Gunshot wounds, drowning, and thermal injury: These are not only important topics of forensic traumatology for the exam but also for the medical routine. Therefore, a good overview of the specific findings and differential diagnoses are of high relevance for the clinically active physician as well as for the medical examiner.

Gunshot wounds

The field of ballistics deals with the study of arms and ammunition as well as the so-called terminal ballistics, the biological impact of the projectiles.

Types of weapons used in gunshot wounds

Generally a rough distinction is made between long-barrelled weapons, also known as shotguns, and short-barrelled weapons meaning the handguns.

The following firearms belong to the long-barrelled weapons:
- **Rifles** are guns with a long barrel meaning in the barrel are spirally arranged grooves (furrows) and ridges (spiral elevations). Rifles shoot bullets.
- **Shotguns** generally have a smooth barrel and shoot shotgun shells.

The following firearms belong to the **short-barrelled weapons**:

- **Revolvers** have a drum-shaped cylinder that revolves during each shot.
  Depending on the manufacturer and type, the cylinder contains a different amount of bullets. Between the cylinder and the barrel is a space from which the gunshot residue escapes to the side.
- **Handguns** feature a closed system as the cartridge chamber is located in the front part of the barrel. They can be classified into the so-called **single-shot pistols**, which have to be reloaded after each shot and the **multi-shot pistols** with repetitive action, which is either manually or automatically controlled.

Furthermore, there are the **flare guns** in the sports sector as well as air guns which use **pneumatic pressure**. The captive bolt guns or cattle stunners, respectively, and the powder-activated guns such as nail guns used in construction are not weapons in the legal sense but they are comparable and potentially life-threatening with regard to their functional principle.

### Ammunition in gunshot wounds

Ammunition are the projectiles that consist of three components: The **projectile** (meaning the bullet or cartridge), the **casing** including the primer and the **charge** in the form of the priming charge and propellant, which provides the pressure for the projectile motion.

The forensically most important types of cartridges are the bullets and the shotgun shells. The **bullet** is usually made from lead and possibly has a full or partial metal jacket. The **Shotgun shells** consist of coarse to very fine lead pellets. Between these and the propellant is wadding made of felt or plastic and at the top of the case, above the shot load, is a cap.

The charge of the projectile consists of a primer and propellant. The **primer** contains impact variable substances with heavy metals such as barium, lead, and antimony, which are the basis of the chemical gunshot residue analysis. The **propellant**, on the other hand, consists usually of nitro-glycerine in the form of powder flakes. After the ignition it burns explosively and forms gas under extremely high pressure. As a result, the bullet is propelled through the barrel.
Internal ballistics in gunshot wounds

Internal ballistics deals with all the processes within the gun. Once the trigger of a gun is pulled, the firing pin strikes the bottom of the cartridge, meaning the so-called primer. As a result, the impact sensitive primer compound explodes and in turn ignites the propellant. This burns very rapidly creating a lot of gas under enormous pressure thus expelling the projectile at a very high speed through the barrel.

Upon exiting the barrel, residue of both the primer and the propellant, the so-called gunshot residue, is released which can settle on the hand that fired the gun and on other objects. On the muzzle, the gases can explosively relax, causing the loud bang and recoil of the weapon.

Terminal ballistics on gunshot wounds

Terminal ballistics deals with the biological effects of the projectile in human beings. These include the effect from the entrance, the penetration, and the exit from the tissue as well as the effects from powder combustion gases and load residues.

Note: Gunshot wounds are a special form of blunt force trauma.

Typical findings of an entrance wounds are a central substance defect, an abrasion collar, a contact ring (also referred to as gunshot residue ring) and a contusion collar with blood exiting. The contact ring is regarded as reliable criteria for a projectile impact in terms of the entrance wound. The other features are mere signs of blunt force. An equally important differentiating feature is that the entrance wound defect is not adaptable.

A trough-and-through shot produces hole fractures (especially in the skull) and comminute fractures (especially in the long bones) of the bone. Hole fractures are usually cone-shaped which can lead to a conclusion as to the direction of the shot. The bone fragments in comminute fractures are also displaced in the direction of the movement of the projectile.

In soft tissues, hydrostatic shock takes place. The high bullet velocity creates a temporary wound cavity and a cave-like rupture of the tissue that contains water like the muscles or the brain. A shock wave originating from the temporary wound cavity leads to organ damage in the surrounding area.
An exit wound is characterised by a laceration-like defect which tends to be smaller than the projectile calibre, as the projectile stretches the skin from the inside. In addition, there is no central substance defect, no laceration, and no abrasion. Bone fragments can act as secondary projectiles and sometimes lead to a large exit wound. The same applies to projectiles with partial jackets that split during penetration.

Special gunshot wounds are the result of the ricochet and the Kroenlein shot. An injury caused by a ricochet is due to a projectile that was diverted outside the body. The Kroenlein shot is defined as a bursting of the cranial cavity due to the increase in intracranial pressure.

Gunshot residue in gunshot wounds

The explosion gases that exit the muzzle immediately after the projectile are composed of unburnt or partially burnt powder flakes, gunshot residue, carbon dioxide, elements of the ignition such as lead, antimony, and barium as well as, possibly, components of weapon care products.

An abrasion collar occurs when the gun barrel is close to the target area. Here, the load residues deposit themselves around the entrance wound like a halo. The firing distance can be determined based on the appearance of the residue image: the greater the distance, the less heavy particles reach the skin.

Shooting Distance in gunshot wounds

One distinguishes between long-range and close-range shots. Furthermore, the close-range shots are divided into relative and absolute close-range shots.

With the long-range shots, no residue is found around the entrance wound. With the relative close-range shot however, residue is found on the skin and with the absolute close-range shot, residue is even found under the skin.
During an absolute close-range shot, the barrel is placed directly on the skin causing the explosion gases to penetrate into the skin, spread radially, and rupture the subcutaneous fat tissue. The result is the so-called **abrasion collar** with powder stippling and carbon monoxide.

![](image)

Hereby the blood that pours out appears bright red and contains CO-haemoglobin. Simultaneously, the skin distends with a radial rupture in the form of a laceration. As the skin touches the hot barrel, a **punch mark** forms in the shape of the muzzle.

The **punch mark** provides important information for the crime reconstruction: Based on the shape, the type of weapon, the shooting position during the shot, and the handedness (in suicide) can be observed.

Firearm injuries are classified depending on the velocity of projectile. Velocity of less than 600 meter per second (m/s) produces low-velocity wounds, and are more commonly seen in civilians. Velocity of more than 600 meter per second produces more severe injury and is commonly seen with military or hunting weapons with a muzzle.

**Special case: captive bolt gun**

The result of gunshot wounds from a captive bold gun is a **bone punch, without finding any projectile in the barrel.**

**Shooting hand in gunshot wounds**

The determination of the shooting hand provides important clues about the perpetrator. **Gunshot residue** is found on the thumb and forefinger – especially when using revolvers. Furthermore, **blood spatters** that are thrown back from the entrance wound can end up on the outer surface of the fingers.

**Back spatter** can be found on hands and clothes in the form of small bone fragments and tissue shreds. Furthermore, the use of assault rifles results frequently in **skin lacerations** on the inside of the hands due to the lateral escape of explosive gases.

**Note:** When the airbag opens during traffic accidents, the resulting development of gas stream can hit the hands and simulate the gunshot residue of a gunshot.
Differentiation between crimes, accidents and suicides in gunshot wounds

<table>
<thead>
<tr>
<th>Type of Crime</th>
<th>Crime</th>
<th>Accident</th>
<th>Suicide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range of fire:</strong></td>
<td>Usually a long-range shot, rarely a close-range shot; surprised while sleeping, etc.</td>
<td>Often a relative short-range shot, while manipulating a weapon such as cleaning or disassembling it</td>
<td>Usually an absolute close-range shot</td>
</tr>
<tr>
<td><strong>Terminal Ballistics:</strong></td>
<td>Entrance wound possible on every part of the body; Clothing is shot through</td>
<td>Entrance wound in chest, face or in open the eye</td>
<td>Frequently in the forehead, temple, mouth; very rarely in the back of the head; clothing is pushed aside</td>
</tr>
<tr>
<td><strong>Type of Weapon:</strong></td>
<td>No weapon present, often only the ejected shell casings</td>
<td>The total scene is to be observed</td>
<td>Own weapon and ammunition; weapon in the hand or on the floor</td>
</tr>
<tr>
<td><strong>Residue:</strong></td>
<td>Bullet impact in the wall or floor after a through-and-through, mostly not in the ceiling</td>
<td>Projectile impact in wall and ceiling</td>
<td>Projectile impact often in ceiling</td>
</tr>
</tbody>
</table>

Gunshot injuries to cranium/brain are often lethal, especially after suicide attempts. For patients with gunshot injuries to the torso, hemodynamic stability decides the prognosis/management.

**Burns and scalds**

Burns are injuries caused by direct exposure to flames, radiant heat or hot gases such as steam or combustion gases. Scalds occur through hot liquids such as water and oil. Typical here are the run off traces on the skin.

**Findings on the Corpse or Survivor, respectively, in Burns and Scalds**

- **Skin:** First degree burn: redness, heals well in a short period of time; second degree burn: blister formation, complete healing is possible; third degree burn: superficial necrosis with a defect healing in the form of a scar; fourth degree burn: a deep necrosis with charring.
- **Hair:** Only occurs with burns (not scalding with water) and hair will turn crinkly to the point of breaking down.
- **Soft tissues:** Boiling of the musculature with shrinkage and a resulting bending of the joints. The corpse takes on the so-called **boxer or fencing position**.
- **Teeth:** These are very resistant to heat and serve the identification of the body even with strong charring.
- **Head:** Heat haematoma are frequent post-mortem bleedings in the skull. These bleedings are caused by a contraction of the dura mater with a detachment from the calvaria during which veins rupture. Furthermore, the heat can blow up the skull.
Signs of Vital Reactions in Burns and Scalds

Among the signs of vital reactions is **redness of the skin** and **skin blisters**. All the other external findings may also occur on the corpse – here only an internal autopsy can provide further information.

During maintained respiratory function, combustion gases such as CO, CO$_2$ and hydrogen cyanide reach the respiratory organs and are traceable in the blood of the corpse. Traceable are **smut** on the mouth and the nostrils, sooty material in the trachea, **heat changes** in the mucous membrane, **acid burns** from the combustion gases in the respiratory tracts and, with CO-poisoning, a **bright cherry red colour** of the livor mortis and internal organs.

Furthermore, crow’s feet can form when actively closing one’s eyes meaning wrinkles around the eyes which were spared from soot.

In the following cases vital reactions do not occur:

- **Cyanide poisoning**
- **Flash fire**: The result of the heat is a laryngospasm and respiratory arrest
- **Heat Rigor**: A functioning impairment of respiratory excursion due to the sudden onset of heat rigor on the chest cavity resulting in death

Causes of death in burns and scalds

In general, CO poisoning and lack of O$_2$ (O$_2$ - loss due to the fire) quickly leads to death by suffocation. Delayed death in cases of very strong burns may occur due to a water-electrolyte imbalance, infections, burns to the airways, and a pulmonary oedema. This is what a lung with acute inhalation injury looks like:

![Image: "Burn injury" by Yale Rosen. License: CC BY-SA 2.0](image)

The rule of nines in burns and scalds

The fatal outcome as a result of burns depends on the **percentage of the total body surface area that has been burnt** and the **biological age of the victim**. As a rule, a burn of over 70 percent of the body surface is fatal.
The rule of thumb is that if the sum of the victim’s age and the percentage of the burnt body surface lies significantly below 100, doubts are in order as to if death occurred as a result of the burns. In this case, an autopsy and toxicological examination are necessary.

The rule of nines is a helpful method for estimating how much body surface area has been burnt. It states that the head, the chest, the abdomen, the back, the top or bottom, respectively, the arms front or back, the thighs and the lower legs, front and back, respectively, each correspond to nine percent of the body surface. A burn of the size of a palm corresponds to one percent.

Differentiating between crimes, accidents, suicides and post-mortem occurrence in burns

<table>
<thead>
<tr>
<th>Type:</th>
<th>Crime</th>
<th>Accident</th>
<th>Suicide</th>
<th>Postmortem Incident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency:</td>
<td>Rare</td>
<td>Frequent</td>
<td>Rare</td>
<td>Frequent</td>
</tr>
<tr>
<td>Characteristics:</td>
<td>Victims usually unconscious due to stabbing, beating or strangulation</td>
<td>Often surprised in the apartment by a smouldering fire while sleeping or caused by children / elderly people</td>
<td>Mostly outdoors after dousing with an accelerant</td>
<td>By setting fire to an object containing the body in order to cover up a crime (so-called arson murder)</td>
</tr>
</tbody>
</table>

Electricity

Injuries and deaths by electrical impact can result if a person becomes a part of a electrical circuit caused by a short circuit or an accidental ground circuit.

Significant for the biological effect is the current flow, which is essentially determined by the skin resistance. The skin resistance is in the range between $100\,\Omega$ (moist skin) and $100,000\,\Omega$ (dry skin). Equally important is the path that the current travels through the body.

Thermal Effects through Joule Heat in Electricity

Heat damage due to high local current density at electrical crossings appears in the form of redness, blisters, and funnel-shaped burns - collectively referred to as the electric mark (Joule burn). This is a purely thermal effect and not a sign of vital reaction.

The Joule burn is usually round, dented, and of grey-white to black colour. An undulating edge (porcelain wall) is just as typical as a histologically detectable parallel arrangement of basal cells. With a large contact area such as water, the current density at the crossing point is low and there is no electric mark.
A direct contact with the current conductor creates a small electric arc whereby the metal component of the current conductor vaporizes and is deposited on the electric mark. This metallization has equally no vital sign. During a current flashover, burn marks appear on the soles of shoes or on the sleeves of jackets.

Specific effects due to depolarisation in electricity

Since current can depolarise tissue, heart arrhythmias, for example, can be caused partially leading to instant death and overstretching and tears of the musculature.

Myoglobin exiting from the muscles can pass via the blood into the kidneys and lead to crush syndrome in the kidneys with possible renal failure. The contraction of the respiratory musculature can lead to congested bleedings and breathing difficulties.

Other autopsy findings are pulmonary oedema, liquid cadaveric blood, and an abundance of blood of the internal organs as well as soft tissue oedema.

Dangerous areas with electricity

Even low currents of a few milliamps have biological effects. The following effects occur with:

- Current above 5 mA: muscle traction
- Current above 25 mA: releasing is impossible
- Current above 80 mA: cardiac arrhythmias
- Current above 800 mA: guaranteed fatal
- Current from 2A on: electric marks and severe burns

Note: Fuses usually blow from 13 amps upward. Therefore, intact fuses are not criteria to exclude electrocution. A GFCI breaker does not necessarily have to jump if the victim is in the current circuit, but has no ground contact.
Differentiating between crimes, accidents, suicides and post-mortem events with electricity

<table>
<thead>
<tr>
<th>Type:</th>
<th>Crime</th>
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</tr>
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<tbody>
<tr>
<td>Frequency:</td>
<td>Rare</td>
<td>Frequent</td>
<td>Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>Characteristics:</td>
<td>Hair-dryer or power cord was placed into a bathtub; current is applied to a door-knob</td>
<td>Amateur electrician; contact with defect household appliances</td>
<td>Mostly death in bathtub</td>
<td>Simulated electrocution; electric marks may be present</td>
</tr>
</tbody>
</table>

Special event: Electrocution in the bathtub

The condition for damage is a closed circuit. As a rule, the ground fault occurs via a metal shower hose or a metal drainpipe. Due to the low skin resistance, usually no electric marks are found. The fuses will not blow.

It is difficult to provide evidence of a killing if the electrical sources have subsequently been eliminated. Suspicious would be the absence of typical drowning signs, especially if narcotics are found in the victim’s blood. In such cases an autopsy, as well as a criminal and electro-technical clarification, has to take place.

Special event: Death in the high voltage area

In the high voltage area, i.e. railroad tracks or power lines, a direct conductor contact is not necessary because the current can skip about one centimetre per 1,000V. Hereby, a bright and very hot light arc is created.

Superficial burns, singed clothing, and melted belt buckles or buttons can be found. The bright light leads to the victims squeezing their eyes shut thus producing the so-called crow’s feet with areas exempt from burns at the outer corners of the eyes.

These kinds of deaths usually happen because of accidents but it can also be a crime if someone was pushed into the danger zone.

Special event: Death by lightning

Here one distinguishes between a direct and indirect lightning effect. The direct lightning effect corresponds with the effects of a high-voltage accident. The indirect lightning effect is produced far from the lightning strike impact. The cause of this is an exponential drop of the voltage around the lightning impact site, the so-called discharge voltage pattern.

If the individual in this area is standing on the ground with spread legs, it can happen that the feet are in areas of different voltage (step voltage) and due to this voltage difference, current flows through the body.

Fine, branched reddening on the legs of the patients are often found, which are referred to as “Lichtenberg figure” – just like the lightning phenomena in the sky.
Death by freezing and hypothermia

Even small changes in body temperature can be dangerous. Heat loss can occur due to radiation (emission), conduction (direct heat transfer to the environment), evaporation (withdrawal of evaporation heat) and convection (ventilation).

Promoting heat loss is low insulation with a thin layer of fat or inadequate clothing, a low volume in relation to the body surface area (as in infants) and an increased heat transfer through a moist environment or heat conducting materials such as wet soil or cold water.

In addition, alcohol promotes heat loss due to the increased blood flow in the skin. Hypothermia is when the core body temperature is below 35° C.

If the thermoregulation of the body has been exhausted in the form of muscle tremor and a centralization of the circulation, the body core cools down. Cooled haemoglobin has a higher affinity to O\textsubscript{2}, which results in tissue hypoxia. Thus, death occurs through inner suffocation and consequent cardiac arrhythmias, such as ventricular fibrillation.

Local frostbite is divided into three stages:

1. Here, erythema (dermatitis congelationis erythematosa) and numbness occur.
2. After that, swelling (dermatitis congelationis bullosa) and blistering (chilblain) occur.
3. Finally, necrosis (dermatitis congelationis gangraenosa) with blackening occurs.

Findings on the corpse in deaths by freezing and hypothermia

- **The brain**: Disturbances of consciousness and hallucinations occur.
- **The heart**: From below 30° C body temperature arrhythmias occur and from below 27°C death by ventricular fibrillation.
- **The skin:** **Perniones** are hemolysis spots (also referred to as cold spots) on the extension side of the extremities (usually on the forearms and lower legs), which are reddish and look like traumatic bleeding. They can be distinguished from them by the fact that the subcutaneous fat is not pinched. Furthermore, red, itchy or painful swelling appears underneath the skin (**frostbite**). These occur particularly in parts of the body with less blood supply such as toes, fingers, and ears.

- **The stomach:** **Wischnewsky bleedings,** which are haemorrhagic erosions of the gastric mucosa that are typical for death due to freezing.

- **The musculature:** Small bleedings are located particularly in the musculature of the body core and microscopic tears of the muscle fibre, i.e. in the musculus ileopsoas.

- **Changes in the blood:** high blood sugar, acidosis, ketoacidosis as a result of fat breakdown. The blood has a bright red colour due to the stronger binding of O$_2$ to haemoglobin.

**Note:** There are no findings specific to hypothermia. The diagnosis can only be made on the basis of several signs or by excluding other types of damage, respectively. These are frost bites on the foot of an individual:

![Image](image_url)

**Paradox sensation of warmth in deaths by freezing or hypothermia**

It is quite typical to find a partially or completely undressed corpse, so that initially the suspicion of a sexual offense can occur. People with hypothermia undress due to the increased **blood circulation in the skin during the dying stage,** which leads to an intense feeling of warmth.

As these victims also suffer from hallucinations due to the lack of oxygen, they totally ignore the reality and dispose of some or all of their clothing. Alcohol promotes this process.

**Differentiating between crimes, accidents, suicides with deaths by freezing or hypothermia**

<table>
<thead>
<tr>
<th>Type:</th>
<th>Crime</th>
<th>Accident</th>
<th>Suicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency:</td>
<td>Relatively rare</td>
<td>Frequent</td>
<td>Rare</td>
</tr>
</tbody>
</table>
### People affected:

<table>
<thead>
<tr>
<th>People affected:</th>
<th>Exposed newborns or abandoned alcoholics</th>
<th>Alcoholics, drug addicts, and homeless people who sleep outdoors</th>
<th>As part of a mental disorder</th>
</tr>
</thead>
</table>

### Characteristics:
- Especially dangerous is cold water; rule of thumb for survival: 1 min per 1 °C

### Drowning

In cases of death in water one has to differentiate between an indirect and a direct drowning. The **indirect or atypical drowning** is the submersion in water due to circulatory collapse or disturbance of consciousness. This includes the classic death by drowning according to Emminger (sudden death in water).

A **direct drowning**, on the other hand, is suffocation under water comprised of the following criteria: gasping for air before going under, holding one's breath after going under (possibly several repetitions of these two processes), shortness of breath with breathing out and inhaling water, pre-terminal pause for breath due to paralysis and death. Overall, drowning takes between three and five minutes.

### Special event: Death in the bathroom

Death in the bathroom refers to **death by coincidentally being in water**. Often this occurs in the bathtub due to an abrupt collapse of the main vital functions, so that all vital reactions are at lost.

### Vital reactions during drowning

Coughing and the convulsions during drowning result in the so-called **plume of froth** at the mouth and nose in recent drowning victims, which can also be seen after it has dried. This whitish foam is produced by the reflective inhalation of water, which mixes with breathing air and the protein-rich bronchial secretion.

In addition, a spasmodic inspiration leads to an inflation of the lungs causing bleeding again, the so-called **Paltauf Spots**. These spots are about the size of a fingertip, subpleural, and of red to brown colour. The macroscopic image of the bloated, red lung is called **erythema aquosum** (only when drowning in fresh water). The lung cannot even be collapsed with the pressure of a finger (**volume pulmonum auctum**).

Water is found in the **alveoli** with typical elements such as plankton and diatoms. With a sediment analysis of the discovery site and an analysis of the composition of the water in the lungs, the drowning site may possibly be reconstructed.

As water was ingested, it can also be found in the stomach. The stomach contents are therefore typically three-layered: foam is at the top followed by water and finally chyme which is referred to as **Wydler’s sign**.

The reflective vomiting of water also leads to tears of the mucosa of the cardia, the **Sehrt’s mucosal tear**. Another common finding is the **Svechniko’s sign**. It describes the presence of the drowning fluid in the sphenoid sinus.

All these findings prove that the person was alive when getting into the water.
Drowned body and drowning

The sign of a longer stay in water is wet clothing and clothing contaminated with mud, injuries caused by floating, injuries caused by boat propellers, wrinkled hands with nail detachment, apidocere (wax-like formation on the skin), bloating of the corpse which was fed on by animals.

As the body floats along in a face down position, abrasions mostly occur on the forehead, the back of the hands, the knees, and toes.

Note: Any corpse recovered from water is referred to as a drowned body. This does not mean, however, that the person has died in the water. It may well be that death occurred outside of the water followed by a secondary depositing of the corpse into the water.

Review Questions

The answers are below the references.

1. What does the term Svechnikov’s sign refer to in forensic medicine?

A. Haemorrhagic bleedings which can be found in the gastric mucosa of an individual frozen to death
B. Sub-pleural bloody spots on the body of a drowning victim.
C. Mucosa tears of the cardia in a drowning victim.
D. Drowning fluid in the sphenoidal sinus of a drowning victim.
E. Subconjunctival haemorrhaging, which can be found in individuals who have died due to a severe thorax compressions.
2. What does not apply to the suicide with a gun?

A. It is usually an absolute close-range shot.
B. The weapon is always in the shooting hand of the body.
C. The projectile is very often stuck in the ceiling.
D. The localisation is usually found in the area of the head.
E. Multiple gunshot wounds are possible.

3. What is not an indication that a person was still alive when a fire occurred?

A. Soot particles in the airways.
B. Bright cherry red colour of the cadaveric blood.
C. Crow’s feet on the lateral corners of the eyes.
D. Corpse in fencing posture.
E. Burn blisters on the skin.

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Correct answers: 1D, 2B, 3D

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