshot Wounds

Possible causes of death following gunshot wounds include:

- Suspension of blood circulation due to severe damage to the heart or part of the aorta
- Exsanguination due to large blood vessel injury
- Exsanguination or cardiac tamponade following injury to the myocardium or coronary arteries

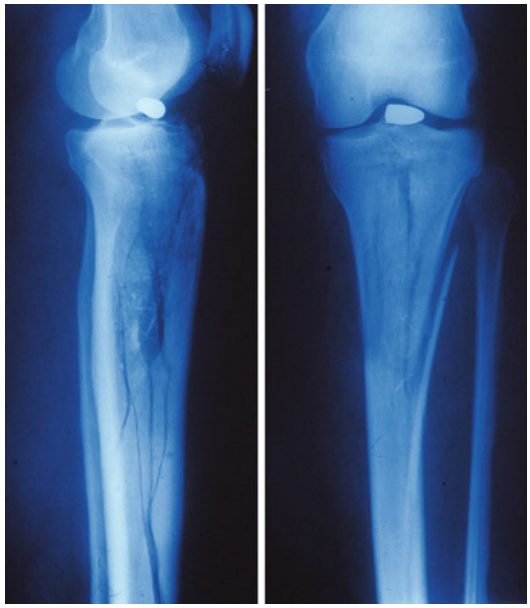

Fig. 10.16 Gunshot wound to the tibia with the projectile reaching its final position in the knee. X-ray of the lower leg in two planes

- Destruction of vital brain areas, in particular the brainstem
- Secondary cerebral swelling following a gunshot wound to the head
- Shock resulting from damage to the central nervous system and subsequent cardiac function impairment

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