Clinical forensic medicine is the application of forensic medical knowledge and techniques to live patients in a clinical setting. European, Australian, and British physicians—known as police surgeons, forensic physicians, forensic medical examiners, or forensic medical officers3,17—have a long history of performing clinical forensic examinations,3 including evaluations of prisoners and victims of physical and sexual assault.5,5

All patients who are victims of physical or sexual assault, abuse, or trauma have forensic needs. When treating injuries without consideration of their forensic significance, physicians may misinterpret wounds, fail to recognize victims of abuse or domestic violence, and inadequately describe the physical appearance of the wounds. During the provision of patient care, evidence that can be of critical significance to criminal or civil proceedings can be lost, discarded, or inadvertently washed away,6-20 despite requirements by The Joint Commission (TJC) to “preserve evidentiary materials and support future legal actions.”21

Emergency medicine programs have identified and described the need for forensic training in their residency curricula.9,10,14,22 In 1991 the Department of Emergency Medicine at the University of Louisville School of Medicine collaborated with the Kentucky Medical Examiner’s Office and established the first clinical forensic medicine training and consultative program in the United States.9,13,19,20 In 2006, the American College of Emergency Physicians established the Forensic Medicine Section to provide emergency physicians with additional forensic resources and training.23 In 2010 the Louisville Police Department created a full-time clinical forensic medicine consultation service to provide forensic evaluations for living victims of crimes, staffed by a forensic emergency physician and three part-time forensic nurse examiners.

Forensic examinations are conducted with the consent of the patient, legal guardian, or court, or by implied consent. The evaluation includes a history and physical examination, photographs, and anatomic diagrams.22 Evidentiary material, including clothing, hair, blood, saliva, bullets, bomb fragments, and the like, are collected when indicated or when ordered by the court.24 If a patient has been admitted from the emergency department (ED) to surgery, an evaluation is done in the operating suite in conjunction with the trauma surgeons.25

In 2006 the British Royal College of Physicians established the Faculty of Forensic and Legal Medicine (FFLM) as the authoritative body on clinical forensic medicine in the United Kingdom.26 The FFLM has created training and certification programs and board-type certification examinations after 2 years of forensic practice for British physicians.26

Evaluations of gunshot and stab wounds, physical or sexual abuse, domestic violence, and motor vehicle–related trauma should be adequately documented for possible use in future legal proceedings. Documentation should include digital photographs as well as a narrative and diagrams.7,13,17-22,25 However, in one trauma center, 70% of cases had improper or inadequate documentation, and 38% of cases had potential evidence improperly secured, incorrectly documented, or inadvertently discarded.8 When physical injuries are misinterpreted and these misinterpretations become the medical record or when valuable evidence is lost or destroyed in the process of providing patient care, there are consequences for the legal proceedings that may follow.1,6-20,26-30 These acts of omission or commission may deny patients their deserved redress in the justice system. To protect the interests of patients, EDs should implement protocols for wound documentation and evidence collection.11,12

FORENSIC ASPECTS OF GUNSHOT WOUNDS

Firearms continue to be the second leading cause of injury-related deaths in the United States—30,913 firearm-related deaths in 2009—after motor vehicle trauma.31 Emergency physicians treat more than 115,000 victims of gunshot wounds, principally from handguns, each year.32 The direct and indirect costs associated with gunshot wounds total $36 billion annually.33

Errors of Interpretation and Terminology

The emergency physician is in the ideal position to evaluate and document the state of a gunshot wound because he or she sees and explores it before it is disturbed, distorted, or destroyed by surgical intervention.6-14,27,30 Documentation of gunshot wounds should include the anatomic location of the wound as well as its size, shape, and distinguishing characteristics, and digital photographs of the wound should be taken. Wounds should be described according to the standard anatomic position with the arms to the sides and palms up.

Clinicians should not describe wounds as “entrance” or “exit” but should document, using appropriate forensic terminology, a detailed description of the wound, including its appearance, characteristics, and location without attempting to interpret the wound type or bullet caliber.27,34-39 Exit wounds are not always larger than entrance wounds, and wound size does not consistently correspond to bullet caliber.18,27,36-42

The size of any wound (entrance or exit) is determined by five factors: the size, shape, configuration or angle, and velocity of the projectile at the instant of impact with tissue and the physical
characteristics of the impacted tissue itself. If the projectile is slowed and its shape unchanged on exiting the skin, the exit wound may be the same size as or smaller than the corresponding entrance wound. 34,41,42 If the projectile increases its surface area by fragmenting or changing its configuration while maintaining a substantial velocity, the exit wound may be significantly larger than the entrance wound. 34,36-42 If the bullet strikes bone, fragments may extrude from the exit wound and contribute to the size and shape of the wound. Tissue elasticity also affects the wound size so that entrance or exit wounds may be smaller, equal to, or larger than the projectile that caused them. 40-42 Wounds on the palm or sole may appear as slits and can be easily mistaken for stab wounds. 34,41,42

Inappropriate terminology should be avoided. 3,37,41,42 One example of inappropriate terminology is the use of the obsolete term powder burns, rather than soot, to describe the carbonaceous material associated with close-range wounds. 34,35,41,42 Powder burns are literally the thermal injuries associated with flaming black powder used in muzzle loaders, antique weapons, and blank cartridges. These injuries do not occur with the smokeless powder used in modern ammunition.

It is unnecessary to comment in the medical record on the manner of a gunshot victim's death. The determination of whether a death is accidental, suicidal, or homicidal is the responsibility of the coroner or medical examiner and occurs only after a detailed investigation of the scene and circumstances of the incident. The patient's position at the time of injury can be determined only after an examination of the scene and collection of all forensic evidence.

A treating physician may be requested to render factual testimony, expert testimony, or both in a criminal case. Expert forensic testimony rendered without an appropriate forensic examination or adequate forensic training may mislead participants in the criminal justice system (e.g., “the entrance wound is always larger than the exit wound”). Opinions related to entrance versus exit wounds or the range of fire can affect the determination of innocence or guilt.* The perennial speculation about entrance and exit wounds in the assassination of President Kennedy is one example of the significance of a forensic evaluation. 29,40,44

Forensic Aspects of Handguns

The Weapon

Handguns are the most common firearm available. There are four categories of handguns: (1) the single-shot weapon (usually a target pistol), (2) the derringer (a small, concealable weapon, usually with two barrels), (3) the revolver (a weapon with a rotating cylinder that advances with the pull of the trigger), and (4) the semiautomatic pistol (which fires with each pull of the trigger). The semiautomatic handgun is the most popular because its magazine, or clip, can hold up to 17 cartridges, whereas revolvers hold five or six cartridges.

Handgun Ammunition

The cartridge, or round, is composed of the primer, the cartridge case, the powder, and the bullet (Fig. 65-1). The bullet is the projectile that is propelled out of the muzzle.

The primer is a small explosive charge in the base of the cartridge that ignites the gunpowder. The primer may contain lead, barium, or antimony. These materials may be deposited on the hands of the shooter, on the victim of a close-range assault, or on objects within a room in which the weapon was discharged. 41

The cartridge case is typically made of brass, although other materials may be used. The function of the cartridge case is to slightly expand, sealing the chamber against the escaping gases and propelling the bullet down the barrel. 41 On detonation, a cartridge case is imprinted with unique microscopic marks that are valuable evidence and should be preserved for law enforcement.

The gunpowder found in all commercial cartridges except blanks is smokeless powder made with a single base (nitrocellulose) or a double base (nitrocellulose and nitroglycerine). 41 When a weapon is discharged, not all of the gunpowder is consumed. A percentage of the unburned or partially burned gunpowder will travel out of the end of the muzzle for a short distance (<48 inches). The distance depends on the physical characteristics and shape of the powder and the weapon's barrel length.

Blank cartridges, muzzleloaders, and other antiques or replicas may use black powder. Black powder (a combination of potassium nitrate, charcoal, and sulfur) does not burn as efficiently as the smokeless powder and results in a large flame and white smoke. It is black powder that produces powder burns by igniting clothing.

The bullet is the projectile that is propelled down the gun barrel at velocities ranging from 700 to 1600 ft/s. The higher velocities are achieved by the inclusion of supplemental gunpowder in the cartridge case (a magnum load, hence a .357 magnum). The diameter of the bullet’s base is called its caliber. Bullet caliber is described in hundredths of an inch or in millimeters. Handgun bullets range from .22 caliber or 5.56 mm to .45 caliber or 11.3 mm. A bullet’s weight is measured in grams, with 7000 grains/lb.

The most common bullet types are the round nose, the full metal jacket, the hollow point, the wadcutter, and the semiwadcutter. Bullets generally are a solid core of lead or steel. If a jacket covers the bullet core, the jacket’s metal is usually copper or aluminum. If the jacket covers only a portion of the core, the bullet is said to be semi-jacketed. If the core is completely covered, it is said to have a full metal jacket. Some bullets have a hole in the tip and are called hollow points. The hole causes the bullet to expand on contact, which significantly increases the damage to tissue.

Handgun Wound Ballistics

Wound ballistics is the study of the effects of penetrating projectiles on the body. 39,45-50 Tissue disruption (wound severity) is directly related to the amount of kinetic energy (KE = ½mv²) transferred to it, not to the total amount of kinetic energy

*References 27, 29, 30, 37, 41, 43.
Table 65-1 Range of Fire

<table>
<thead>
<tr>
<th>RANGE</th>
<th>INCHES (BARREL TO SKIN)</th>
<th>PHYSICAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>0</td>
<td>Soot, seared skin, triangular tears</td>
</tr>
<tr>
<td>Close</td>
<td>0-6</td>
<td>Soot, abrasion collar (abrasion collar may be obscured by soot)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>&lt;48</td>
<td>Tattooing, abrasion collar</td>
</tr>
<tr>
<td>Distant or indeterminate</td>
<td>Any distance</td>
<td>Abrasion collar (intermediate objects will prevent soot and gunpowder from contacting the skin)</td>
</tr>
</tbody>
</table>

The principal mechanism for tissue damage by bullets is crushing. A bullet traveling through tissue generates two cavities, one permanent and the other temporary. The temporary cavity, a result of tissue stretching, lasts 5 to 10 msec from its generation until its collapse and leaves behind the permanently crushed tissue and the permanent cavity.39,41,45 The size of the permanent cavity varies with the size, shape, and configuration of the bullet. A hollow-point bullet that mushrooms can increase its diameter 2.5 times on impact and will increase the area of tissue crush 6.25 times compared with a nondeformed bullet.41

Forensic Evaluation of Handgun Wounds

Entrance Wounds

Range of fire is the distance from the muzzle to the victim and can be divided into four general categories: contact, near-contact or close range, intermediate or medium range, and indeterminate or distant range (Table 65-1). The size of the entrance wound does not correlate with the caliber of the bullet41 because the entrance wounds over elastic tissue will contract around the tissue defect and have a diameter much less than the caliber of the bullet.39,41

Contact Wounds. There are three subcategories of contact wounds: (1) tight contact, in which the muzzle is pushed hard against the skin; (2) loose contact, in which the muzzle is incompletely or loosely held against the skin; and (3) contact through clothing.

In a tight contact wound, all material—the bullet, gases, soot, the incompletely burned pieces of gunpowder, and metal fragments—is driven into the wound. These wounds can vary from a small hole with seared blackened edges from the discharge of hot gases and an actual flame to a gaping stellate wound (Fig. 65-2). Large wounds occur when the wound is inflicted over thin, inelastic or bony tissue, and the injected hot gases cause the skin to expand until it stretches and tears. These tears will have a triangular shape, with the base of the triangle overlapping the entrance wound. Tears are generally associated with .32 caliber or greater, or magnus loads. Large stellate contact wounds are easily misinterpreted as exit wounds if the determination is based solely on their size (see Fig. 65-2B).39,41

Stellate tears are not pathognomonic for contact wounds, however. Tangential wounds, ricochet or tumbling bullets, and some exit wounds may also be stellate. These wounds’ appearance differs from a tight contact wound’s by the absence of soot and powder within the wound and a lack of seared wound margins.34,41,42 In some tight contact wounds, expanding skin is forced back against the muzzle of the gun, leaving a characteristic muzzle abrasion or muzzle contusion (Fig. 65-3).34,41,42 Patterns such as these should be documented before wound débridement or surgery because they are helpful in determining the type of weapon used (revolver vs. semiautomatic).25,41

When a gun’s muzzle or barrel is in loose contact with or is angled to the skin, the soot and gunpowder residues are present both within and surrounding the wound. The angle between the muzzle and the skin determines the soot pattern. A tangential, loose, or near-contact wound produces an elongated searing and soot deposit surrounding the wound.

Discharge of a weapon in contact with clothing results in the gases and soot being deposited between the garment and the skin. This results in a diffuse pattern of soot surrounding a wound with seared margins (see Fig. 65-2C).

Close-Range Wounds. Close range is the maximum range at which soot is deposited on the wound or clothing. The muzzle-to-target distance is usually less than 6 inches but may be as much as 12 inches.40–42 Beyond 6 inches, most of the soot usually falls away and does not reach the skin or clothing. The concentration of the soot varies inversely with the muzzle-to-target distance and is influenced by the type of gunpowder and ammunition used, the length of the weapon’s barrel, and the caliber and type of weapon itself (Fig. 65-4).

A precise range of fire (e.g., 2 inches vs. 5 inches) cannot be determined from examination of the wound alone. A forensic firearms examiner can attempt to reproduce the patient’s soot pattern on a target by test-firing the offending weapon at different ranges using ammunition similar to the ammunition that caused the wound (Fig. 65-5). The validation of this test and the determination of a range of fire depend on the accuracy and detail in the physician’s report regarding the size of the soot pattern. Because soot can be removed with débridement or wound cleansing, its presence and configuration around the wound should be noted and photographed before débridement unless the patient’s clinical condition precludes this attention to detail.25

Intermediate-Range Wounds. Tattooing, or stippling, is pathognomonic for an intermediate-range gunshot wound. Tattooing appears as punctate abrasions and is caused by contact with partially burned and wholly unburned pieces of gunpowder (Fig. 65-6). Tattooing or stippling cannot be wiped away. Tattooing rarely occurs on the palms of hands or soles of feet because of the thickness of the epithelium.41

Tattooing may occur as close as 1 cm to and as far away as 1.3 m from the weapon but is generally found at distances of 60 cm or less.40–42,51 The density of the tattooing and the associated pattern depend on the length of the barrel, the muzzle-to-skin distance, the type of gunpowder, the presence of intermediate objects, and the caliber and type of ammunition. Clothing, hair, or other barriers may prevent tattooing from occurring. The presence of partially or entirely unburned pieces of gunpowder and gunpowder residues on clothing or skin aids in determining the range of fire. On rare occasion, pieces of gunpowder can penetrate thin clothing and leave punctate abrasions (Fig. 65-7).

Long-Range Wounds. The distant or long-range wound is inflicted from far enough away that only the bullet makes contact with the skin. There is no tattooing or soot. As the bullet penetrates the skin, the skin is indented, resulting in the creation of an abrasion collar, also called an abrasion margin, abrasion rim, or abrasion ring (Fig. 65-8).41,42 This collar is an abraded area of tissue that surrounds an entry wound as the result of friction between

Possessed by the bullet.39,41,45 Bullets fired from rifles generally have a higher velocity (1500 to 4000 ft/s) than do those fired from handguns (700 to 1600 ft/s). Rifle bullets have more kinetic energy and therefore a theoretically higher wounding potential, but wound severity is the result of multiple variables, the most important of which are bullet type (weight, deforming type, fragmenting type), bullet velocity, and the characteristics, location, and nature of the impacted tissue itself (tissue over bone or tissue over organs).39,41,46–50
Figure 65-2. A, Tight-contact entrance wound from a .38-caliber revolver. The wound margins are seared from the discharge of hot gases and an actual flame from the end of the barrel. The triangular tear is the result of tissue expansion from the discharge of gases into the tissue. B, Tight-contact entrance wound with large stellate tears from a .380 semiautomatic pistol. The large triangular tears are the result of rapid expansion of gases under the skin. C, Tangential-contact wound from a 9-mm pistol on the medial aspect of the left calf. The presence of soot at the superior aspect indicates a close range of fire. The patient initially reported that he was shot from a distance of 3 or 4 feet and later admitted that he had accidentally shot himself while withdrawing his pistol from his boot. Large wounds as seen in B and C may be misinterpreted as exit wounds because of their size.

Figure 65-3. A muzzle contusion is a contusion caused by skin expansion against the barrel of the weapon. Muzzle contusions are associated with contact wounds.

Figure 65-4. Close-range wound with soot deposition. Soot is associated with a range of fire of 6 inches or less.
describes the range of fire. A wound inflicted from 10 feet will appear the same as a wound inflicted from 100 feet. An exact range cannot be determined with a distant wound.

Determining the range of fire may be complicated when clothing prevents the deposition of soot and powder on the skin. Without the overlying clothing or without information regarding the crime scene, the wound may appear to be from a distant range of fire. In reality, the range may have been close or intermediate.

Conversely, a projectile discharged from a distant range of fire may describe the bullet and the epithelium. The width of the abrasion collar varies with the angle of impact. Most entrance wounds will have an abrasion collar. Entrance wounds on the palms and soles are exceptions. These usually appear slitlike.

The abrasion collar is not the result of thermal changes associated with a hot projectile. The abrasion collar of a contact or close-range wound may be undetectable because hot gases and a flame have seared the tissue. When an abrasion collar is the only visible superficial clinical finding present, indeterminate range

Figure 65-5. Gunshot residue testing conducted at 6 inches with a .32-caliber revolver. The testing searches for the presence of soot (burning of gunpowder), nitrites (unburned gunpowder), and vaporized lead residue. These tests determine the range of fire from the barrel to the clothing.

Figure 65-6. Tattooing results from contact with pieces of unburned gunpowder. These punctate abrasions are associated with an intermediate range of fire, generally less than 36 inches. The density of these abrasions depends on the length of the gun’s barrel, the distance from the muzzle to the skin, the type of gunpowder used, and the presence of any intervening objects.

Figure 65-7. Gunpowder can penetrate thin clothing and deposit tattooing on the skin. A 3-year-old was shot with a .45-caliber round at close range, and pieces of gunpowder passed through the T-shirt.
Exit Wounds

Exit wounds are the result of a bullet pushing and stretching the skin from the inside out. The skin edges generally are everted with sharp but irregular margins.

The size of the exit wound is determined by the energy transferred from the bullet to underlying tissue and by the bullet’s size and configuration as it exits the skin (Fig. 65-12).41,42 When a bullet enters the skin, its configuration may change from its usual nose-first attitude owing to tumbling and yaw. A bullet that exits the skin sideways, or one that has increased its surface area by mushrooming or transferring its energy to underlying bone, will have an exit wound larger than its entrance wound.34,41

Atypical Exit Wounds. A shored-exit wound is a wound that has an associated false abrasion collar. If the skin is pressed against or supported by a firm object or surface at the moment the bullet exits, the skin can be compressed between the exiting bullet and the supporting surface (Fig. 65-13).41,42,57 Examples of supporting structures include belts, floors, walls, doors, chairs, and mattresses.

Rarely, soot may also be present at an atypical exit wound site.58 If a contact entrance wound is located close to its associated exit wound, soot can be propelled through the short wound track and appear faintly on the exit wound surface (Fig. 65-14).

Forensic Evaluation of Centerfire Rifle Wounds. Projectiles discharged from centerfire rifles have the potential to inflict massive tissue damage (Fig. 65-15). A bullet’s wounding potential is based on the kinetic energy it possesses. Centerfire bullets, .223 to .308 caliber, are similar in diameter to handgun ammunition, but based on the formula for kinetic energy ($KE = \frac{1}{2}mv^2$), their wounding potential is greatly enhanced by the higher velocity of the round.41 Injuries result from the transference of energy from the projectile to tissue, organs, and bony structures. With medium-velocity rounds (2000–3000 ft/s) and high-velocity rounds (>3000 ft/s), a temporary cavity is formed along the wound tract, which may be 11 or 12 times the diameter of the bullet. High velocity rounds can also cause tissue damage away from the physical tract taken by the projectile.49 Because of the amount of energy possessed and transferred to underlying tissue, exit wounds associated with centerfire rifles, in contrast to those associated with handguns, are generally larger than their corresponding entrance wounds (see Fig. 65-15).41,42

Entrance wounds associated with high-velocity, centerfire projectiles do not significantly differ from those of handguns. Entrance wounds will generally exhibit abrasion collars or microtears on the skin surface (Fig. 65-16). Wounds will also have associated soot deposition and tattooing, but because of a number of variables, such as muzzle length, amount of power in a given cartridge, muzzle configuration, and type of gunpowder, the range of fire in

![Figure 65-8](image1.png) An abrasion collar is the abraded area surrounding the entrance wound created by the bullet when it indents and passes through the epithelium. The collar or rim is the result of friction between the bullet and the epithelium. The width of the abrasion collar will vary with the angle of impact.

![Figure 65-9](image2.png) “Pseudotattooing” or punctate abrasions from glass fragments, not unburned gunpowder, on the medial aspect of the thigh associated with a gunshot wound. The leg was showered with glass fragments after the round penetrated the windowpane.
rifle wounds is not as clearly defined as in handgun wounds. The determination of an exact range of fire for rifles and shotguns is best established through controlled testing performed by a firearms examiner at a crime laboratory.

High-velocity bullets with jackets and lead cores generally break up into hundreds of fragments, called a “lead snowstorm,” on entering tissue, resulting in significant tissue damage (Fig. 65-17). If the tissue they penetrate is deep, the bullet fragments may fail to exit and remain embedded. It is therefore possible to sustain an injury from a high-velocity round and not exhibit an exit wound. High-velocity rounds with steel cores will almost uniformly exit intact.

Forensic Evaluation of Shotgun Wounds. Shotguns, have the barrel length of rifles, but can discharge pellets or single slugs down a smoothbore barrel. The caliber of a shotgun is defined by the term gauge. Historically, the gauge of a gun referred to “the number of lead balls of the given bore diameter that make up a pound”—for example, 12 lead balls to make 1 lb. A shotgun cartridge may contain only a single slug or may contain hundreds of pellets (Fig. 65-18A). Pellets range in diameter from 0.05 inch (#12 birdshot) to 0.36 inch (“000” buckshot). A shotgun cartridge is made of several components that will be of forensic value and should be collected in the ED (Fig. 65-18B).

Shotgun slugs are single projectiles that may weigh 200 times more than handgun ammunition—for example, a 12-gauge slug weighs 547 grams, and a .22 long rifle bullet weighs 2.6 grams (see Fig. 65-18B). The massive damage caused by slugs may obliterate the abrasion collar usually associated with entrance wounds. Shotgun slugs will almost uniformly exit the body with large exit wounds. The velocities of shotgun slugs are in the range of 1500 to 1800 ft/s.

Microscopic Examination of Wounds

The débrided epithelial margins of wounds should be submitted to the pathology department for a histologic examination. The microscopic presence of soot, gunpowder, and thermal damaged will help determine if the wound is an entrance or exit wound and the range of fire.58-60 Evidence

A victim’s clothing may yield information about a bullet’s range of fire and help distinguish entrance from exit wounds.* Clothing fibers will deform in the direction of the passing projectile. Gunpowder residues and soot will deposit on clothing as they do on skin. Residue may be invisible to the naked eye, but nitrites and vaporized lead can be visualized with standard forensic staining techniques. Some bullets, as they make initial contact with clothing, leave a lead or lubricant residue that is termed bullet wipe. Articles of clothing removed from a wounded patient need to be placed in separate paper bags to avoid cross-contamination of evidence.11,17

A gunshot residue (GSR) test may determine whether a victim or suspect has been in proximity to a weapon that has been discharged.41,61-70 The GSR test checks for the presence of invisible residues from the primer: barium nitrate, antimony sulfide, and lead peroxide. The presence of residue can be checked by

*References 7, 11, 12, 22, 24, 41, 61.
Figure 65-12. A, Slitlike exit wound from a .22-caliber bullet. B, Perforating gunshot wound to the left deltoid area with soot deposition around the larger entrance wound. No soot is present around the smaller exit wound. Exit wounds are not consistently larger than their corresponding entrance wounds.

Figure 65-13. Shored-exit wound with a false abrasion collar. This type of wound occurs when the skin in the region of the exiting bullet is in contact with a supporting structure (e.g., a wall, floor, or mattress). The skin is slapped against the supporting structure, which results in a false abrasion collar.

Figure 65-14. Soot can be associated with an exit wound. The patient sustained a contact wound to the posterior aspect of the ear and the soot was forced thorough the tissue and deposited anterior to the ear.
The specificity and sensitivity of the GSR test are unclear. Residue will deposit on the hands of the individual who fired the weapon in only 50% of cases. Residue may spread throughout a crime scene, and secondary contact with the weapon or furniture on which residue was deposited will result in a false-positive test result. The transference of residue from police officers to suspects has also been reported. The sensitivity of the test decreases with time, and law enforcement agents may not have access to a patient during the “golden hour.” Actions that decrease sensitivity include washing the skin with alcohol or betadine, placing tape on the skin, rubbing the hands against clothing, and placing plastic bags over the patient’s hands, which precipitates moisture on the skin. If a GSR test is to be performed or if soot is noted on the patient’s hand, paper bags should be placed over the hands early in the treatment.

The bullet, the bullet jacket, and the cartridge case are invaluable for identifying or excluding a suspect weapon. When a weapon is discharged, the discharge imprints multiple microscopic marks on the side of a bullet and on the bottom or side of the cartridge case. The markings result from the bullet’s contact with the tool marks or “rifling” in the gun’s barrel. These marks are unique to each barrel and are reproducible. These marks are the gun’s “fingerprint,” so to speak. Cartridge case marks are from contact with the firing pin, the breech lock, the magazine of semiautomatic weapons, and extractor and ejector mechanisms. These microscopic “fingerprints” can be obliterated by removing a bullet with hemostats or pickups. Bullets should be handled with gloves, and the tips of surgical instruments should be covered with gauze (Figs. 65-19 and 65-20) or plastic tips—“suture booties”—to ensure the preservation of these microscopic marks. It is not necessary to place initials or other markings on the bullet if adequate notes are made in the patient’s medical record regarding the chain of custody.

Radiographs also help locate retained projectiles and may be of evidentiary value in determining the number of projectiles and the direction of fire.

**FORENSIC ASPECTS OF PHYSICAL ASSAULT**

**Identifying Assault Victims**

Studies estimate that up to 22 to 33% of patients in urban EDs are victims of domestic violence, yet very few are recognized as such. In a study of victims of domestic violence, 43% of
patients with acute trauma came to the ED six or more times before they were identified as victims of abuse; nearly half of these patients came to the ED at least 12 times.84 Victims admitted to the trauma service also go unrecognized.85

Every weapon leaves a mark, design, or pattern stamped or imprinted on or just below the epithelium. The epithelial imprints of these weapons, called pattern injuries, are consistently reproducible.19,25,35,86 These injuries are classified into three major categories according to their source: blunt force, sharp force, and thermal.

Accurate documentation of the anatomic location of the injuries makes it easier to determine the implement, tool, or weapon responsible for producing each wound.

Blunt Force Pattern Injuries

The most common blunt force injury is the contusion, along with abrasions and lacerations. A weapon with a unique shape or configuration may stamp a mirror image of itself on the skin (Box 65-1).19,35,86

Pattern Contusions. A blow from a linear object leaves a contusion that is characterized by a set of parallel lines separated by an area of central clearing (Fig. 65-21).19,35,86 The blood underlying the striking object is forcibly displaced to the sides, which accounts for the pattern's appearance (Fig. 65-22).

Circular or linear contusions suggest abuse or battery. Circular contusions 1.0 to 1.5 cm in diameter are consistent with fingertip
Some injuries allegedly occur during police custody. Specific pattern contusions can include parallel contusions from a flashlight or nightstick. Handcuff or shackle marks are narrow parallel contusions or abrasions on the wrists or ankles. Handcuff and shackle marks are generally more prominent on the lateral aspects of the extremity.42

The history should be recorded and injuries documented with diagrams and photographs, when possible. The incident is best reviewed by an internal affairs unit of the investigating law enforcement agency and not by the emergency physician. Conclusions regarding the alleged perpetrator and the mechanism of injury should generally be avoided.
A bite mark may appear as a pattern contusion, an abrasion, or a combination of both (Fig. 65-25). Bite marks vary greatly in the quality of their identifiable features, depending on the location of the bite and the motion of the teeth relative to the skin. Some bite marks may not be readily identifiable as such and may appear as nonspecific contusions, abrasions, or contused abrasions.

When an acute bite mark is identified, care should be taken not to wash away potential evidence. The skin surface should be swabbed with a sterile cotton-tipped applicator moistened with sterile saline. DNA from buccal cells may also be deposited over an acute bite mark.11,17

When available, a forensic odontologist can evaluate a bite wound with accuracy. The use of alternative light sources, such as ultraviolet or infrared, may reveal a pattern contusion within or under the epithelium that is not visible to the naked eye.87 These light sources are routinely used by the forensic odontologist on bite marks that are faint, old, or difficult to identify.

The emergency physician may be asked to render an opinion regarding the age of a contusion. The development of a contusion is based on a number of variables: the amount of blunt force applied to the skin, the vascularity of the tissue, the oxygenation of the extravasated hemoglobin, the depth of the hematoma, skin tone, and the amount of blood that escapes into the surrounding tissue.88-90 As a result, no reproducible standard for the dating of a contusion is possible based on its color.86-90 New techniques based on reflectance spectrophotometry are currently being tested.91 A tissue biopsy examining the hemosiderin breakdown may be the only scientifically accepted method to determine the approximate age of a contusion.92

**Pattern Abrasions and Lacerations.** A *pattern abrasion* is a rubbing or scraping away of the superficial layers of the epidermis, which is not important for treatment but may be invaluable from a forensic and injury reconstruction perspective.90 A *laceration* is defined as a tear in the skin produced by blunt trauma and should not be confused with an incised wound produced when a sharp-edged implement (e.g., knife, scalpel, or piece of glass) is drawn across the skin.19,35 A laceration has characteristically abraded or crushed skin edges and unique “tissue bridges” (Fig. 65-26).

**Sharp Force Pattern Injuries**

An *incised wound* is longer than it is deep, and the *stab wound* is defined as a puncture wound that is deeper than it is wide. The wound margins of sharp force injuries are clean and lack the abraded edges and tissue bridges of injuries resulting from blunt forces.

Forensic information can be gathered during the examination of a stab wound. Some of the characteristics of a knife blade, single edged or double edged, can be determined from visual inspection (Fig. 65-27A and B).19,86 Additional blade characteristics, such as serrated versus sharp, can be seen if the blade was drawn across the skin during its insertion or withdrawal (see Fig. 65-27C). Serrated blades do not always leave characteristic marks.19,86

Patients with self-inflicted wounds frequently visit the ED claiming an accident, self-defense, or assault. When the patient history, the injuries, and the forensic evidence are not consistent, the forensically informed emergency physician is in a unique position to extrapolate the truth. With an understanding of how to identify the patterns of self-inflicted knife wounds, the physician can provide appropriate referrals, conserve resources, and assist law enforcement in the investigation of an alleged crime.

When a patient claims to have been assaulted and the victim of a crime, his or her injuries become physical evidence. It is important for the treating physician, who may be called as an expert witness, to recognize patterns of self-inflicted injury to distinguish self-inflicted wounds from those sustained during an assault (Fig. 65-28 and Box 65-2).

**Thermal Pattern Injuries**

A thermal pattern injury is a common form of abuse or battery. The history should include the position of the patient relative to the thermal source. This information will help determine whether the injury was intentional or accidental.86

A sharp or clear line of demarcation between burned and unburned tissue characterizes immersion or dipping burns. In contrast, splash burns are characterized by an irregular or undulating line or by isolated areas of thermal injury, usually round or oval in shape, caused by droplets of hot liquid.

The severity of thermal or scald injury depends on the length of contact time and the temperature. Water causes full-thickness damage in 1 second at 158° F (70° C) and in 600 seconds at 120° F (48.9° C) (Fig. 65-29).95 Law enforcement routinely measures the household’s or institution’s water temperature in any investigation involving a scald injury.
Figure 65-27. A, A single-edged knife blade will cause a wound to be formed with a sharp edge and a dull edge. If the blade penetrates to its hilt, a “hilt mark” may be seen overlying the sharp edge. B, Single-edged stab wound. C, Single-edged stab wound made by a serrated blade. Abrasions from the blade’s serrated edges are seen on the left margin of the wound.

Figure 65-28. The presence of multiple, parallel superficial incised wounds, sometimes termed “hesitation marks,” are indicators of self-inflicted wounds.

Box 65-2 Characteristics of Self-inflicted Knife Wounds

- Multiple superficial incisions located on the anterior trunk, arms, and face
- Multiple superficial stab wounds located on the anterior trunk, arms and face
- Parallel incisions, in close proximity to each other, on the nondominant side of the body
- Sparing of sensitive body areas
- Linear or curved incisions toward the hand inflicting the wound
- Intact clothing covering the wound
- Evidence of prior wounds in repeat offenders

Figure 65-29. Relationship between water temperature and the duration of contact required to produce a full-thickness thermal injury. (Adapted from Katcher ML: Scald burns from hot tap water. JAMA 246:1219, 1981.)
FORENSIC ASPECTS OF MOTOR VEHICLE TRAUMA

Law enforcement officials investigating an incident involving serious or fatal injuries from a motor vehicle or pedestrian collision may benefit from information regarding injury patterns and the collection of trace evidence from the victim. This information can help determine whether an occupant was a driver or passenger. It may help to identify a suspect vehicle involved in a hit-and-run pedestrian collision or a pedestrian’s position (standing or lying) when struck in the roadway.42

Determination of a vehicle occupant’s role may be simple (e.g., if the driver is pinned behind the steering wheel) or complex (e.g., if the vehicle’s occupants are ejected). Many impaired drivers claim to be passengers. Short-lived evidence or pattern injuries that might be destroyed or altered in the delivery of patient care should optimally be preserved and photographed.94,95

An opinion on an occupant’s position should be avoided because an occupants’ role is difficult to determine based solely on the statements and physical findings in the ED.94,95 Such an opinion is best rendered by someone who has examined the scene, the vehicle, other occupants, and trace evidence; has reviewed postmortem examinations; and has had the collision reconstructed to determine vehicle dynamics (Box 65-3).94,96

Pattern Injuries

Matching pattern injuries with components within a vehicle often reveals an occupant’s position during a portion of the vehicle’s collision sequence.94,96 Common pattern contusions, abrasions, and lacerations are seen from steering wheels, air bags, air bag module covers, window cranks, radio knobs, door latches, dashboard components, and front and side window glass.94-98 An occupant’s movement and subsequent contact with a vehicle’s components are dictated by the forces applied to the vehicle through its interaction with the environment. Vehicle occupants, restrained or unrestrained, will initially move toward the primary area of impact.94 Movement within the vehicle is called occupant kinematics. Occupant movement toward the primary area of impact is described as a motion parallel and opposite to the principal direction of the force (PDOF) developed by the impacting object.94,95 The PDOF will predict the direction in which a particular occupant will move and therefore what component within the vehicle may be struck.

A deploying air bag may induce a pattern abrasion to the face, cornea, forearms, or other exposed tissue. Pattern lacerations, specific fracture patterns, and amputations are seen when the deploying air bag module cover impacts the hand or forearm (Fig. 65-30).97,98 The correlation of these injuries and the transfer of DNA from the driver or passenger to the deployed air bag are helpful in assessing an occupant’s role as driver or passenger.97,98

Laminated glass (windshields) and tempered glass (side and rear windows) produce pattern injuries. The windshield has two layers of glass laminated together with a thin layer of clear plastic sandwiched between. Laminated glass breaks into shards on impact and causes linear incised wounds. Tempered or safety glass is a single layer of glass that breaks into small cubes when fractured, imparting a “dicing” pattern to the skin (Fig. 65-31).42,94,95

Trace Evidence

Clothing, shoes, and biologic standards (hair, tissue, and blood) may determine an occupant’s role.95-99 The soles of leather shoes may reveal the imprint of the gas or brake pedal (Fig. 65-32). Preservation of clothing permits the comparison of clothing fibers with those fibers transferred to vehicle components during the collision.95-99 Imprints of fabric may also be transferred to

| Box 65-3 Evidence Collection—Driver versus Passenger |
| Victim | Examine for Pattern Injuries |
| Steering wheel contusion | Radio knob contusion |
| Window crank contusion | Striated incised facial wounds |

“Dicing” wounds

| Collect Biologic Standards |
| Hair |
| Blood |

| Collect Clothing Standards |
| Damage |

| Vehicle | Examine for Pattern Damage |
| Steering wheel | Radio, knobs, dashboard |
| Window crank, side door | Windshield (laminated glass) |
| Side and rear window (tempered glass) |

| Collect Standards |
| Glass |
| Carpets and seats |
| Gas and brake pedals |
| Broken dashboard components |

| Examine for Transferred Material of Pedestrian |
| Hair on windshield and components |
| Blood on windshield and components |

| Examine for Transferred Material on Car Occupants |
| Fabric fibers |
| Imprinted fabric pattern |

*Each article of clothing should be collected in a separate paper bag. This avoids cross-contamination, and wet material will dry. Do not collect evidence in plastic bags because moisture will condense within the bag and may degrade biologic material.

† Each article should be marked with the patient’s name, item collected, date and time collected, location of collection, name of the collector, and name of law enforcement official to whom the evidence was given. This information will preserve the “chain of custody.”

Figure 65-30. A traumatic partial amputation of the hand resulted from contact with a deploying air bag module cover.
components within the vehicle, including the steering wheel. Contact with the windshield often transfers hair and tissue to the glass. Glass collected from within a patient’s wound can be matched with a particular window within the vehicle. Airbags can be an excellent source of trace evidence. Examples of transferred evidence include skin, blood, makeup, and hair (Fig. 65-33).^

**Evaluation of Pedestrian Collisions**

**Pattern Injuries**

Approximately 59,000 people were killed or seriously injured in pedestrian collisions in 2009; 87% are struck by a vehicle’s front bumper or grill area. When struck by the front of a vehicle, a standing adult will sustain “bumper injuries,” which include open and closed fractures of the tibia and fibula, soft tissue damage, and pattern injuries from vehicle components and hardware. The height of bumper injuries, measured from the heel and including the height of the patient’s shoe, can be correlated with the height of the vehicle’s bumper to determine whether the vehicle was braking at the moment of impact. Application of the brake results in the dipping of a vehicle’s front end. The presence or absence of braking may help determine the driver’s intent. The presence of bumper injuries at one height on one leg and at another height on the other may indicate that the pedestrian was walking or running at the moment of impact, with one leg elevated. Examination of the soles may show lateral striations when a patient has been dragged.

A victim who is struck from behind may have pattern contusions on the calf or thigh (Fig. 65-34), whereas pattern contusions from a grill on the anterior aspect of the thigh indicate the pedestrian was standing and facing the vehicle. Pedestrians struck by a glancing portion of a vehicle may also display a pattern injury (Fig. 65-35). Victims who are run over may display a tire tread pattern (Fig. 65-36). Tire marks and the absence of bumper injuries suggest that the patient was supine or prone in the roadway before he or she was run over (Box 65-4).

**Law Enforcement Exemptions to the Health Insurance Portability and Accountability Act**

Title 45 Part 164 of the Health Insurance Portability and Accountability Act (HIPAA) of 1996 permits hospitals to disclose, without patient consent, to investigating law enforcement agencies specific information regarding a victim or suspect. Section 45 CFR 164.512 permits the release of protected health information, without a court order, “in response to a law enforcement official’s request for such information for the purpose of identifying or locating a suspect, fugitive, material witness, or missing person.” A hospital or physician may disclose the information listed in Box 65-5 only to an investigating law enforcement officer.
Figure 65-34. A, A pattern imprint contusion on the posterior aspect of a pedestrian’s right thigh was the result of contact with the vehicle’s grill. The location of the contusion provides information about the configuration of the patient at the moment that the car struck him. The patient was struck from the rear. B, The grill of the striking vehicle.

Figure 65-35. A, Three horizontally oriented wounds were noted on the back of a pedestrian struck by a semi–tractor trailer on a highway while changing a flat tire. B, The pattern injury was matched to the lug nuts of the front right wheel.
Evidence Collection—Pedestrian Collisions

Victim
Examine for Pattern Injuries
Height of bumper injuries
  Contusion
  Fracture
  Head and neck injuries
  Crush injuries

<table>
<thead>
<tr>
<th>Examine Clothing for Transferred Material*†</th>
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</thead>
<tbody>
<tr>
<td>Paint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass (windshield, headlight)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil or grease</td>
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</tbody>
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Collect Biologic Standards
Hair
Blood or tissue

Collect Clothing Standards
Damage or tears

Vehicle
Examine for Pattern Damage
Bumper height and damage
Specific components
Windshield damage
Wheels and undercarriage

Collect Standards
Paint
Glass
Oil or grease

Examine for Transferred Material of Pedestrian
Hair
Blood or tissue

Examine for Transferred Material on Vehicle
Fabric fibers
Imprinted fabric pattern

Law Enforcement Exemptions to the Health Insurance Portability and Accountability Act (HIPAA): 45 CFR 164.152

- Name and address
- Date and place of birth
- Social security number
- ABO blood type and Rh factor
- Type of injury
- Date and time of treatment
- Date and time of death, if applicable
- A description of distinguishing physical characteristics, including height, weight, gender, race, hair and eye color, presence or absence of facial hair (beard or moustache), scars, and tattoos

KEY CONCEPTS

- Knowledge of wound mechanics and production, as well as wound appearance, can provide practicing emergency physicians with important clues regarding the forensic interpretations of injuries.
- Wounds and injuries should be diagrammed and photographed.
- The medical record should accurately document objective findings associated with a patient's wounds. Physicians should not speculate about their mechanism or the cause.
- Any evidence collected during the course of treatment must be documented in the medical record, including to whom the evidence was given, for the chain of custody to be preserved.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.

*Each article of clothing should be collected in a separate paper bag. This avoids cross-contamination, and wet material will dry. Do not collect evidence in plastic bags because moisture will condense within the bag and may degrade biologic material.

†Each article should be marked with the patient's name, item collected, date and time collected, location of collection, name of the collector, and name of law enforcement official to whom the evidence was given. This information will preserve the “chain of custody.”

Figure 65-36. Tire tread imprints on the skin indicate this victim of a hit and run collision was on the ground when he was hit.
References

30. Randall T: Clinicians’ forensic interpretations of fatal gunshot wounds often miss the mark. JAMA 1993; 269:2058.
47. Lindsey D: The idolatry of velocity, or lies, damn lies, and ballistics. J Trauma 1980; 20:1068.
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