# INJURY, FATAL AND NONFATAL

Contents



## Documentation

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### Introduction

The need for medical practitioners to keep objective factual records of consultations and contact with individuals whom they see in the course of professional work is a principle that is generally accepted in most jurisdictions. The need for such records becomes much more apparent in issues where medicine may be interrelated with various legal processes – of which criminal matters and medical negligence are key examples. In both cases the medical practitioner's records will be scrutinized by a number of lay persons and medical and legal professionals, and failure to have kept appropriate records can lead to criticism of a practitioner's competence, or fitness to practice. It is therefore in the interest of every medical professional to take great care in the contemporaneous documenting and recording of notes. It is not just in the interest of the forensic medical professional. This article focuses on appropriate documentation of injuries in the living injured person, although the broad principles apply to the deceased and have been covered in other articles.

### Need for Documentation of Injuries

Documentation of injuries presenting to medical practitioners in the community or in hospital is generally poor. In many cases documentation is appropriate for the therapeutic management of the injured person, but is rarely of the quality required subsequently to assist in issues such as causation or timing of an injury. Such issues may still be difficult to determine even where documentation has been good, but it is in the interests of the injured person, those alleged to have caused the injury, and justice in general to ensure that as much information as possible is available. The purpose of assessment and documentation of injury is, as far as possible, to define the type of injury caused, to assist in establishing how such a wound or injury was caused, and to determine how consistent the varying accounts of causation are with those that may have been given. Terms such as injury, assault, and wound may have specific applications dependent on jurisdiction, and it may not be for the medical practitioner to assign those definitions within a case, but merely to assist the court in making the determination. For example, in England and Wales the term "wound" has specific meaning relating to whether the skin or mucosa is completely breached. This article will use the term "injury" in the following sense: "damage to any part of the body due to the deliberate or accidental application of mechanical or other traumatic agent." All forensic practitioners should be aware of the definitions in the jurisdiction in which they work. It is appropriate for those documenting injuries to ensure that they have documented the account of causation, and the nature of the injury, accurately in detail and unambiguously so that the courts or other bodies interpreting the findings can make the decision as to the most appropriate judicial interpretation of the injury or injuries described and their specific relevance to the case in question. The examination may be of victims, of perpetrators, or those where cross-allegations and the early stage of the investigation may make it unclear who is the aggrieved individual. Therefore, it is of the absolute essence that any documentation reinforces the principles of independence and fairness, so that courts or other legal bodies can make judgments based on the best possible factual information.

### Examination and Documentation of Injury

Examination and documentation of injury and its interpretation follow broad general medical principles. It is dependent on establishing a good history of how injury occurred (from the injured person or others if not possible or if they can add to the history), a more general medical history exploring other matters that may affect the nature or interpretation of the injury and undertaking a physical examination appropriate to the injury and documenting the findings clearly and unambiguously. An examination should always be done with the best possible lighting conditions available, and if necessary moving the person being examined to better light or bringing additional light sources in. A hand magnification lens may be useful to look at details such as wound edges and patterns, and to establish the direction of force in scratches and skin lifts. It must always be borne in mind by the examining doctor that each interpretation and each set of notes and records may subsequently be reviewed by other medical professionals, legal advisers, and interested parties, and the courts or other legal bodies. Consent for the assessment including for the taking of the history, the examination, the taking of samples, and for subsequent production of a medical report should be sought from the individual being examined, with a clear explanation made as to the possible extent of circulation of any reports or notes. An individual may give a limited consent to certain aspects of such consent, and if so its limitations and potential problems must be explained to the examinee and documented in the notes. It should also be borne in mind that vexatious or frivolous accusations of assault can be made, and examiners should place themselves in the best position to establish the veracity of any accounts, as false allegations and counterallegations frequently occur, by ensuring the completeness of the assessment.

## Specific Factors

A number of factors can be relevant when assessing injury in the living person (Table 1) and all should be considered when a history is taken. It is important to reinforce that it may also be very important to document relevant negatives in certain cases, for example the absence of preexisting skin disorder, or the absence of bleeding diatheses.

Not each of the factors in Table 1 will be applicable or relevant for every individual. A general health background is as important to establish as preexisting illnesses and this may include the use of regular prescribed medication (e.g., steroids, anticoagulants) or intermittent or pharmacy-bought preparations (e.g., aspirin) which may cause systemic effects that may alter or change the appearance of an injury. Misinterpretation of disease processes for injury is not uncommon and can sometimes result in inappropriate criminal charges. Figures 1 and 2 show two examples where a more detailed history and assessment may have prevented the misdiagnosis. Figure 1 illustrates a patchy psoriasis by the elbow which was interpreted as a series of abrasions by a junior doctor and Figure 2 shows a 2-day-old burn (which had been deliberately inflicted due to unpaid debt) in which the primary care physician accepted the account of a fall to concrete causing abrasion 2 h earlier.

Participation in certain contact sports may result in the presence of injury unrelated to any alleged assault. It is very important to document for each injury the time or dates at which the injury was said to have occurred. Most injuries heal and thus the appearance of an injury following assault is time-dependent. In

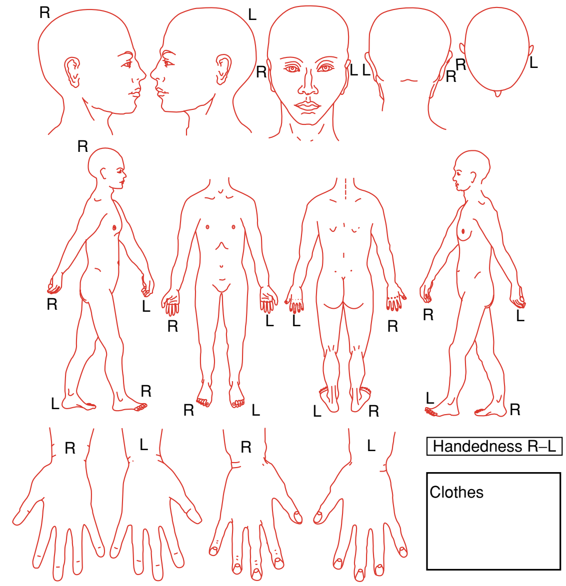
**Table 1** Some factors that may be relevant from a history

| *Factor* | *Additional comments* |
|---|---|
| Time of injury or injuries | With multiple injuries, ensure that accounts of timings and causation are relevant for each |
| Has the injury been treated? | If so, how, when, and where? Be aware that there may be a different history given which may conflict with the one obtained at this examination |
| Preexisting illness | Particularly those that can mimic or be misinterpreted as injury |
| Regular physical activity | Particularly issues such as contact sports where injury unrelated to any allegation of assault is common |
| Employment | Is the employment likely to result in injury, even of a minor nature (e.g., burns to hands of a chef)? |
| Regular medication | Any prescribed or nonprescribed medication which may predispose to worsening appearance of an injury, e.g., anticoagulants, steroids. Establish how well the treatment regimen is complied with. Antiepilepsy medication may indicate fits which themselves may result in sites of injury |
| Handedness of victim and suspect | May be relevant when comparing accounts of how a particular injury was sustained |
| Use of drugs and/or alcohol | Acute or chronic drug or alcohol intoxication may affect injury assessment in a number of ways, including: (1) memory for incident; (2) misinterpretation of factors related to drug use, e.g., intravenous sites, being interpreted as an assault injury. Chronic alcoholics commonly have multiple different ages of bruises and scars related to accidental injury whilst intoxicated |
| Type of weapon or implement used | Knowledge of type of implement may allow matching up of particular patterns of assault, e.g., imprint bruises |
| Clothing worn | Clothing might have affected result of assault: many layers may reduce effect. Occasionally may have account of clothing and mechanism of injury that are not consistent, e.g., stab wound through clothing with no disruption or cut in fabric |

**Figure 1** Patchy psoriasis on elbow – the emergency physician interpreted these lesions as abrasions. Reproduced with permission from J Payne-James, ''Assault and Injury in the Living'', from Jason Payne-James, Anthony Busuttil, William Smock, *Forensic Medicine: Clinical and Pathological Aspects*, 2003. Greenwich Medical Media, now published by Cambridge University Press.

**Figure 2** A 2-day-old burn to the arm, passed off and accepted as a 2-h-old graze. Reproduced with permission from J Payne-James, ''Assault and Injury in the Living'', from Jason Payne-James, Anthony Busuttil, William Smock, *Forensic Medicine: Clinical and Pathological Aspects*, 2003. Greenwich Medical Media, now published by Cambridge University Press.

many cases assaults may be reported days or weeks afterwards. There may be a number of injuries from different incidents. The same principles apply to injuries that may be sustained as a result of the individual's type of employment. Specific times should be sought for each. Similarly, the type of assault (e.g., baseball bat, kicks, fists, knives, scissors) must be documented, and if more than one type of assault has occurred clear records must be made of which injury was accounted for by which implement. Document the handedness (left- or right-, or both) of both victim and assailant if known, as this may affect the interpretation of injury causation. The size (weight and height) of victim or assailant may have relevance and if this information is available it




No other injuries observed or complained of ☐ Time of injury ☐ Time of photographs ☐

Samples taken:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| .../1– | at | h | .../4– | at | h | .../7– | at | h |
| .../2– | at | h | .../5– | at | h | .../8– | at | h |
| .../3– | at | h | .../6– | at | h | .../9– | at | h |

Additional samples:..........................................................................................

Given to..................................at...................h

I consent* to a full examination and/or taking of samples and/or taking of photographs for educational purposes including publication in scientific & medical journals, books and all other media including electronic and am aware that formal reports/statements may be prepared from these notes for police, court and other purposes, and I consent to such reports/statements being made: *** delete as appropriate**

Name ..................................... Witness *(name and signature)*
Signed ................................... ..........................................................

**Figure 3** Example of a recording system for injuries and taking of samples.

should be documented. It is often the case that widely diverging accounts are given by different witnesses – it is the forensic physician's role to assist the court in determining the true account. These differing accounts may also be influenced by the effect of drugs and/or alcohol and it is appropriate to assess the influence that these may have in each case. An assessment of the state of intoxication (or lack of) at the time of examination is important and this should also be related to what the likely state was at the time injury was sustained. Knowledge of the type of weapon used can be very important when assessing injury: particular implements (e.g., batons, serrated-edged knives) give characteristic identifiable injuries. The type of clothing worn (e.g., long-sleeved shirts, armless vests) should be noted. It is not unusual for individuals to make claims about how an injury (e.g., knife wound, bite) occurred despite the presence of clothing which would have precluded that particular mechanism of injury. When examining any individual for injury all these features should at least be considered to see whether they may have relevance

**Table 2** Possible characteristics which may be relevant for each injury (optional and dependent on history)

| *Characteristic* | *Additional comments* |
|---|---|
| Location | The site of an injury may have relevance with regard to whether it is feasible for such an injury to have been created in the way alleged. If there are a number of injuries, then documentation of the precise site can be assisted by precise anatomical distance measurement from fixed anatomical landmarks (e.g., olecranon or greater trochanter). Does it overlie significant anatomical landmarks? |
| Pain | The site of pain should be documented, as this may subsequently be the only documented evidence of injury |
| Tenderness | Similarly, the location and size of the area of tenderness (determined by manual palpation and inquiry of the injured person) may be the only documented evidence of injury |
| Limitation of range of movement | Which joints are involved? How much is the limitation? Is there a possibility of fracture? |
| Type | What type of injuries are represented, e.g., bruise, laceration, incised wound, fracture? When examining, consider what alternative mechanisms may account for what is seen, and whether the account given is itself consistent |
| Size | Use uniform systems of measurement, preferably metric. Estimates are not appropriate or accurate – always use a ruler. Accurate measurements may become important, for example, when attempting to establish the size of a weapon, e.g., knife, used in an assault |
| Shape | Describe or draw as clearly as possible the shape. Does it have any patterning characteristics? |
| Surface | Is there a palpable swelling or deformity, or other abnormal feature? |
| Color | Important to describe but be aware of substantial inter- and intraobserved variation. Where possible, if color may be significant, e.g., in certain aspects of bruise aging, get photographs with color bars |
| Orientation | May be significant in terms of causation |
| Age | Note the age of the injury as indicated by the individual. Is it consistent with the account given? If not, ask for clarification and document account given |
| Causation | Do the accounts of injury vary? If so, which ones seem consistent and which ones don't? |
| Handedness | Is the person right- or left-handed, or ambidextrous? |
| Time | Note the time for which each injury is said to occur. Is it consistent? If not, seek clarification |
| Transientness (of injury) | The appearance of injury, particularly reddening or bruising after blunt impact, can be subject to quite marked change, even after a few hours, in the living. Do the accounts and the appearance appear consistent at the time of examination? Is there any need to suggest further reassessment of additional documentation such as photography or video? |

to the case; others may become relevant as the examination progresses or as other accounts of any assault are given.

Documentation of injuries can be in a variety of formats, including hand-drawn notes, annotated pro forma diagrams, photographic, and video. Figure 3 illustrates one form of body chart and note system. However, more detailed body charts may be required where multiple or complex injuries are apparent.

Table 2 lists some of the key characteristics that may be needed to document each injury appropriately.

Digital and print-on-paper photographic images are an acceptable means of documenting injury in some jurisdictions but in each case the image evidence should be supported by contemporaneous written and hand-drawn notes. Storage and chain of custody of such images can represent problems in terms of admissibility of evidence and disclosure of images. If photographs are being taken by a photographer ensure that he/she is aware what is to be photographed and to include color charts and rules in each photograph. It is best to form an opinion at the time of examination as to whether injury or injuries are new or old, and whether they have specific characteristics of particular types of injury (e.g., self-inflicted, defense-type). Ensure at the time of examination that each injury is accounted for by the account given. If an injury appears not to be consistent with the account given, question it at the time. In many cases individuals who have been involved in fights or violent incidents are simply unaware of the causation of many sites of injury. It is often appropriate (particularly with blunt injury) to reexamine injuries 24–48 h later to see how injuries evolve and whether bruises have appeared or other sites of injury noted. Pre- and posttreatment examination and photography may be very useful. Those injured should always be advised to document any visible or symptomatic evidence of injury that later becomes apparent.

## Other Issues for Nonforensic Healthcare Professionals

Anyone assessing injury in the living also has a duty to ensure that appropriate treatment has been undertaken or further investigations of management advised. It is helpful when referring an injured person to another professional for further review to advise on the nature of findings and the account that the person has given for the injuries obtained.

In a number of cases of the more seriously injured, the individual may pass straight to specialists – e.g., emergency medicine, surgeons, or intensivists – for life-saving treatment. Colleagues outside the forensic setting should be aware that even on the operating table or in the resuscitation room, attention should be paid to documenting the injury – once stability of health status has been achieved, this early documentation of injury is more likely to be useful in later legal proceedings. In particular, the size, shape, and form of stab or other cutting injuries are useful if documented before exploration and suture or repair. Additionally, the apparent depth of penetration of an injury is also an issue that frequently arises in assault cases and can be assisted by good medical documentation. A photograph of a healed wound several weeks after the assault combined with medical notes that simply report "stab to abdomen" and an operation note that simply reports "stab wound to abdomen explored at laparotomy" may be the only evidence on which to try and interpret depth of penetration and causation – an impossible task. The presence or absence of other materials, e.g., from firearms, or materials carried into a wound, should be documented. It would be good practice for all such departments, which may see victims of assault and other violent crime, to have standard protocols for the secure documentation of injury appearance and collection of potentially forensically relevant material. In some jurisdictions, forensic medical specialists can make themselves available to document injury and supervise evidence collection, whilst those primarily responsible for the medical care can focus on the treatment of the individual.

## Conclusion

The appropriate documentation of injury is crucial in order to assist courts with consistency of accounts and causation. Generally such documentation is poorly done. Proper attention using the general medical principles of history-taking and examination applied to the documentation of injuries, taking into account the particular aspects of general health and injury, will allow appropriate assessment and interpretation of injuries sustained by individuals, and therefore assist the legal and forensic process for which it is undertaken. Those not directly involved in forensic medicine may find it of use to seek forensic advice at an early stage when treating or investigating those involved in assaults or violence causing injury.

## See Also

**Injury, Fatal and Nonfatal:** Blunt Injury; Burns and Scalds; Explosive Injury; Firearm Injuries; Sharp and Cutting-Edge Wounds

## Further Reading

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# Blunt Injury

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## Introduction

Blunt impact to the human body is arguably the most common type of injury sustained by humans – all of us regularly incur bumps and bruises in our activities of daily life. Blunt-force injury also represents a common cause of serious injury and death. Motor vehicle collisions are one of the leading causes of death in all countries, whether industrialized or nonindustrialized. Additionally, many severe injuries occurring in accidental or assaultive situations at home or work are blunt-force injuries. These have a high cost to society, as they often result in loss of productivity or life.

Often, small injuries may have extreme forensic importance. Many times such injuries are so minor or superficial that they are completely overlooked or ignored by medical caregivers, who are interested in injuries requiring treatment and medical intervention. But it is often these same injuries that show patterns or configurations that can help elucidate the factors involved in the traumatic incident. Such injuries may allow the examiner to interpret many factors surrounding their production, such as the instrument involved, the direction and duration of impact, and the minimum number of impacts. A clear understanding of blunt-force injuries and their formation allows the medical professional to understand better and interpret the forces and events that cause them.

## Anatomic Regionalization

Various anatomic regions of the body possess unique compositions and characteristics that affect the injury patterns resulting from the application of blunt force. Whenever injury patterns are assessed, the examiner must consider the substrate – the nature and composition of the tissue involved in the impact. Skin trapped between underlying bony prominences and impacting surfaces may display injuries such as abrasions, contusions, and even lacerations, as the skin and intervening soft tissue are crushed between the impacting object and the underlying rigid skeleton. These injuries may appear very different from cutaneous injuries in other areas of the body in which there is abundant subcutaneous tissue, or no immediately underlying bone.

The head is arguably a unique region, as the relatively soft gelatinous brain is encased in a tough fibrous protective layer (the dura mater), which in turn is encased within the rigid bony skull. The skull is then covered by a relatively small amount of soft tissue with a rich vascular supply (the scalp). Added to this is the unique anatomic location of the head, able to move and rotate in many directions, atop the neck. Because of these physical properties, the head and its intracranial contents manifest different reactions to the application of blunt force, and therefore are considered elsewhere in this encyclopedia.

The torso of the human body, composed of skin and soft tissue external to a discontinuous axial skeleton which protects and supports the visceral organs, may suffered marked, even lethal internal injuries while the external skin surface appears relatively pristine. This may occur due to the pliability of the external soft tissues, such that forces are transmitted through the more superficial tissues to damage the deeper vital organs. Blunt forces impacting the torso will cause varied injury responses, depending on many factors, including, but not necessarily limited to, the angle of force, the angle of impact in relationship to the anatomic configuration (longitudinal loading versus side impact), and the composition of the body at the impact site. For example, impacts identical in duration, amount of force, and direction may create different injury patterns depending on whether the impact occurs on the skin overlying the vertebral column and/or ribs, or the midportion of the anterior abdomen, with its insulating adipose tissue and lack of rigid bony structures. In injuries over the bony prominences of the torso, cutaneous abrasions, lacerations, and contusions, with or without underlying osseous fractures, are likely resulting injuries. In contrast, blunt impacts to the soft pliable abdominal wall may result in serious injury to vital organs with relatively little external evidence of injury (Figures 1 and 2).

Blunt forces acting upon the extremities will cause varied injury responses as well, depending on the

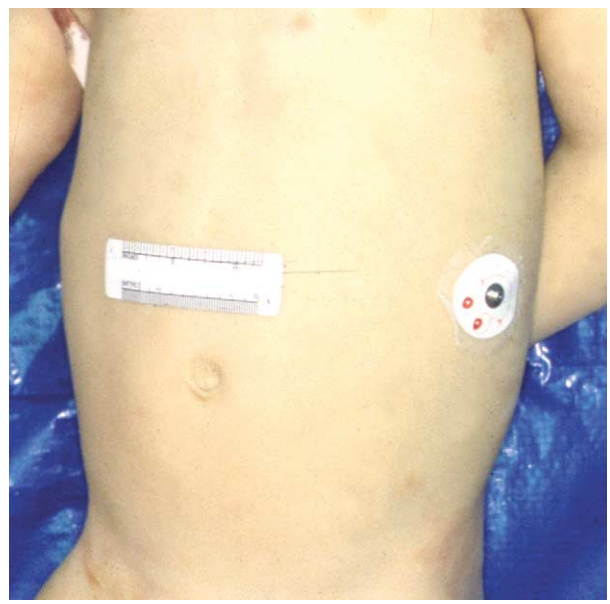

**Figure 1** External skin surface of a child dying of blunt abdominal trauma. Note the absence of significant injury on skin surface of the abdomen.

**Figure 2** Internal findings of the child depicted in Figure 1. Massive hepatic lacerations resulting in complete transection caused by blunt-force injury.

many factors elucidated above. Again, the composition of the tissue at the impact site affects the appearance of the wound pattern as much as the type, force, and duration of impact. The same type and force of blunt impact may create different injury patterns depending on whether the impact occurs on the skin overlying the lateral malleolus of the ankle (with relatively little in the way of soft tissue between the skin surface and the bony protuberance), or the upper one-third of the thigh, with its more abundant adipose tissue and heavy musculature encasing the shaft of the femur.

In this article, the injuries will be artificially separated into various types. First, injuries to the skin and soft tissues will be considered, followed by osseous injuries, and last by blunt-impact injuries to internal viscera. In reality, a single impact may cause injury to all three structure types within a given anatomic location. Additionally, the reader is urged to refer to other articles dealing specifically with blunt impacts to various anatomic locations for more detailed accounts of the effects of such trauma to the internal viscera.

## Blunt Injuries to the Skin and Subcutaneous Tissues

Blunt-force injuries to the skin and subcutaneous tissues usually fall into one of three broad categories: (1) abrasion; (2) laceration; and (3) contusion.

An abrasion is often the most superficial and minor of these three injury types. It commonly happens as an impacting object moves over the skin surface with an angle of impact of less than 90° (Figure 3). A scraped or skinned knee on a child sustained in a bicycle mishap is an example of a superficial abrasion. Often the abrasions are located over bony prominences. More often than not, the pattern and shape are nonspecific. In fact, the pattern and shape may be more reflective of the underlying anatomic structures than the actual impacting object (Figure 4). Even so, there are indeed instances in which it is possible to determine information regarding the causation. An abrasion may demonstrate an impact "rolled edge" of skin along one side of the abrasion, allowing the examiner to determine the direction of force, or the injury itself may display a pattern or periodicity reflective of the impacting object (Figure 5).

A laceration occurs when the skin tears open in response to a blunt impact. Various areas of the body, such as those in close proximity to underlying bone, may be more likely to lacerate in response to an impact. Classically, lacerations exhibit two characteristics that allow differentiation from sharp-force injuries: (1) wound margin abrasions; and (2) wound bed tissue bridges.


**Figure 3** Healing superficial abrasion.

**Figure 4** Superficial abrasion over bony prominence. The injury configuration is dictated by the contour and composition of the body (rounded osseous tissue immediately deep to cutaneous surface) rather than by the impacting object.

First, the wound margins of a laceration often display abrasions which were formed at the time of impact, as the tissues are crushed by the impacting object (Figure 6). Second, the wound bed displays tissue bridges. The subcutaneous tissues have many different types of tissue of varying strengths and angles of orientation in relation to the angle of impact. Therefore, some tissues may tear while others remain intact. This creates varying amounts of "bridging" of tissues within the wound bed itself (Figure 7).

**Figure 5** Pattern abrasions and contusions mirroring the basic shape of the impacting object. The victim in this case was beaten with a crutch – the pattern mirrors a surface of the impacting instrument.

**Figure 6** Lacerations with abrasions along the wound margins.

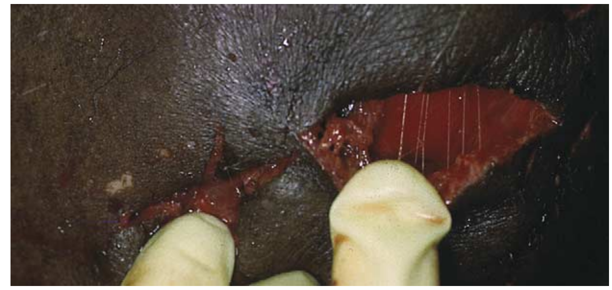

**Figure 7** Laceration with tissue bridging of the wound bed.

**Figure 8** Pattern contusion ''outlining'' the impacting object. The impacting object in this case was a hand.

A contusion may be defined as an area of bleeding beneath the intact skin at the site of impact. It is commonly referred to as a bruise. Contusions are usually nonspecific in shape. At times, however, pattern contusions may be present. A pattern contusion may be defined as a contusion in which the size and shape mirror a portion of the object which created it, a contour of the body, or a combination thereof.

A rapid impact with a relatively lightweight object may create a contusion in the shape of the outline of the object. Cylindrical objects will thus create patterns consisting of two parallel linear contusions with central sparing. This occurs because the tissues that are deformed and damaged the most are those along the edges of the object (Figure 8). With heavier impacts or objects, the tissues beneath the impacting object are crushed as well, and the contusion pattern is solid rather than outlined (Figure 9).

The terms contusion, ecchymosis, and hematoma should not be used interchangeably, but when used must be used with an understanding of each term. As stated earlier, a cutaneous contusion is bleeding beneath the intact skin at the site of impact. In contrast, an ecchymosis represents a collection of blood that has dissected through fascial planes from one site to another. An ecchymosis may be associated with blunt trauma, or it may be associated with other forms of injury. The source of blood in ecchymosis often involves an osseous fracture. Blood dissects from the site of origin through fascial planes to a subcutaneous location where it is observed as an area of discoloration. Perhaps the most common ecchymosis observed in forensic pathology is the periorbital ecchymosis associated with a fracture of

**Figure 9** Pattern contusion caused by impact with a large wooden instrument with intervening clothing. The tissue underlying the impacting object was crushed, and therefore the injury appears as a solid pattern.


**Figure 10** Periorbital ecchymosis associated with a gunshot wound.

the anterior fossa (orbital plate) of the base of the skull (Figure 10). This is often seen in conjunction with contact gunshot wounds of the head. Other commonly encountered ecchymoses include discoloration over the mastoid process in association with the basilar skull fracture, and discoloration over the flank in association with a pelvic fracture. Hematoma is an additional term that should be differentiated from the term contusion. The term hematoma simply refers to a collection of extravasated blood either within the tissue parenchyma or within a potential space. Examples include subcapsular hematomas of the liver, and intracranial subdural hematomas. Hematomas may occur in the absence of impact, and must be interpreted in the context of the individual case. The mere presence of a hematoma in a given case does not allow the examiner to conclude automatically that blunt impact has occurred.

## Osseous Injuries

A fracture may be defined as an interruption in the structure of a bone. There are various types of fractures, as described in more detail in other articles in this encyclopedia. Regarding fractures associated with blunt trauma, a bone will usually fracture at leverage point, as this represents the point of maximum tension. Assessment of the distribution and nature of fractures may help to elucidate the causative events. Precise determination of fracture location may be important in cases such as pedestrian injuries and assessment of driver versus passenger in motor vehicle collisions. In the living patient, fractures may be documented by radiographic methods. In the deceased patient, fractures may be documented through radiographs and/or autopsy examination. Some fractures occur as a result of direct blunt impact, while others occur for a variety of reasons and in a variety of biomechanical scenarios. It should not be assumed that the presence of a fracture necessarily indicates blunt-force trauma at the fracture site.

## Visceral Blunt Injuries

Blunt forces applied to the torso may result in injuries to the visceral organs. As stated previously, the head represents a unique structure and is considered elsewhere. Blunt-force injuries to the visceral organs of the thorax and abdomen may include contusions or lacerations of the organ itself, or avulsion of the organ from its pedicle or supporting structures. Mortality and morbidity of blunt traumatic injuries depend on many factors, including the organs involved, the degree of trauma, and access to medical treatment. The degree of injury evident on the external skin cannot be used to assess the degree of damage to the internal organs. This is particularly true in injuries to the abdomen where it is not uncommon to find severe – even fatal – internal injuries while the external skin surface appears atraumatic.

Visceral blunt trauma associated with death often involves lacerations of either the heart or the liver. In lacerations of the heart, if the pericardial sac remains intact, then a hemopericardium with cardiac tamponade may result in death within minutes. Depending on the nature of the trauma, this injury may be solely causative or may be found with other lesser, but contributing injuries, such as pulmonary contusions and/or lacerations arising from motor vehicle collisions.

Compared to other visceral organs, the liver is relatively friable, has little elastic tissue, and is very vascular. While clinicians may rate lacerations on a numeric scale to describe severity, forensic pathologists usually assess the anatomic location and general size of the traumatic lesion. Large complex hepatic lacerations may cause internal exsanguination within relatively short order (minutes).

Blunt traumatic injuries of other solid visceral organs may, on some occasions, be the sole cause of death, but are more commonly seen as contributing factors in multiple blunt traumatic injuries. These organs may include the spleen, the pancreas, the lungs, and the kidneys. When the latter two are involved as the sole cause of death, the injury pattern often involves disruption of the large vessels supporting these organs.

## Dating of Injuries

Forensic physicians are frequently asked by investigators to assess the age of a blunt-force injury. The injury in question may be any of the four main types previously discussed (abrasion, laceration, contusion, or fracture). Commonly, a forensic physician will be asked to assess the age of cutaneous contusions. Various medical texts display charts on the dating of contusions based on color. It is strongly advised that such charts be used only as a very rough guide, as many factors affect contusion color and the evolution thereof. Factors affecting contusion colors include: (1) depth of bleeding; (2) amount of bleeding; (3) environmental lighting; and (4) overlying skin color.

Experimental animal studies have confirmed the variability of the evolution of color and contusions. Indeed, in one prospective study involving sheep, only one consistent statement could be made regarding injury duration and color change: contusions displaying yellow color had been present for at least 18 h. In deceased individuals, tissue samples submitted for microscopy may assist in age estimation based upon the breakdown of red blood cells and the succession of inflammatory cells responding to an injury site. Recent research has involved investigation of various immunohistochemical markers in an attempt to narrow the time window further; however, no specific marker has emerged to date. Even with microscopy, individual variation exists. In summary, dating of injuries in general, and contusions in particular, remains an imprecise science. Although general comments and subjective terms may be of use, precise timing of injury duration is not possible with our current state of knowledge.

## Summary

With the "bumps and scrapes" of everyday life, blunt injuries are undoubtedly the most common type of trauma sustained by humans. More severe blunt traumatic injuries are significant causes of morbidity and mortality, resulting in substantial loss of both productivity and life.

Blunt trauma should be assessed in several ways. Individual injuries are examined regarding size, shape, and color. The anatomic location of the injury is noted. Patterns are assessed for consistency with external objects and/or body contours. The injury is examined in relation to, and in the context of, the overall injury pattern. Historical information of the causative event is then compared to the injury for assessment of consistency with the size, shape, severity, and distribution of the injury pattern. Documentation of specific information regarding blunt injuries allows reassessment at later times and/or independent assessment by other parties. This documentation may include reports, diagrams, and photographs.

Written documentation of blunt injuries includes a description of injuries' size, shape, color, pattern, and anatomic location. Preparation of a "wound diagram" consists of noting the location of injuries or other notable external findings on a standard diagram of the human form or a particular anatomic region.

Photographic documentation provides a permanent representation of the injury in question. Ideally, photographic documentation includes distant images and close-ups. Distant images document the injury in relation to the body as a whole, and also in relation to other injuries. Close photographs allow documentation of injury pattern details. Photos are obtained in a plane of focus perpendicular to the injury. A measurement scale in the plane of injury allows both assessment of injury size and the potential to develop computer-generated comparisons of possible causative instruments at a later date.

In certain cases, it is often the small blunt injuries to the external surface that provide more information to the forensic investigator than the larger, lethal internal injuries. Such small subtle injuries may help elucidate the events leading to, or involved in, the death. Proper appreciation of the importance of such injuries improves the quality of forensic investigations. Adequate documentation of a pattern injury allows the injury to "speak for itself" when the examiner is called upon to defend his/her conclusions and opinions.

## See Also

**Children:** Physical Abuse; **Computer Crime and Digital Evidence**; **Deaths:** Trauma, Head and Spine; Trauma, Thorax; Trauma, Abdominal Cavity; Trauma, Musculo-skeletal System; Trauma, Vascular System;

**Imaging:** Photography; **Injury, Fatal and Nonfatal:** Firearm Injuries; Sharp and Cutting-Edge Wounds; **Injury, Transportation:** Motor Vehicle

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# Burns and Scalds

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## Introduction

Burns are a commonly encountered forensic problem. Even though the majority of cases presenting with burns are accidental, the forensic practitioner is often required to rule out abuse. A body pulled from a fire may not necessarily have died from burns or smoke inhalation. The fire may be used to destroy evidence and deter identification. Postmortem burns have to be differentiated from those caused before death. Artifacts caused by burns have to be recognized.

Burns are defined as tissue reaction to injury due to heat, chemicals, or radiation. It causes disruption of the metabolic processes of cells that ultimately ends in tissue death. The main cellular manifestation is coagulation necrosis.

This article describes clinical classification, type of burns encountered, causation of burns, and the medicolegal aspects.

## Classification of Burns

Burns may vary from simple erythema (e.g., sunburn) to soft-tissue burns to deep charring. In clinical practice, burns are classified according to the depth: superficial, partial-thickness, and full-thickness. In another classification, the depth is categorized as first-, second-, and third-degree burns (**Table 1**).

The mildest skin damage is simple erythema. The most common cause is sunburn. It involves only the epidermis and manifests clinically as erythema and pain. Mild blistering may occur and, in most instances, there will be peeling of the damaged skin after a few days and healing without any scarring.

In partial-thickness burns, the epidermis is destroyed together with part of the dermis. Partial-thickness burns are further divided into superficial or deep. There is usually preservation of the appendages of the skin in a superficial partial-thickness burn. Pain sensation is preserved. Blisters may occur. The wound usually heals without scarring. A deep partial-thickness burn is also known as a deep dermal burn. Most appendages are destroyed. The clinical appearance is not unlike full-thickness burns with little or no pain. Scarring will occur if left to heal naturally.

In full-thickness burns, the entire layers of epidermis and dermis are destroyed. There is destruction of blood vessels and nerve endings, rendering the area avascular and painless. The clinical appearance is white or leathery brown due to blood vessel damage. Healing occurs through epithelialization from the edges, and will produce scarring unless skin grafting is performed.

In most cases, patients will present with burns of different depth in different regions of the body, often next to each other. Clinically it may be difficult to diagnose the depth accurately. It may become clearer after a few days and a repeat examination may be needed for accurate assessment. Doppler or thermographic imaging has been used to assess the depth of burns but does not seem any better than clinical assessment.

An important clinical assessment is to estimate the extent of burns on the body surface. The surface area involved has a direct effect on the morbidity and mortality. The assessment can be made roughly by using the rule of nines. This is where various body parts are given certain percentages of total body surface (9% for head and each upper limb, 18% for each lower limb, front and back of trunk) (**Figure 1**). A more accurate assessment can be made by using the Lund and Browder chart, which is available in most hospitals.

In addition to body surfaces, inhalation injuries and burns in the gastrointestinal tract can occur. The proportion of inhalation injuries in burn victims is known to be quite high and found in about 20% of admissions to burn centers. Dry heat does not penetrate easily and is limited to the oropharynx and upper airway. On the other hand, steam penetrates further (4000 times better) and thermal injury may be seen beyond the larynx. Apart from heat, chemicals in smoke may cause bronchospasm and mucous

**Table 1** Classification and brief clinical presentation of burns

| *Classification* | *Depth and appearance* | *Clinical* | *Healing* |
|---|---|---|---|
| Superficial | Epidermis only. Dilation of vessels | Erythema, mild discomfort | Skin peeling within 5–10 days without scarring |
| Partial-thickness: Superficial (first-degree) | Epidermis with part of dermis. Skin appendages preserved | Erythema with blisters formation. Painful | Heal within 10–14 days without scarring |
| Deep (second-degree) | Entire epidermis with part of dermis. Most skin appendages destroyed | Usually no blisters. May or not have pain sensation | Heal slowly (months) with dense scarring |
| Full-thickness (third-degree) | Entire epidermis and dermis. All skin appendages including blood vessels destroyed | White to brown leathery appearance. No pain sensation. May have charring or carbonization | Heal slowly (months) with dense scarring |

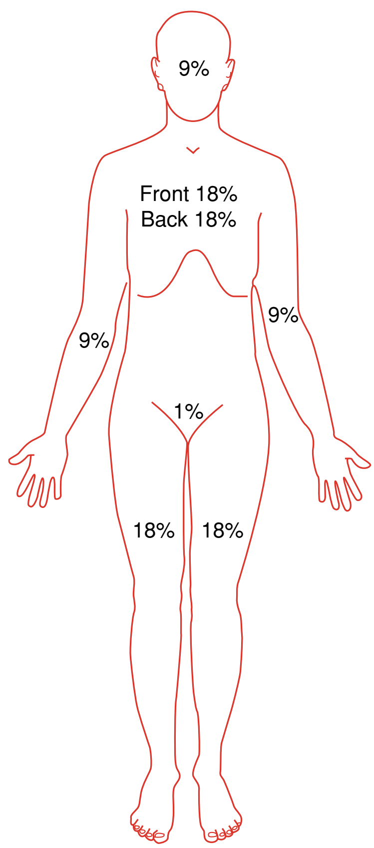


**Figure 1** Rules of nines for estimating extent of surface burns.

membrane ulceration, including damage to the cilia and edema.

Gastrointestinal burns may occur when hot food or liquids are ingested. They may occur accidentally, in the setting of abuse, or in suicidal attempts such as ingestion of corrosive and caustic chemicals.

## Mechanism of Injury

Thermal injury occurs when energy is transferred from a heat source to the body, causing an increase in the temperature of local tissue. When tissue temperature rises above a certain threshold, irreversible cellular injury will occur, with interruption of metabolic processes. Experiments by Moritz and Henriques, as far back as 1947, revealed that burns will not occur if the temperature is below 44 °C. Once heat applied is 44 °C or above, tissue injury will occur, although it requires at least 6 h. Above 44 °C but below 51 °C at the skin surface, the rate of thermal injury doubles with each degree increase in temperature. Temperature above 51 °C will cause almost immediate destruction of the epidermis. Above 70 °C, full-thickness tissue destruction occurs in seconds. An estimation of thermal injury according to time and temperature is given in Table 2.

**Table 2** Summary of contact time with temperature in causing partial-thickness burns[a]

| | | | | | |
|---|---|---|---|---|---|
| Temperature (°C) | 45 | 50 | 55 | 60 | 65 |
| Time taken | 3 h | 4 min | 30 s | 5 s | 1 s |

[a]Data modified from: Moritz AR, Henriques FC (1947) Studies of thermal injury. II. The relative importance of time and surface temperature in the causation of cutaneous burns. *American Journal of Pathology* 23: 695–720; Department of Health and Social Security (1977) Safe temperature for heated surfaces and hot water. Quoted in: Hobbs CJ, Hanks HGI, Wynne JM (1999) *Child Abuse and Neglect. A Clinician's Handbook,* 2nd edn, Chapter 5. London: Churchill Livingstone.

Using this table and charts in similar studies, a deduction of the severity of burns can be made. However, due to limitation of the experiment (e.g., based on certain parts of the body and exposure of temperature with a heated metal pipe), it is at best an estimate rather than a clinical certainty. Other variables such as variation in thickness of skin at different sites of the body, circulation of blood, and influence of clothing also play a vital role in influencing the outcome.

## Clinical Effects of Burns

The clinical effects of burns are dependent on a few important factors:

- percentage of body surface involved
- depth of burns
- location of burns
- presence of inhalation or gastrointestinal burns.

Other important factors influencing severity of burns include age of patient and presence of associated injury or disease.

Any burns exceeding more than 50% of body surface are regarded as potentially fatal, regardless of the depth. The most important complication in the early stages is loss of body fluid, which may result in hypovolemic shock if not corrected promptly. The loss of fluid is further exacerbated by tissue edema.

Infection is also a common and serious complication. Devitalized tissue provides an ideal site for bacterial colonization leading to septicemia. Another source of infection is from the lungs. Sepsis with multiple organ failure is probably the most common cause of death encountered by forensic pathologists in burnt patients with a period of survival. Fatal infections are often caused by virulent opportunistic organisms such as *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus*, and fungi.

Another important effect is an increase in metabolic rate necessitating nutritional support. Failure to correct the hypermetabolic state may lead to loss of protein and eventual starvation. There is excessive heat production, which may lead to eventual heat loss.

## Source of Burns

Burns can be caused by a variety of means: physical, electrical, chemical, and radiation are among the known causes.

### Physical Burns

Transfer of heat to the skin results in burns. There are two main types of physical burns: those caused by dry heat and liquid (scalds).

**Dry heat** Dry heat causes burns by direct conduction or radiation to the skin. In flame burns, there is direct contact with flame. Contact burns involve physical contact of body with a hot object. Radiant burns are caused by exposure to a heat source. The most common radiant-heat injury is due to sunburn. A special type of burn is due to flash fire. Here, one normally sees singeing of hair with partial-thickness burns due to brief but intense exposure to heat.

Depending on the severity of the heat and time of exposure, the burns can be partial or full-thickness. If left exposed longer, charring and carbonization may occur; this involves deeper tissues or even bones, as commonly seen in bodies recovered in a fire.

**Scalds** Scalds result from hot liquids. The source is usually water but hot oils, other liquids, and even steam can cause scalds.

A scald caused by water does not cause charring or singeing of hair since the temperature is not high enough (Table 3). It is usually well demarcated. If caused by immersion, patients will present with a horizontal fluid level commonly known as a "tidemark." If hot fluid has been tipped over the body, there will be a trickle pattern with the part of initial exposure being the most severe. As the fluid flows down the body, the width will be narrower due to the mechanics of flow and rapid cooling at the edges. Splash burns may be seen in association with such burns.

In addition to surface burns caused by steam, inhalation burns may occur due to its greater penetration capacity.

### Electrical Burns

These are specific burns, which are usually deep and may involve extensive tissue damage. Thermal injury occurs when electrical energy is converted to heat, causing local damage. The thermal effects and picture are dependent on the type of current (domestic or industrial), time of exposure, and resistance of tissues. Electrical burns can occur at both entry and exit points.

The typical electrical burn consists of a depressed leathery area of tissue necrosis, occasionally with a blister. There may be a faint rim of erythema. Metallization may occur.

**Table 3** Differences between dry heat and scalds

| | *Dry heat* | *Scald* |
|---|---|---|
| Source | Contact or flame burns | Hot liquid, usually water or steam |
| Clinical appearance | May be partial- or full-thickness<br>May have charring or carbonization<br>Hair may be singed<br>Variable borders | Red base with blisters. Usually partial-thickness<br>No charring or carbonization<br>Hair not singed<br>Usually sharply demarcated. May have splash marks |
| Uniformity of burns | Usually not uniform | Usually uniform depth |

**Figure 2** ''Crocodile skin'' due to burns resulting from high-voltage electrocution.

A specific severe burn is caused by the application of high-voltage electricity. In addition to the contact mark, further thermal injuries are caused by arcing. Presentation may show spotty areas of burns, sometimes described as "crocodile skin" (Figure 2).

Lightning causes a specific type of burn. Exposure is usually brief, with the current passing over the body with a flashover effect. It causes streaks of interrupted linear burns, which reflect its passage downwards to the ground. There is usually partial charring and singeing of hair. There may be arborescent fern-like markings known as Lichtenburg figures or filigree burns. Histology of the lesion shows extravasated red blood cells in the subcutaneous fat with intact epidermis and dermis. Burns due to heating and melting of metallic objects worn by the deceased may be seen.

### Chemical Burns

The extent of burns is dependent on the concentration, area of exposure, duration of contact, and type of chemical. Burns can also occur in the gastrointestinal tract in both accidental and suicidal ingestion. Inhalation of fumes can cause respiratory damage. Systemic toxicity due to absorption of the chemicals through skin can be more serious than the burns.

A common type of chemical burn is due to acids and alkalis, followed by a range of other increasingly complex chemicals (Table 4).

The chemical will continue to cause tissue damage as long as it is present and will cease when neutralized by tissue or other means. Tissue damage is dependent on the following factors:

1. type of chemical
2. concentration
3. quantity
4. duration of contact
5. presence of exothermic reaction.

**Table 4** Summary of chemicals capable of causing burns

| | |
|---|---|
| Acids | Exothermic reaction in addition to corrosive injury. Results in coagulation necrosis. Further penetration is inhibited |
| Hydrofluoric acid | Similar to other acids. Fluoride ion binds with tissue Ca and Mg ions, resulting in cell death. Causes intense pain |
| Alkali | Saponification of fat-forming soluble proteinates, resulting in liquefactive necrosis. Tendency to penetrate deep to cause deep burns |
| Phenols | Weak acid. The burn may be painless because it causes demyelination of nerve fibers and destruction of nerve endings. Due to easy absorptivity of phenols, systemic toxicity may occur |
| Petroleum products | Defattening. Usually results in irritation unless there is prolonged exposure |
| Mustard gas | Mustard gas causes blisters leading to sloughing of skin. May cause inhalation injuries |

**Acids** The mechanism is usually direct corrosion (via its hydrogen ion) and heat (exothermic) reaction. It causes coagulation necrosis, which prevents deeper tissue from being exposed to the chemical. It acts quite rapidly, causing superficial burns after only 5 s of contact and full-thickness burns after 30 s.

An important exception is hydrofluoric acid. Apart from its corrosive effect, it exerts further destruction effect via the fluoride ion. The ion can penetrate deeply into the tissue, combining with intracellular calcium and magnesium and causing cell death.

**Alkalis** The main mechanism of the hydroxyl ion is saponification of fat and alkali proteinates to cause liquefaction necrosis. Although they do not act as rapidly as acids, alkalis have the ability to penetrate much deeper into the tissue, exerting their effects longer.

**Other chemicals** There is an ever-increasing number of organic and inorganic compounds. Traditional ones include organic solvents and phenols. Chemicals of warfare, including mustard gas (vesicants) and lewisite, can cause blistering of skin similar to burns.

### Radiation

The incidence of radiation burns is low. In principle, long-wavelength radiation causes direct damage by producing heat. Short-wavelength radiation on the other hand causes severe burns due to ionization of tissue in addition to local production of heat. Table 5 summarizes different types of radiation.

A specific type of radiation burn is caused by microwave ovens which use nonionizing radiation.

**Table 5** Types of radiation

| | |
|---|---|
| Nonionizing radiation | Radiowave, microwave, infrared light, ultraviolet light |
| Ionizing radiation | X-rays, gamma-rays |

The microwave oven heats food from within, unlike conventional ovens, by creating molecular agitation of polarized molecules such as water. Thus, tissue with high water content produces more heat than tissue with low water content. Typically, it produces sandwich-type burns involving skin and muscle with relative sparing of the subcutaneous fat.

## Histology

The effect of heat is to cause coagulation necrosis of the cells. The cellular features will appear indistinct and become more intense with histological stains.

In the skin, blister formation will occur by subepidermal separation of epithelium. The vesicles may contain occasional inflammatory cells. The cells at the periphery of the blisters become elongated and show streaming which is parallel with the basement membrane. There is a decrease in the thickness of the epidermis with a compact homogeneous dermis without empty spaces between collagen bundles. It is postulated that the epidermis has been compacted by the dermis swollen by heat, resulting in horizontal stretching of the cells. These findings are similar to those seen in electrocution marks on the skin.

Thermal injury to the airway will cause destruction of respiratory epithelium with sparing of areas protected by mucosal folds and ducts of mucous glands. The necrotic epithelium may be fused together to form a pseudomembrane or form casts within the airway. There is submucosal edema and capillary congestion. It may be accompanied by inflammation when there is adequate survival time.

## Forensic Aspects

There are numerous settings where the forensic practitioner will see persons with burns. Burns can deliberately be induced to maim, kill, or torture. Fire has been used to commit suicide. It has also been used as a means of committing offenses (e.g., arson). Suspected cases of abuse must be differentiated from accidental causes. An autopsy has to be performed on a body recovered in a fire not only to find out the cause of death but also to confirm how it occurred. Additional forensic pathology issues such as artifactual injuries, identification and differentiation between antemortem or postmortem burns are also essential assessment during autopsy.

### Accidental Burns

Most burns and scalds are accidental. Only a small proportion is deliberate. Accidental burns can occur due to neglect.

Accidental burns occur in extreme age groups. In younger children, burns and scalds are common. The peak age of accidental burns is usually 1–2 years old, when they acquire mobility to explore but insufficient dexterity to avoid accidents. Most elderly burn victims have some form of motor impairment. Another group who are prone to burns are epileptics. Usually, the burns are full-thickness type and may involve the bones and joints. Persons who are intoxicated are also more susceptible to burns.

Spill injuries resulting in scalds are common. Children tend to pull cups, saucepans, and other utensils. The flex of an electrical kettle can be pulled. Similar accidents can occur to the elderly and infirm. Tapwater scalds are not uncommon. A hot water tap may be turned on accidentally to wash hands without appreciating the dangers, both by children and those who are mentally impaired. Accidental immersion of hands into the sink containing hot water is not unknown.

Contact burns can be found especially with heaters, irons, or hair dryers.

Flame burns can occur when children start playing with fire using matches or cigarette lighters. Clothes may catch fire accidentally, causing serious burns. In countries that use kerosene or wood/charcoal stoves such as India, accidental ignition of clothes has been reported. The severe burns are usually found in the front of the body. Burns on hands, particularly the dominant one, can occur due to attempts to put out the flames.

Another potential hazard is chemical burns. Household chemicals with corrosive potential include bleach and hydrocarbons. Accidental burn caused by bathing a child in bleach solution due to ignorance on the part of the carer has occurred before.

### Abuse

The commonest setting of burns is in child abuse but it can be seen in all forms of abuse, including domestic and elderly abuse. It must not be forgotten that burns can occur due to criminal neglect.

In physical child abuse, burns and scalds occur in about 10% of cases, usually in conjunction with some other form of trauma. About 10–25% of burns in children are deliberate. The mortality rate is significantly higher when compared to accidental burns (30% compared to 2%). Burns in child abuse may be impulsive but more often than not are premeditated.

A common injury is exposure to hot tapwater. Children are punished by exposing their limbs, frequently their hands, to hot water, causing scalds limited to that part of body.

Another frequent injury is forced immersion in hot water. It may affect hands, feet, and buttocks but sometimes almost the whole body (Figure 3). Depending on the position the child is immersed in the water, a clear demarcation between scalded and unburnt skin is noted. The usual position is a child being forced on to a basin of hot water, causing scalds to the hands, feet, and buttocks. There will be a glove-and-stocking distribution with sparing of the soles and part of buttocks if held firmly against the cooler base. There will be minimal splash marks associated with accidental fall into the bath.

Another form of scalding is due to splashes from deliberate spilling or throwing a bucket or bowl of hot water. The margins are irregular, influenced by gravity, and characterized by nonuniform depth of injury. One would find flow marks and "satellite" scalds due to splashes. The mark will typically narrow inferiorly following the flow pattern. The findings may be modified by clothing. Clothing can either protect the child from further injury or retain hot water (heat) to cause more severe scalds.

Another common injury is cigarette burns (Table 6). Cigarette burns can occur not only in the setting of child abuse but also in domestic and elderly abuse. They appear as full-thickness burns with craters. It is important to differentiate accidental burns from intentional acts. Accidental cigarette burn is usually due to brief brush contact. Care must be taken to exclude skin conditions (e.g., impetigo) with a similar appearance.

Contact burns using hot objects can sometimes be seen. Usually domestic objects are used. For example, a child may be forced to sit on a hot plate. An iron may be used. Usually, the burns take a similar shape as the offending object (Figure 4). A careful history has to be taken to differentiate accidental burns.

Other forms of burns may be due to force-feeding of hot food into the mouth, resulting in burns around the lips and cheek. Other atypical types of abusive burns include corrosive and electrical burns. Deep burns due to placing the infant/child inside a microwave oven have been reported. A summary of the types of burn seen in abuse is given in Table 7.

Presentation in abuse cases may be acute, chronic, or when complications arise, for example, secondary infection. Suspicion may be aroused when there is a delay in taking the victim for medical treatment, the presence of other injuries, evidence of neglect, or discrepancy in history (Table 8).

**Figure 3** Glove distribution of scalds on hands of child due to forced immersion into basin of hot water. Courtesy of Dr. Bhupinder Singh.

**Figure 4** Burns due to hot iron in domestic abuse. Note the shape of the burns.

**Table 6** Differential diagnosis of cigarette burns

| | |
|---|---|
| Abuse | Deep and cratered, full-thickness, may be on unusual sites not associated with accidental injury, e.g., soles of feet. Usually healed by scarring. Old cigarette burn scars may be present |
| Accidental | Area of reddening, sometimes with a tail or elliptical in shape, signifying an accidental brushed contact |
| Bullous impetigo | Usually clustered together. Healed without scarring, usually centrally |

**Table 7** Types of burn found in abuse

| | |
|---|---|
| Scalds | Immersion burns |
| | Spill burns |
| | Tap burns |
| Flame burns | Fire/matchstick |
| | Cigarette burns |
| Contact burns | Hot plates |
| | Domestic objects such as iron, hair dryer, heater grills |
| Miscellaneous | Forcibly feeding hot food/liquids |
| | Use of caustic/corrosive liquid |
| | Electrical burns |
| | Microwaves |

**Table 8** Features suspicious of abuse

- Inconsistent history
- Physical features of burns not in keeping with the history
- Burns not compatible with psychomotor ability
- Delay in treatment or treatment when complications arose
- Presence of old burns and/or other injuries
- Features of neglect and/or sexual abuse
- Burns/scalds typical of abuse (e.g., glove-and-stocking distribution, clear tidal marks, atypical sites – buttocks, back of body, genitalia, back of hands, soles of feet)
- Signs of abuse in siblings (for child abuse)

A particular type of abuse encountered in South Asian communities is dowry death. Here the young bride is tortured or burned to death by the husband or in-laws due to poor expectation of dowry or other reasons. Death may be initially reported as accidental (e.g., while cooking). In most instances, kerosene, which is the most common accelerant used, may be detected on the body or clothing. Information on the type of stove (kerosene or otherwise) would be important to rule out accidental death. There may be the presence of both antemortem and postmortem burns (e.g., heat contractures and fractures), which indicates burning even after death. Information of burns in other members of the family may be useful as it indicates an attempt to douse the fire.

### Punishment by Causing Hurt

Unlike blunt and sharp injuries, thermal injury is not common as a form of assault.

In Asian society, corrosives are well known as a weapon to cause hurt and injury. The typical situation is that of a spurned jealous lover who deliberately uses a corrosive in order to scar his partner. The corrosive is usually aimed at the face in order to cause maximum deleterious effect.

The usual corrosive is concentrated acids rather than alkalis. This may be due to the public perception of the rapid action of acids. The findings are usually coagulation burns with flow marks due to gravity. They may be modified by the clothes and rapidity of treatment (washing). The eyes may be affected. Unfortunately, the injuries heal by scarring. Occasionally death can occur, especially when inhalation occurs, causing chemical pneumonitis or when complications arise (e.g., secondary infection).

### Torture

Among the reported methods of torture that cause thermal injury are use of hot implements (branding), molten liquids, cigarette burns, and electrical injury. There is usually variation depending on local culture. A common problem is the long delay between injury and time of examination. Consequently, the victim presents with scars or keloids as manifestation of previous burns.

### Self-Infliction

Suicidal death by burning is known as immolation. The frequency is dependent on culture. It is a common method of suicide in South Asia but uncommon in the west. Immolation has been used as a method of political protest.

It can occur within the confines of a house or vehicle, which is deliberately set on fire. More commonly, the victims douse themselves with an accelerant, commonly petrol or kerosene. There are usually extensive burns more prominent on the front of the body with sparing of skin folds.

Swallowing of corrosives is a known method of suicide. Severe damage may occur in the upper gastrointestinal tract, leading to erosion and healing by stricture formation.

Occasionally, burns are self-inflicted for the motive of gain or spite, e.g. through the use of an iron. The usual characteristics of self-inflicted injuries are applicable (similar depth, usually superficial, clustering).

### Examination of Deaths due to Burns

If death occurs immediately or soon after the incident, the victim usually presents with severe burns. Inhalation of smoke is frequently attributed as a cause of death. In house fires, the body may be charred. Additional issues such as identification of severely charred body, whether the person was alive before the fire, reconstruction of circumstances, and postmortem induced artifact may be a problem.

In deaths occurring after a period of survival, it is important to document the burns, evidence of medical intervention (e.g., skin grafting, escharotomy), inhalation injuries, and presence of medical complications. Known complications include shock due to burns, secondary infections, including septicemia and pneumonia, pulmonary embolism, small intestinal ulceration (Curling ulcer), renal failure, and other miscellaneous causes such as pancreatitis and fat embolism.

### Other Situations

Occasionally the forensic physician may be asked to examine a suspected arsonist, especially when the alleged person has ignited the fire directly. Liquid accelerants can evaporate easily, forming an explosive mixture with air. Inexperienced offenders risk an explosion when attempting to ignite the accelerants, sustaining burns as a result.

According to Bohnert and coworkers, the explosion causes typical heat changes and injuries to the exposed person. There may be singeing of exposed hair (frontal head hair, facial hair, and hair on exposed body) and skin burns of varying degree (back of hand, face). These features, especially singed hair, may be seen weeks after an alleged offense. Toxicology analyses of the blood for accelerants and evidence of inhalation of smoke (carbon monoxide levels) may be useful if the assailant is apprehended soon after the offense.

### Natural Disease Mimicking Burns

Certain natural disease, especially dermatology conditions, can mimic burns. Bullous disease like porphyria and erythema multiforme can present with blisters, which are similar in appearance to burns. Impetigo and chickenpox can be mistaken for cigarette burns. Other conditions capable of an appearance similar to burns include allergic conditions (allergic dermatitis, urticaria) and insect bites.

## Approach to Investigations

A few considerations may be undertaken to ascertain if the circumstances are consistent with appearance of burns:

1. A full and detailed history. More often than not, the injuries inflicted may not be consistent with the history. This is true not only in child abuse but in other types of domestic abuse as well. Persons who are abused may not reveal the truth for fear of further reprisals or to protect the abuser.
2. Scene visit may be important. This may include examination of the alleged appliances used, assessment of the water temperature and the position in which the body is found.
3. Full examination, including careful charting of burns.
4. Often in abuse cases there may be other associated injuries. Therefore, it is imperative that a detailed examination is carried out, partly to rule out sexual abuse.
5. Assess if the manifestation of burns is consistent with the circumstances. This includes taking into account the history, scene examination, and time period exposed to the heat source.

In addition, there are several other considerations in a postmortem examination:

1. Was the person alive before the fire? The standard technique is to look for evidence of smoke inhalation in the airway and the presence of agents of combustion (e.g., carbon monoxide) in the blood.
2. Cause of death, for example, smoke inhalation or directly to thermal injury. If death occurs after a period of time, complications of burns may be responsible for death.
3. Look for antemortem injuries, which may be masked by destruction of body. Conversely, assess whether any of the injuries present are artifactual.
4. Issues of identification if the body is badly disfigured. An X-ray of the body may be useful for identification purposes. It can also assist in ruling out other forms of injury, which may be masked (e.g., gunshot wounds) by the disfigurement.
5. Collection of trace evidence (e.g., clothes for evidence of accelerants) and toxicology to look for products of combustion (e.g., carbon monoxide) and contributing factors such as drugs and alcohol.

## See Also

**Autopsy, Findings:** Fire; **Children:** Physical Abuse; **Drug-Induced Injury, Accidental and Iatrogenic**; **Drugs, Prescribed:** Licencing and Registration; Product Liability; **Electric Shocks and Electrocution, Clinical Effects and Pathology**; **Torture:** Physical Findings

## Further Reading

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# Explosive Injury

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## Introduction

Terrorist activity in many parts of the world is associated with the use of a variety of explosive devices, and the doctors treating live casualties from bomb explosions as well as pathologists dealing with the dead need to have knowledge of the types of injury explosion can cause. Pathologists in particular may find themselves dealing with large numbers of bodies requiring identification and examination to establish the cause of death. In addition, a careful examination of the victims and in particular the nature and distribution of their injuries may help in reconstructing the circumstances in which the death occurred.

It is important to appreciate that terrorists use bombs for different reasons against a variety of targets, which may range from simple crudely constructed homemade devices using "low-order" explosives to sophisticated bombs using powerful military plastic explosive materials and incorporating elaborate radio-controlled detonators and antihandling devices. Pathologists and others must be aware of the use of "suicide" bombers and should therefore bear in mind that amongst the casualties/fatalities there may be those who have actually instigated the incident by detonating a device attached to their body.

An understanding of what happens during an explosion is important in order to appreciate the types of injuries seen in victims. When an explosion occurs, the explosive material is suddenly converted into a large volume of gas with the release of tremendous amounts of energy. Pressures of up to 150 000 atm can be generated, and the temperature of the explosive gases can rise to 3000 °C. Exposure to an explosion produces a well-defined pattern of injury from:

- direct transmission of a detonation shock wave, manifested principally as blast lung, bowel contusion, and tympanic membrane rupture
- secondary injury caused by fragments and other missiles
- injury resulting from displacement of the victim's body as a whole by the complex pressure loads imposed upon it (any injury caused by collapse of buildings or nearby structures is included in this category).

Thus individuals in the vicinity of an explosion can experience a number of effects:

1. If they are very close to the seat of the explosion, they may be blown to pieces and scattered by the force of the explosion gases.
2. If they are near enough for the skin to be in contact with the explosion flame, they may sustain flame burns, whilst at greater distances, exposure to the momentary heat radiation causes "flash" burns.
3. They may be injured by the shock wave, which spreads concentrically from the blast center. This pressure wave is followed by a postblast wind, which also does damage.
4. They may be struck by flying missiles propelled by the explosion.
5. They may be injured or crushed by falling debris and masonry, usually of buildings demolished by the explosion.
6. They may be overcome by fumes formed as a result of the explosion or from the effects of fire (burns and smoke inhalation) if a secondary fire develops, for example, following fracture of a gas main.

## Types of Injury

The injuries seen in victims of explosion can be separated into six categories:

1. complete disruption
2. explosive injury
3. flying-missile injury
4. injury from falling masonry
5. burns
6. blast.

### Complete Disruption

When individuals are in the immediate vicinity of an explosion there may be complete disruption of the body. The victim may be literally blown to bits and the parts scattered over an area of 200 m radius. This is relatively uncommon but may occur in current terrorist situations when someone is carrying a large bomb that explodes or when a victim is blown up by a landmine. It is also to be expected in suicide bombers who strap explosives to their bodies.

When collected, washed, and examined, the identifiable remains are typically seen to comprise pieces of scalp and skin, portions of spine, major limb joints, and lumps of muscle. Usually most of the internal organs are missing (Figure 1). Nonhuman tissue is often found amongst the material submitted for examination and must be identified and discarded. In one explosion in a fish market, the terrorist as well as nine victims were killed. Amongst the material submitted for examination there was a variety of different types of fish and crustaceans.

### Explosive Injury

Perhaps surprisingly, most individuals close to the seat of an explosion remain, by and large, relatively intact. Those within a couple of meters of the explosion may have parts of their limbs blown off (traumatic amputation) and sustain severe mangling of other parts of the body, often with breaching of the chest or abdominal cavities, but they usually remain sufficiently intact for a detailed autopsy to be carried out (Figure 2). A detailed study of the mechanism of traumatic amputation by bomb blast in victims in Northern Ireland concluded that flailing of the limbs is not the cause but instead direct coupling of explosive shock waves causes fractures and preferential amputation through the shafts rather than the joints of the long bones (Figure 3).

Those injured or killed following a bomb explosion usually exhibit wounds, not from the effects of blast,

**Figure 1** Complete disruption of the body caused by a terrorist bomb. The remains were scattered over a large area and consisted of pieces of scalp and skin, lumps of muscle, and a few of the major limb joints. The severity of the injuries indicate that the victim must have been in contact with the bomb when it exploded. He was in fact a terrorist blown up when the bomb he was loading into a vehicle exploded prematurely.

**Figure 2** Explosive injury. There is severe mangling of the head, trunk, and limbs but the body has remained relatively intact. The arms and feet were blown off. The victim was a terrorist killed by his own bomb which exploded prematurely. Identification required comparison of his teeth with dental records.

**Figure 3** Traumatic amputation of right lower limb and left forearm following a bomb explosion. Note the fragment of patterned clothing on the left forearm, which gave a clue to the identity of the deceased.

but because of the effects of material propelled in all directions from the seat of the explosion, possibly shrapnel deliberately placed around the device or frequently, in the terrorist situation, from fragments of a car filled with explosive. Other kinds of solid material propelled by the explosion consist of the remains of the explosive mixture itself and debris from the surroundings, for example, brick, plaster, and wood, varying from reasonably large fragments to dust. In general, the larger the fragment, the deeper it will penetrate the body and the more lethal it is likely to be.

The characteristic type of injury due to fragments propelled by an explosion is a triad of small bruises, punctate abrasions, and irregular puncture lacerations (Figure 4). The triad of injuries may be so confluent as to give the skin a purple discoloration. The bruises and abrasions tend to be quite small, up to 1 cm in diameter, whilst the lacerations, which may vary between 1 and 3 cm in diameter, may contain small fragments of metal or wood derived from the bomb or its container. Superimposed on this triad of small lesions, larger lacerations may be present due to the penetration of fragments of greater size (Figure 5).

Dust or minute fragments of dirt will also be propelled by the explosion and, when there is a large amount, it can be driven into the skin to cause fairly uniform tattooing and a dusky purple discoloration of the skin. This discoloration provides a background for the triad of small bruises, abrasions, and puncture lacerations. Whereas the fragments that cause the triad of injuries have sufficient momentum to perforate clothing, the dust/dirt tattooing is typically only seen on exposed skin (Figure 6).

### Flying-Missile Injury

The triad of bruises, abrasions, and puncture lacerations is due to the violent impact of small particles and the victim usually has to be within a range of a few meters of the explosion to be struck by debris of this size. Beyond this distance the peppering injuries disappear but serious injury and death can occasionally result from the impact of larger separate fragments, usually of metal (Figure 7).

It is difficult for those with no firsthand experience of explosions to appreciate the penetrating force of a

**Figure 4** The triad of punctate bruises, abrasions, and puncture lacerations typical of bomb explosions. This victim was several meters away from the bomb when it exploded.

**Figure 5** Explosive injury. In addition to the triad of small bruises, abrasions, and puncture lacerations there are larger irregular lacerated wounds due to penetration by larger fragments.

**Figure 6** Dust tattooing of the lower limbs following a bomb explosion. Note how the feet have been protected by footwear and the thighs by clothing.

**Figure 7** Flying missile injury. This victim was struck by a solitary fragment of metal from a window frame. The fragment penetrated the underlying chest causing fatal hemorrhage. She sustained no other injuries.

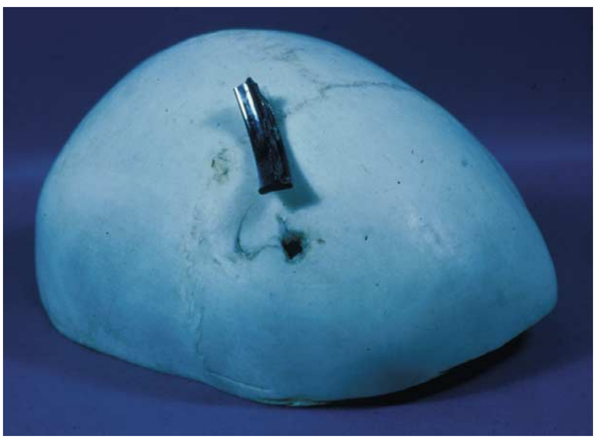

**Figure 8** Penetration of the skull by a fragment of door handle from a car which was packed with explosives. The victim was over 100 m away from the vehicle when it blew up.

relatively small explosion fragment. These fragments can penetrate the soft tissues of the body quite deeply, even traversing bone, their momentum being obtained not from their mass but from their velocity (Figure 8).

### Injury from Falling Masonry

Many of the victims inside or adjacent to a building demolished by an explosion are buried under the rubble. They can receive serious or even fatal impact injuries from the collapse of heavy structural components or may suffer crush asphyxia; on many occasions these injuries are the only effects of the explosion on the body.

When removed from the rubble the body and its clothing are soiled by dust from brick, cement, or plaster, and the extent and nature of the injuries are only revealed when the clothing has been removed and the body thoroughly washed (Figure 9). The injuries, which do not differ materially from those seen in people killed in "ordinary" accidents, are often found to be sufficient to account for death.

If death is due to crush (traumatic) asphyxia, the signs are usually quite clear – purple discoloration of the upper parts of the body with petechial hemorrhages in the skin and conjunctivae and perhaps some congestive hemorrhage from the nose and ears.

### Burns

When a bomb explodes, the temperature of the explosive gases can rise to 3000 °C. Contact with the momentary flame causes burns but individuals close to the seat of the explosion usually sustain severe disruptive injuries and the burns are a minor component, if any at all, in the fatal outcome (Figure 10). Individuals outside this range can be burned by the radiant heat but the effects decrease rapidly from the seat of the explosion and protection from heat radiation of this intensity is afforded by solid objects and even clothing.

Severe burns are usually the result of any later fire started by the bomb either because of the incorporation of incendiary materials into the device or as a result of disruption of a source of flammable material, for example, liquefied petroleum gas tanks. Severe burns may present difficulties in respect of identification and obliteration of surface injuries (Figure 11).

Flash burns may also be seen when bomb-making chemicals ignite. The ignition is associated with a momentary flash of very high temperature and those exposed can have their outer clothing burned off and sustain extensive uniform-thickness cutaneous burns. Tight clothing such as a bra, underwear, and footwear may protect the underlying skin (Figure 12).

### Blast

An explosion is associated with a narrow wave of very high pressure, which expands concentrically from the seat of the explosion and temporarily engulfs a person in its path. The pressure is exceptionally high at the front of the wave but decreases toward its rear and becomes a slight negative pressure, or partial vacuum, before the wave is complete. The total duration of the

**Figure 9** Injury from falling masonry. A body recovered from a building demolished by a bomb explosion. The exposed skin and clothing are heavily soiled by dust, plaster, and cement. Death was due to crush injuries of the trunk.

**Figure 10** Burns. Singeing of the hair and scorching of the skin of the face and neck in an individual close to the seat of an explosion. Note also the presence of explosive injuries.

shock wave is brief; the pressure component lasts perhaps 5 ms for a relatively modest explosive device whilst the negative suction component may be 30 ms. As the distance from the explosion is increased, the pressure component lasts longer because the front of the wave where the pressure is highest always travels faster than the tail of the wave where the pressure is much lower. The blast wave can knock a person down, move objects, and demolish buildings – these effects are usually due to the impact of the steep pressure wavefront (Figure 13).

It was previously thought that lung damage resulting from blast was due either to a wave of pressure traveling down the trachea or to the suction component of the wave acting also through the trachea. These mechanisms have now been discredited. Whilst the mechanism of blast lung is still not fully understood, the three favored hypotheses as summarized by Maynard and coworkers are:

**Figure 11** Burns. These victims were inside a building which went on fire after an explosive device, incorporating cans of petrol, exploded on an outside wall. Twelve badly charred bodies were recovered from the scene.

1. damage to epithelial surfaces within the lungs as a result of a stress wave passing through the parenchyma and encountering interfaces of different density
2. transmission of pressure pulses and subsequent flow of blood from the great vessels of the abdomen to the pulmonary vessels leading to rupture of pulmonary capillaries
3. compression and subsequent violent reexpansion of small air spaces in the lungs as a result of the passage of the shock wave.

Blast lung is the term used to describe the direct damage to the lung produced by the interaction with the body of the blast wave generated by an explosion. Macroscopically it is apparent as areas of blotchy purple-black areas of subpleural hemorrhage. Usually these are scattered at random but occasionally may be seen as parallel bands of bruising related to the overlying ribs (Figure 14). Sectioning the lungs reveals more discrete areas of hemorrhage scattered in the tissue, often with a tendency to be more central than peripheral. The rest of the tissue is patchily edematous. The overall weight of the damaged lung is increased due to both hemorrhage and edema.

Microscopically there is intraalveolar hemorrhage, sometimes confined to within intact alveoli but also

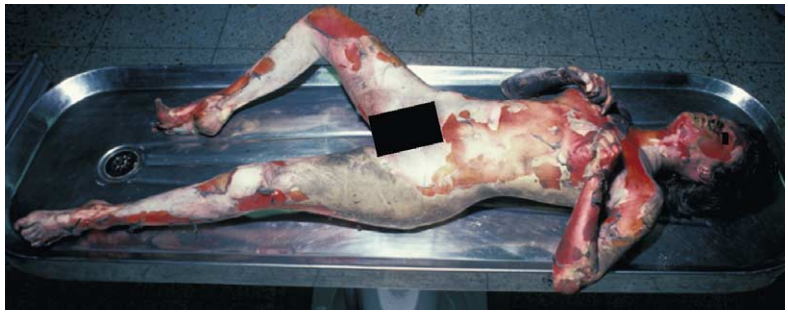

**Figure 12** Flash burns associated with the ignition of bomb-making chemicals.

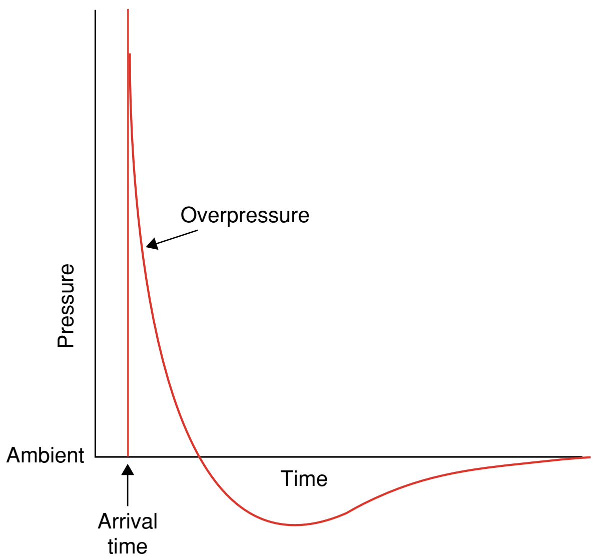


**Figure 13** Illustration of blast wave, with steep pressure wavefront.

larger areas of confluent hemorrhage may be identified with disruption of alveolar walls. Hemorrhage extends into the bronchioles in places and there is a variable amount of edema fluid in the alveoli. Emphysematous dilatation of some of the alveolar ducts may be identified. In patients who survive, the changes are modified by infiltration with a neutrophilic inflammatory reaction and often by the development of adult respiratory distress syndrome (ARDS).

Primary blast injuries to the lungs are rarely of major significance in civilian casualties from terrorist bombs. To be injured by blast, one has to be in the immediate vicinity of the explosion, say within a few meters, and at such a range, the victim is likely to die at the scene from other injuries. Also it must be borne in mind that not all lung injury is due to blast. Sometimes the lungs are bruised by direct blows on the chest by bomb fragments and debris.

Blast damage to the ear may be associated with bruising and/or rupture of the tympanic membrane

**Figure 14** Blast lung. There are extensive areas of blotchy purple-black subpleural hemorrhage on the surfaces of both lungs.

and occasionally damage to the cochlea. Most victims who survive an explosion may initially complain of deafness associated with tinnitus but usually recover if the ossicles have not been damaged.

Gastrointestinal tract injury following blast is inconsistent and takes the form of hemorrhage into the peritoneum and bowel wall. Perforation of the bowel is uncommon but has been described.

## Investigations of Deaths Following a Bomb Explosion

Following a terrorist bomb there may be many fatalities and the forensic pathologist dealing with such cases may have to invoke a predetermined mass-disaster plan for dealing with large numbers of bodies. The main problems are:

- identification of the victims
- confirming the number of victims
- ascertaining the causes of death
- determining the circumstances of death
- the retrieval of forensic evidence.

### Identification

Surprisingly, most of the victims of terrorist bomb explosions can usually be visually identified. Mistakes can be made however when there are a number of fatalities from one bomb. Usually it is a relative of the deceased, severely traumatized by the event, who makes an incorrect identification – perhaps because of deformity of the skull or facial injuries or because the body is heavily soiled by blood and dirt (Figure 15). In such circumstances, if reliance is to be placed on visual identification alone, a second person, preferably not a relative, should also be requested to view the body to confirm identity. Even then, a sample of blood for DNA analysis should always be retained.

As a preliminary step in the identification process help may be obtained from distinctive clothing, although appearances can be misleading when it is burned or contaminated with plaster, oil, and blood. Jewelry may also be of assistance in making presumptive identification but would normally require confirmation by other means. Scars and tattoos, particularly if the latter are distinctive, are obviously important (Figure 16).

Fingerprinting bodies should never be omitted, since it may prove identity in some cases. If the victim is a known terrorist, his/her fingerprints may be held on record by the police. If an explosion victim has not been previously fingerprinted, the fingerprints taken after death may still be important if the identity of the individual is suspected. Latent prints taken from personal items which have been handled at home or at work can be compared with those taken from the body (Figure 17).

Dentition can also be used to establish identity provided a good dental record is available. Examination of the mouth, or if necessary of the excised upper and lower jaws, should be carried out by an appropriately experienced dental surgeon and compared with antemortem charts and X-rays.

Ideally all bodies recovered after a bomb explosion should be fully X-rayed. Old bony injuries, deformities, and prostheses may be identified as well as fragments, which may be of forensic interest. Most mortuaries are not however equipped with appropriate X-ray facilities and at a time when the hospital X-ray department may be struggling to deal with large numbers of injured casualties, it may simply not be practicable to undertake this task. Experience has shown that only rarely does postmortem radiography in such cases lead to retrieval of forensic significant material.

All bodies examined following a bomb explosion should, as a matter of routine, have material retained for DNA examination. In many cases such examination may prove unnecessary but at least it is available if required. Items such as toothbrushes and hairbrushes may provide a suitable source of antemortem DNA in individuals killed and badly mutilated in explosions. Alternatively samples may have to be obtained from the deceased's relatives.

**Figure 15** Severe facial injuries precluding visual identification, following a bomb explosion. Note that the absence of injury to the mouth thereby enabled a dental comparison to be carried out.

**Figure 16** A distinctive tattoo, including the individual's name on the forearm. The deceased was a soldier who was killed in a bomb explosion. The extent of the injuries to the head precluded visual identification.

**Figure 17** Amongst the mangled remains of this explosion victim was a relatively well-preserved hand from which fingerprints could be taken. Note also the engraved signet ring which was also of assistance in identifying the victim.

**Figure 18** After an explosion in a customs shed, eight mangled bodies were recovered as well as many pieces of human tissue. Amongst the scraps of tissue was an identifiable penis. It belonged to a ninth victim, a terrorist blown up and completely disintegrated by the explosion.

### Number of Bodies

When people are blown up in a civilian situation, as by a terrorist bomb, it is clearly important to ascertain the exact number of victims. Most of the dead will be sufficiently intact to be counted, but occasionally those victims near the seat of the explosion may be so disintegrated that their presence is only recognized after a careful search and examination of material collected from the scene.

In practice, it is best to start the examination with those bodies sufficiently intact to count. Any limb parts are apportioned to the appropriate bodies and portions of trunk are similarly matched. Once this has been done, attention is focused on smaller pieces of soft tissue, which are usually mangled and heavily dirt-soiled. Each piece must be thoroughly washed and carefully examined and, whilst the task might seem unrewarding, it is surprising how frequently the tissue yields important clues. On one occasion an unattached penis indicated an extra fatality, whilst on another, two prostate glands and two uterine cervices proved the existence of four further victims (Figures 18 and 19).

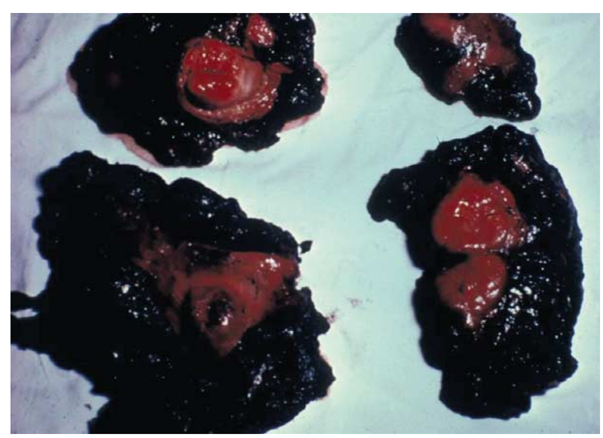

**Figure 19** Two uterine cervices and two prostate glands recovered after a number of bodies were disintegrated by a large bomb – conclusive proof of at least four victims, two male and two female.

### Cause of Death

When a badly injured body is retrieved after an explosion, the *prima facie* inference is that death was caused by the explosion and that all but a cursory external examination is required. Furthermore the examining pathologist may not be sufficiently experienced in dealing with such cases to appreciate specific types of injury and the significance of their localization on the body.

There is usually little doubt when there is severe localized explosive injury or when the triad of peppering injuries is apparent to conclude that death was due to the explosion. However, a victim who is pulled from the rubble and who bears, instead, nondestructive abrasions, lacerations, and fractures, or signs of crush asphyxia, is more likely to have been killed by falling masonry. Occasionally burns can be shown to have played a part in the fatal outcome.

The effects of blast may give rise to extensive pulmonary hemorrhage and edema which, if severe, may lead to death within hours of the explosion. Systemic air embolism may also occur as a result of air gaining the pulmonary veins after blast damage to the lungs.

Care must be taken not to miss a death from shooting. Terrorists have been known to fire indiscriminately at victims before planting a bomb, for example, in a crowded bar, and it is quite possible for a person to be fatally shot and left at the scene while others flee in panic (Figure 20). Likewise a householder or business owner who is resisting the planting of a bomb on his/her premises may be shot and sustain masking injuries in the subsequent explosion. Again, X-raying bodies may be of assistance in these instances by revealing the presence of bullets.

### Circumstances of Death

Reconstructing the circumstances of death can be the most rewarding aspect of autopsies on explosion victims. As with other deaths involving terrorist groups, it is not unusual for an explosion to be followed by rumors and allegations, which the pathologist can often confirm or refute. When a bomb goes off prematurely – perhaps whilst being manufactured, loaded into a car, or primed – and a terrorist is killed, it may be alleged that the deceased was an innocent passer-by. When a bomb goes off whilst being transported by car, it might be said that a terrorist blown out of the vehicle was a pedestrian. When a bomb goes off inside a building, some of the dead may be terrorists planting the bomb whilst others are uninvolved innocent victims. It is thus essential, if possible, to demonstrate the relative positions of the victims and bomb.

**Figure 20** This man's mangled body was recovered from the scene of a bomb explosion. Note the bullet wound on the back of the chest.

To do this one must compare the injuries of the victims – their severity, distribution, and pattern. Interpretation rests on two factors. First, explosive force declines rapidly with distance and only those victims very near to the source are badly mutilated. Second, the force is highly directional and it is often possible to determine the position of the device in relation to the deceased – thus an explosion at ground level injures the legs of those nearby more than other parts of their bodies. Similarly, the legs especially show severe mangling injuries when an under-car booby trap device explodes (Figure 21).

An intelligence assessment of this kind is often invaluable in the investigation; however, unless the significance of the features is readily apparent, this kind of evidence should be used with care in court. Unusual things can happen, bizarre wounds can occur, and a particular pattern of injuries sometimes proves misleading.

### Retrieval of Forensic Evidence

On occasions, fragments recovered from the bodies of explosion victims may have important forensic significance. They may help to determine the particular characteristics of the explosive device and thus implicate a specific terrorist organization. Furthermore it may be possible to link components recovered from bodies with similar items seized by the security forces in searches and raids on suspected terrorists (Figure 22).

**Figure 21** Mangling and traumatic amputation of the lower limbs due to an under-car booby trap device.

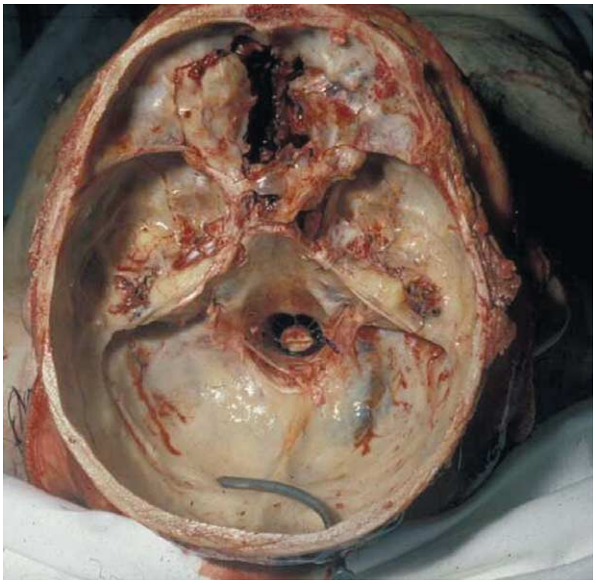

**Figure 22** A nail embedded in the skull following detonation of a nail bomb. Comparison of the retrieved fragment was made against nails seized at the premises of a suspect.

As previously indicated, X-raying bodies prior to autopsy will assist in the identification and recovery of shrapnel from bodies but rarely in the experience of this author has this included specific components from the bomb itself. Recovery of fragments from soft tissue can be extremely tedious and occasionally it may be worthwhile excising the tissue and subjecting it to digestion. Trypsin or meat tenderizer can be used to facilitate this. Biological washing powder also works effectively.

## Suicide Bombers

Although suicide bombers have been well recognized amongst Tamil Tigers in Sri Lanka and Palestinian extremists in the Middle East, the extent to which some organizations and their fanatical members will go was only brought home to most people as a result of the attacks in the USA on September 11, 2001.

The majority of suicide bomb attacks are of two types: either an individual, with explosives strapped to his/her body, detonates the device amongst a crowd of civilians or close to a targeted individual; or a vehicle, packed with explosives, is driven by the bomber into a specific location such as accommodation being used by civilians or military personnel.

The body of an individual strapped with explosives is invariably completely disrupted by the blast. Typically most of the trunk is blown away but remarkably the head and lower limbs remain relatively intact and are usually found some distance away from the seat of the explosion. The suicide car bomber, usually because of the large size of the device, is completely disrupted and little of the body may be recovered. When the area is scoured the parts that are collected are usually the fairly obvious portions of the body such as a segment of spine, perhaps a foot, and pieces of scalp and skin. The internal organs are rarely recovered.

## Types of Explosive Devices

Terrorist bombs come in all shapes and sizes and with varying degrees of sophistication. Experience during the "troubles" in Northern Ireland has seen the following specific types of devices used by paramilitary terrorist organizations:

- under-car booby-trap devices
- car bombs
- culvert bombs
- incendiary devices
- firebombs
- drogue bombs
- letter/package devices
- pipe bombs
- nail bombs
- mortar bombs.

### Under-Car Booby-Trap Device

This small device, containing only a kilogram or so of plastic explosive, such as Semtex, is attached magnetically to the underside of a motor vehicle, usually beneath the driver's seat area (Figure 23). A simple timer mechanism, such as a wristwatch or parking timer, is included in the device and this in turn is activated by a mercury tilt switch that operates once the vehicle is in motion. These devices are used to eliminate specific targets, usually the driver of the vehicle, although occasionally innocent passengers are also killed or seriously injured. Mangling and

**Figure 23** Under-car booby trap device. A small quantity of commercial explosive is used in these devices which are usually placed beneath the driver's seat area of the vehicle.

amputation of the lower limbs are typically seen in such cases (Figure 21).

### Car Bombs

Vehicles of one sort or another are ideal for not only transporting and concealing a bomb but also serve as a devastating container in which to house and detonate. A car boot can be packed with a large quantity of explosive material and the vehicle driven to its intended target. A simple timer mechanism can be used to effect detonation once the bombers have safely made their escape. Destruction of the car results in multiple secondary missiles radiating from the seat of the explosion, which can cause death or serious injury. In addition, the damage to the vehicle may render useless any attempts to recover forensic evidence such as fingerprints, fibers, or low copy number DNA relating to its occupants.

### Culvert Bombs

Large quantities of homemade explosive, usually made from ammonium nitrate fertilizer and sugar, were often concealed in galleys and water culverts beneath country roads in Northern Ireland by republican terrorist organizations. The security forces would then be lured to the scene, usually by an anonymous report of suspicious activity in the area. Terrorists, concealed at a vantage point some distance away, would detonate the device as the police or army patrol drove over the culvert (Figure 24).

**Figure 24** Typical culvert bomb beneath a road. Homemade explosive has been packed into a number of milk churns ready for detonation.

### Incendiary Devices

These small devices, sometimes concealed in audio cassette cases, contain a small quantity of low-order explosive, a detonator, and a simple timer (such as a wristwatch) (Figure 25). They are often left concealed in commercial premises and are intended to detonate when the premises have been vacated for the evening. Their purpose is primarily to cause destruction of the building and its contents by the fire, which is generated by detonation. Occasionally, nightwatchmen or security staff remaining within the premises after closing may be caught and unable to escape the ensuing conflagration.

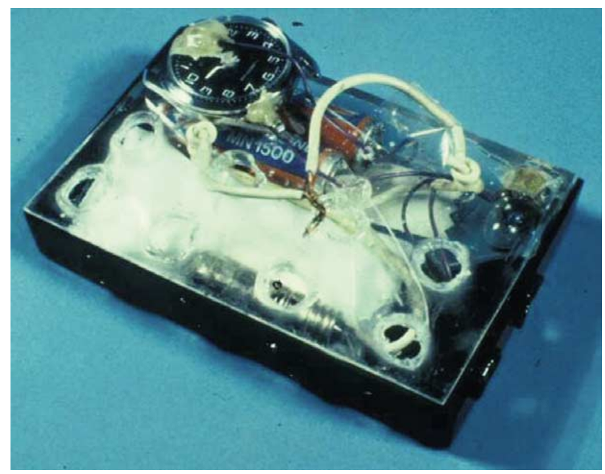


**Figure 25** Incendiary device packed into an audio cassette. Note the wrist watch used as a timer.

### Firebombs

These are considerably larger than incendiary devices and consist of an explosive device attached to a container of flammable liquid such as petrol (Figure 26). The force of the explosion causes rupture of the container and the release of inflammable vapor which then ignites. The fire associated with detonation of these devices develops rapidly and may engulf buildings within seconds, resulting in death of the occupants.


**Figure 26** Firebomb. The explosive device is attached to metal containers filled with flammable liquid and designed to rupture on detonation of the device.

### Drogue Bombs

These homemade devices were developed by terrorists in Northern Ireland and were intended to be dropped or thrown from the upper floors of buildings or bridges at police or military vehicles passing below. Their construction included a hollow cylindrical cooper core which melted on detonation and could penetrate the armor-plated roofs of these vehicles (Figure 27).

### Letter/Package Devices

It is not uncommon for small explosive devices to be sent in the post to targeted individuals. The device is usually contained within a large padded envelope and detonation is usually achieved when the envelope is opened by an unsuspecting recipient. Injuries sustained in such circumstances are usually confined to the face and are often characterized by linear abrasions and lacerations radiating from a point in front of the face (Figures 28 and 29).

### Pipe Bombs

These are fairly crude improvised devices essentially consisting of a length of metal pipe filled with low-order explosive such as that decanted from fireworks or shotgun cartridges (Figures 30 and 31). A simple taper fuse is attached and, once lit, the device is thrown at the intended target. Fatalities

**Figure 27** Drogue bomb. Homemade drogue bomb using metal food can. These devices were intended to be dropped or thrown onto passing military vehicles.

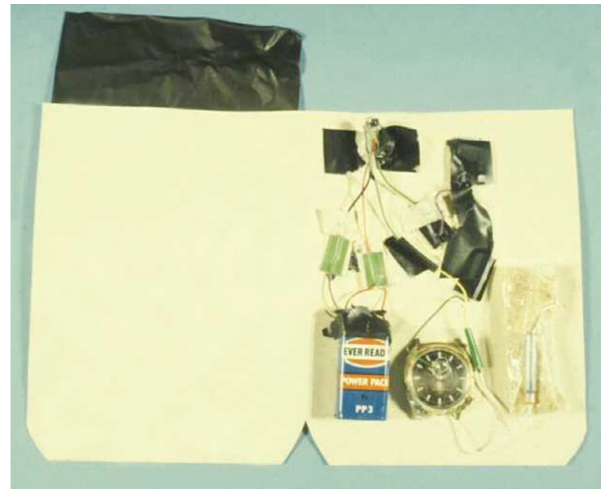

**Figure 28** Letter bomb contained within a padded envelope. Note the battery and watch attached to the device.

**Figure 29** Facial injuries sustained when a letter bomb exploded as it was being opened.


**Figure 30** Pipe bomb.

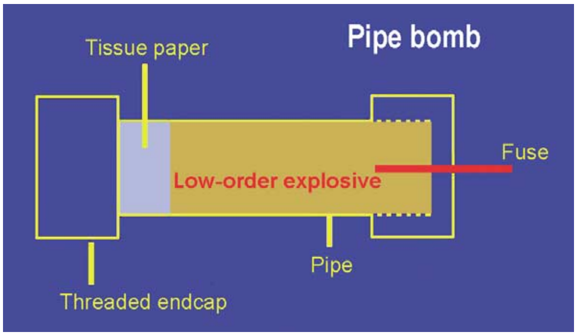


**Figure 31** The pipe bomb device consists of a length of metal piping filled with low-order explosive.

have occurred in those inadvertently picking up thedevices, or when the device explodes prematurely, whilst being thrown. The pattern of the injuries sustained in such cases is clearly important in determining the innocence or guilt of the casualty.

### Nail Bombs

These small devices were also intended to be thrown by hand at a target, possibly a member of the security forces or a group of rioters from an opposing faction. The construction involved a small explosive charge wrapped in corrugated cardboard and containing numerous long nails. Those close to the point of detonation could sustain serious or even fatal injuries due to being struck and impaled by the contents of the device.

### Mortar Bombs

These devices consist of metal cylinders packed with explosive and are designed to detonate on impact with their intended target. They are usually launched from firing tubes constructed on the back of an open lorry or a van fitted with a false roof. The advantage of this moving firing point is that it can be located relatively close to even a "protected" target and then abandoned, allowing the terrorists to make their escape before timed detonation occurs. The mortars may travel up to about 200 m but are inherently inaccurate and frequently fail to detonate on impact. It is not unusual for such devices to miss their intended target such as a police station or military camp by a long way, and instead explode in an area populated by civilians.

## Conclusion

Terrorist violence, that is, violence perpetrated for political objectives, is now common throughout the world. It often has the sympathy, if not the active support, of large sections of the communities in which it occurs and such support frustrates the activities of the security forces in trying to apprehend the perpetrators and bring them to justice. It is often directed against the establishment, either the government or its law enforcement agencies. Doctors who examine the injured and pathologists who examine the dead are usually doing so in an "official" capacity and thus their impartiality may be called into question. Furthermore practitioners in some jurisdictions may feel pressurized into modifying or amending their findings to suit their authorities. To maintain credibility, it is essential that doctors undertaking this work do so in a scrupulously objective manner. All such work must be meticulously detailed and findings properly recorded for evidential purposes. The reports prepared, and the opinions offered, in such cases must be scrupulously fair and unbiased and unaffected by personal prejudice or partisan pressure of any kind. Finally, reports that are to be used in evidence for criminal proceedings must tell not only the truth but also the whole truth.

## See Also

**Terrorism:** Medico-legal Aspects; Nuclear and Biological; Suicide Bombing, Investigation

## Further Reading

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# Firearm Injuries

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## Introduction

Firearm wounds are a common form of trauma in many parts of the world. The accurate interpretation of these wounds is important for clinical management in the living and for medicolegal reasons in both the living and the dead. Studies in the USA and

South Africa, countries with high incidences of firearm injuries, have shown that major inaccuracies in the interpretation and documentation of firearm wounds by trauma doctors are common. An understanding of terminal ballistics and especially the nature of wounds left on the body by firearm projectiles is essential if medicolegal evidence relating to firearm injuries is to be accurate and reliable.

## Classification

Firearm wounds can be classified according to the nature of the weapon, range of fire, and whether entry or exit. An examination of wounds should, in most instances, allow important information regarding their classification as well as the direction of fire to be determined (Table 1).

### Gunshot Wounds

The most commonly encountered weapons with rifled barrels that fire individual projectiles in civilian practice are handguns (pistols and revolvers), although hunting and assault rifles are not uncommon in many parts of the world. In terminal ballistic terms, such weapons produce gunshot wounds (as opposed to shotgun wounds, which are described later).

**Table 1** Factors that may be determined by firearm wound examination

1. Confirmation that the wound is a firearm wound
2. Number of shots that struck the body
3. The nature of the weapon and ammunition
   a. Rifled weapon (handgun or rifle)
      i. Low- to medium-velocity
      ii. High-velocity
   b. Shotgun
4. The range of fire
   a. Contact
      i. Hard contact
      ii. Loose contact
   b. Near
   c. Intermediate
   d. Distant
5. Entry or exit wound
   a. Atypical features
6. The direction of fire

**Entry gunshot wound** The appearance of an entry gunshot wound is dependent on many factors, including the type of firearm, ammunition, distance of fire, angle of impact, passage through intermediate objects, stability of the projectile, and area of the body struck. This allows interpretations to be made from examination of the wounds (Table 2).

When a handgun or rifle is fired, it is not only the projectile (bullet) that is propelled from the barrel; also emerging from the end of the barrel are flame, vaporized metal, gases, smoke and soot, and burning and unburned particles of propellant powder. These all have greatly varying densities and travel different distances from the weapon. An appreciation of the effects of these components on the surface of the body of a victim of a gunshot wound is important in assessing gunshot wounds (Table 3).

*Distant gunshot wound* A distant gunshot wound is one that is fired from a range where only the bullet leaves a visible sign on the skin. In other words, there

**Table 2** Differentiating typical entry and exit gunshot wounds. It is important to note that no single factor is pathognomonic or always present, and all features are seldom present together

| *Entry wound* | *Exit wound* |
|---|---|
| Abrasion collar | No abrasion collar |
| Regular round to oval ''punched-out''' defect | Irregular lacerated defect |
| Inverted skin edges | Everted skin edges |
| Smaller than bullet diameter and exit wound | Larger than entry wound |
| Features of close-range fire | No features of close-range fire |
| Grease wipe on inner edge | No grease wipe |
| Increased carbon monoxide in tissue | No increased carbon monoxide |

**Table 3** Range of gunshot wounds

| *Range* | *Distance (handguns)* | *Distance (rifles)* | *Features* |
|---|---|---|---|
| Contact | 0 cm | 0 cm | Central defect with abrasion collar<br>Muzzle imprint<br>Searing and blackening<br>Stellate wound over bone |
| Near | $<$1 cm | $<$1 cm | Central defect with abrasion collar<br>Searing and blackening<br>Concentrated tattooing |
| Intermediate | 1–65 cm | 1 cm–1 m | Central defect with abrasion collar<br>Tattooing<br>$\pm$Blackening |
| Distant | $>$65 cm | $>$1 m | Central defect with abrasion collar |

is no effect from the other products of discharge, such as propellant powder or soot. The actual distance is variable and dependent on factors such as the type of weapon, length of barrel, velocity, and bullet loading. In general terms, distant wounds for handguns may be considered as those fired from greater than 40–75 cm. For rifles, the range is usually greater than 60–100 cm. No other deductions about range can be made beyond these distances.

The typical entry gunshot wound has a neat round to oval defect with a punched-out appearance and inverted skin edges (Figure 1). The size of the entry wound is usually slightly smaller than the diameter of the bullet and, in cases of wounds from some high-velocity rifles, it may be considerably smaller. There is usually a narrow surrounding collar of abraded skin. This is formed as the bullet strikes the skin, forcing it inward until the elasticity is exceeded and the skin tears, with the edges being abraded by the penetrating projectile. If the bullet strikes the skin perpendicularly, the abrasion collar will be concentric. If the entry is angulated, the abrasion collar will be eccentric and widest at the edge in the direction from which the bullet entered (Figure 2). This provides information about the direction of fire relative to the body. This factor cannot be considered reliable in areas of loose skin or pendulous parts of the body because there is no way of knowing their position when the bullet struck. Abrasion collars may be absent, especially where the skin is taut and in some high-velocity wounds. A grease wipe from the bullet may be present on the inner aspect of the wound, although this is not constant.

*Intermediate-range gunshot wound* Intermediate-range wounds are characterized by the effect of propellant powder grains on the skin surrounding the central hole caused by the bullet. The appearance of the central wound is the same as in distant wounds. Burning and unburned propellant powder grains impact the skin, causing superficial fine discrete punctate lesions, commonly referred to as powder tattooing or simply tattooing (Figure 3). In antemortem

**Figure 1** Entry gunshot wound with a neat round central defect and surrounding abrasion collar.

**Figure 2** Multiple-entry gunshot wounds showing central defects and concentric and eccentric (bottom right) abrasion collars.

**Figure 3** Intermediate-range gunshot wounds with central defects surrounded by powder tattooing. The upper wound shows more concentrated tattooing than the lower one.

wounds, vital reaction causes tattooing to have a reddish-brown appearance. Postmortem desiccation causes the lesions to darken. The lesions cannot be wiped away. Occasionally, unburned powder grains may be present on the surface of the skin within the zone of tattooing.

The distribution of tattooing is influenced by the angle of impact of the gunshot. In perpendicular strikes, the distribution will be concentric around the central bullet wound. In angulated strikes, the distribution will be eccentric with the greater diameter furthest from the barrel. The pattern of tattooing may also be affected by intervening objects, such as clothing or jewelry, between the propellant powder and skin.

The actual range of fire in intermediate-range wounds varies depending on the type of weapon, velocity, cartridge loading, and physical nature of the propellant powder. For handguns, tattooing is usually present up to maximum distances of 40–75 cm. Where tattooing is present, a useful generalization is that the shot was fired from within an arm's length. For rifles, the maximum distance for intermediate-range wounds is 60–100 cm.

Not all gunshot wounds in the intermediate range will show tattooing. Tattooing may be absent due to intervening objects, such as clothing or dense hair. Tattooing may also be present on areas of the body that were distant from the entry wound but were adjacent when the shot was fired, such as on a hand held up to the area of wounding.

*Near-contact gunshot wounds* Near-contact gunshot wounds (or "near wounds") occupy a gray zone between contact and intermediate wounds. In near wounds, the flame and soot expelled along with the bullet impact on the surrounding skin. This produces a zone of soot blackening overlying seared skin surrounding the central bullet wound (Figure 4). The blackening, but not the searing, can be easily wiped away. Concentrated tattooing is also present but is often not apparent due to the searing effect of flame on the skin. Hair may be singed, but this is an unusual finding, probably due to hair being displaced by the expelled gas.

In angled near wounds, soot radiates out from the barrel, causing a pear-shaped area of blackening with the larger area on the side nearer the barrel (in contrast with angled loose-contact wounds) (Figure 5).

*Contact gunshot wounds* Contact gunshot wounds may be tight, where the end of the barrel is held with pressure against the skin, forming a seal even during firing, or loose, where the expelled gas forces a gap between barrel and skin, allowing the escape of some

**Figure 4** Near gunshot wound with a central defect, searing of the skin, soot blackening, and concentrated tattooing. Some unburned powder granules are present on the wound surface.

**Figure 5** Near-entry gunshot wound with a central round defect and extensive surrounding blackening.

products of discharge. In both forms of contact wounds, the bullet will perforate centrally.

In tight-contact gunshot wounds, the barrel may leave an imprint abrasion (Figure 6). The skin within the circumference of the barrel will be seared and blackened. Except in cases where the wound is over superficial flat bone (skull, sternum, and scapulae), the bullet defect will resemble that at other ranges. Where the entry is over superficial bone, gas is forced under the skin and reflected off the bone, blowing the

**Figure 6** Tight-contact entry gunshot wound with a muzzle imprint, seared wound margins, and blackening within the wound.

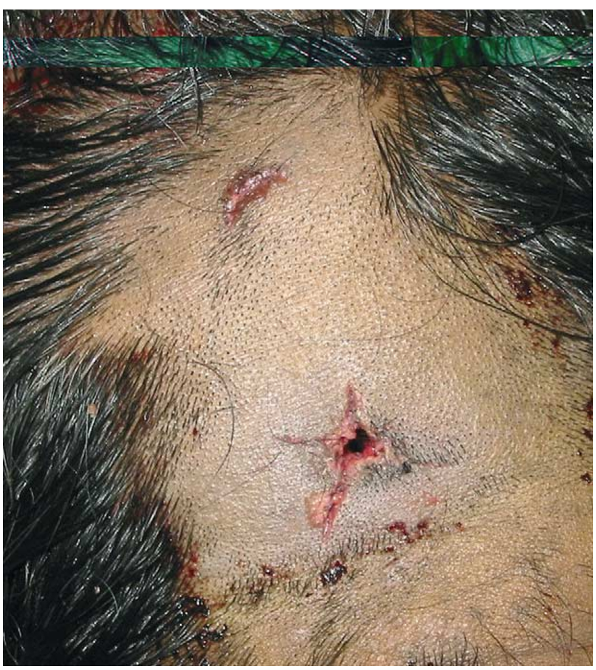

**Figure 7** Contact gunshot wound over bone with a stellate laceration (lower wound). A crescentic laceration caused by the expelled cartridge case is also seen (upper wound).

skin away from the bone and causing a large irregular stellate laceration (Figure 7). In such cases, there is usually blackening of the underlying subcutaneous tissues, including a rim surrounding the entry fracture defect on the outer table of the bone.

Loose-contact gunshot wounds are characterized by a narrow surrounding zone of searing and blackening. A variant is the angled-contact gunshot wound, where gas and soot escape from the side of the barrel not in tight contact with the skin, causing an eccentric

**Figure 8** Loose-angled contact gunshot wound with an incomplete muzzle abrasion and eccentric blackening and searing of the skin.

area of blackening and searing (Figure 8). The larger diameter of this zone will be on the side opposite the angled barrel.

In some contact wounds from pistols, a 5–10-mm crescentic laceration is found within a few centimeters of the entry wound. This is caused by the expelled cartridge case striking the skin.

*Atypical gunshot wounds* Anything that causes the bullet to be unstable or tumble in flight may cause the entry wound to appear atypical (Figure 9). This most commonly occurs when the bullet has passed through an intermediary target or ricocheted off another surface before entering the body. This includes a reentry wound from a bullet that has perforated another part of the body. Such entry wounds may be irregular and unusually large, with an irregular, eccentric abrasion ring.

Another effect of a bullet perforating an intermediary target is the possible impact of fragments of that target on the skin, modifying the appearance of the entry wound. Multiple small fragments, as arise when a bullet passes though safety glass, may cause superficial lacerations around the entry wound and these are referred to as pseudotattooing (Figure 10). Pseudotattooing is distinguished from powder tattooing by its usually larger and more irregular appearance.

**Exit gunshot wounds** Exit gunshot wounds may vary greatly but are mainly differentiated from entry wounds by their more irregular, lacerated appearance (Figure 11). The wound edges may be everted. Exit wounds typically do not have an abrasion collar or grease wipe. Exit wounds are usually larger than

**Figure 9** Atypical-entry gunshot wounds with irregular shapes. The top and middle wounds on the right mirror the profile of bullets, indicating that the bullets struck the body side-on.

**Figure 10** Atypical-entry gunshot wound with pseudotattooing. A shrapnel fragment is seen at the bottom right.

**Figure 11** Exit gunshot wound with irregular shape and lacerated margins.

entry wounds, but this is highly variable and a poor discriminant on its own.

*Atypical exit wounds* Occasionally, an exit wound will show a broad surrounding area of abrasion. This occurs when the bullet exits through skin pressed against a firm object, such as a belt or backrest of a chair. This is referred to as a shored exit wound (Figure 12). Another atypical form of exit wound is the incomplete exit wound where the bullet lacerates the skin but is trapped and lodged within the skin wound. Occasionally, a single bullet may produce more than one exit by fragmentation of either the projectile or bone, producing secondary projectiles of metallic or bony fragments.

**Determining the direction of fire** In single perforating gunshot wounds, the direction of fire can be readily determined by differentiating between the entry and exit wounds. If there is no exit wound, the direction may be inferred from the form of the abrasion collar surrounding the entry wound, but the wound track in the body is also an important factor to be considered. Difficulties may arise where there are

**Figure 12** Atypical incomplete and shored exit gunshot wound with the bullet seen within the wound. The edges of the wound are abraded.

multiple gunshot wounds, and it is not always possible to match each entry with its own exit wound. General directions of fire, however, can usually be deduced. It must be remembered that the description of gunshot directions relative to the "anatomical position" typically used in diagrams seldom reflects the position of the body in real life, which is often quite dynamic and should be correlated with evidence from the scene of the shooting.

### Shotgun Wounds

A shotgun fires multiple lead pellets (shot) from a smooth-bored barrel, and these pellets emerge as a compact mass that spreads out as the distance from the barrel increases. As with gunshots, similar accompanying components are expelled along with the shot. In addition, wads and occasionally fragments of the cartridge case are also expelled (Table 4). A wad is a disk-shaped piece of plastic, cardboard, or felt that separates the pellets from the propellant powder. In some modern shotgun cartridges, a plastic cup replaces the wad. All these components may contribute to a shotgun wound. It must be remembered that clothing may markedly alter the appearance of wounds at closer ranges.

**Table 4** Components of a shotgun discharge contributing to wounds

1. Pellets
2. Soot
3. Burning and unburned propellant powder
4. Flame
5. Hot gases, including carbon monoxide
6. Wads
7. Cartridge case fragments
8. Primer

**Entry shotgun wounds** The differentiation of entry from exit shotgun wounds is usually obvious in that, in most cases, due to the relative low velocity and mass of individual pellets, the shot does not exit the body. The most important deduction to be made from the wound is the estimation of range. The differential distances that the constituent components of a shotgun discharge travel as well as the dispersion of the pellets are used for this purpose. The choke of the shotgun influences the rate of dispersion of the pellets; thus, test firing of individual weapons is necessary for accurate range estimations, especially for distant wounds (Table 5).

**Table 5** Range of shotgun wounds

| *Range* | *Distance* | *Features* |
|---|---|---|
| Contact | 0 cm | Single round hole<br>Stellate wound over bone<br>Muzzle imprint<br>Minimal blackening and searing<br>Wad in wound |
| Near | <15 cm | Single round hole<br>Soot blackening and searing<br>Wad in wound |
| Intermediate | 15 cm–2 m | Central round or crenated wound<br>Satellite pellet holes<br>Tattooing<br>Wad may be in wound |
| Distant | >2 m | Central hole (up to 6–10 m)<br>Satellite pellet holes |

*Distant shotgun wounds* Distant shotgun wounds are those in which only the pellets penetrate the body. In some cases, up to about 5 m, the wad may still strike the body, causing a laceration, abrasion, or contusion below the entry wound. Modern plastic cups usually open in flight, forming a cross shape, and on impact may leave a distinctive Maltese cross or flower petal-patterned abrasion or contusion. At distances of up to 10 m, sufficient pellets may still form a central mass to cause a larger central hole, with surrounding small satellite holes caused by dispersed individual pellets (Figure 13). As the range increases, the central hole will disappear and the entry wound will consist only of individual pellet holes. The diameter of dispersion of these pellet holes can be used to estimate the range by comparison with test firing the same weapon using similar ammunition. When this cannot be done, rule-of-thumb estimation can be used, but its accuracy is poor.

**Figure 13** Distant-entry shotgun wound with individual pellet holes but still showing central clustering.

Every 2.5 cm of spread is said to be equivalent to approximately 1 m of range (or 1 inch of spread for 1 yard of range).

*Intermediate-range shotgun wounds* Powder tattooing and a central wound with scalloped edges and surrounding satellite wounds characterize intermediate-range wounds. Tattooing is usually less dense than that seen in handguns due to more complete combustion of propellant powder. The maximum distance at which tattooing is seen varies with the weapon and type of powder, but tattooing is seldom present beyond 1 m.

As the central mass of pellets begins to disperse, entry wounds have a large central defect, the edges of which appear scalloped, looking somewhat "rat-nibbled" or resembling the pattern of a cookie cutter. As the range increases, some pellets make individual holes in a rim surrounding the central hole.

Blackening from soot may be present at the lower end of intermediate-range wounds, but it is usually not present beyond 30 cm. The wad is usually present within the wound track.

*Near shotgun wounds* Shotgun wounds from a range of less than about 15 cm usually have a single circular hole with a smooth, or occasionally slightly scalloped, margin (Figure 14). Obliquely angled wounds may be oval. Concentrated powder tattooing, blackening, and singeing of the surrounding skin and hair are present. The wad is usually in the wound track.

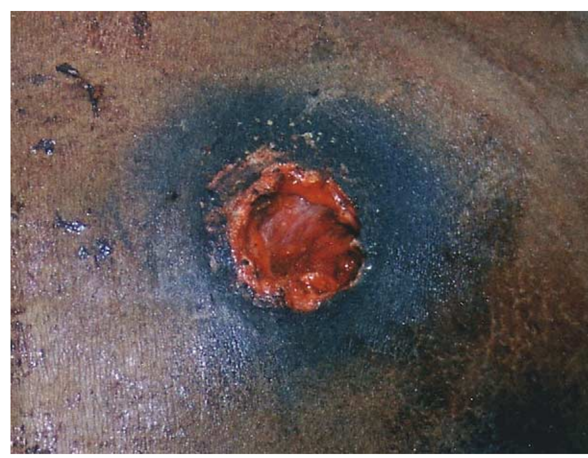

**Figure 14** Near-entry shotgun wound showing a single large central defect with scalloped edges and surrounding searing and blackening of the skin.

*Contact shotgun wounds* When a shotgun is fired with the barrel held against the body, a single round wound approximately the size of the bore of the weapon is produced. If the contact entry is over flat bone, as in the head, the entry wound is large and stellate due to tearing of the skin by the large amount of gas forced into the wound and reflected off the skull. Contact shotgun wounds of the head are typically very destructive.

In tight-contact wounds, a muzzle imprint may be visible and this is incontrovertible evidence of a contact wound. Soot blackening and searing are minimal unless the contact is loose, allowing some escape of flame and smoke on to the surrounding skin. Carbon monoxide in the gases of discharge may bind to myoglobin in the wound, giving the entry wound a characteristic pink coloration.

**Exit shotgun wounds** Exit wounds are uncommon, particularly in the trunk, due to the relatively low energy of individual pellets. Exit wounds are more common in children, in limb wounds, and in contact wounds of the head. Where they are present, the appearances are similar to those found in bullet exit wounds.

### Rubber and Plastic Baton Rounds

Rubber and plastic baton rounds (bullets), which are typically used in riot-control situations, produce blunt-force injuries on impact. Rubber baton rounds cause contusions, whereas plastic baton rounds produce a characteristic wound with a discrete annular abrasion and a smaller abrasion at the center. When fired at close range, lacerations with or without penetration of the projectile and underlying fractures may occur.

### Air Guns

Wounds from air guns that fire single-shaped pellets are usually small punctures resembling the individual entry of a shotgun pellet. An abrasion ring may be present. Because there is no propellant powder used in the weapon, no features of singeing, blackening, or tattooing are present, even in close-range wounds. Exit wounds are rare and when present will also resemble those of shotgun pellets.

## Documentation and Forensic Interpretation of Firearm Wounds

The priorities of clinicians and forensic pathologists obviously differ when examining gunshot wounds, with the clinician's first responsibility being the treatment of the patient. However, the clinician may at a later date be expected to give testimony regarding the description and interpretation of the wounds. Hence, it is important for clinicians to recognize and accurately document wounds and their characteristics. Even if it is not possible to record all details of the wounds, a sketch of the positions, shapes, and approximate sizes of wounds can provide valuable information for later interpretation by experts. The presence or absence of features of close range should be noted. It must be remembered that one feature, soot blackening, is transient and can easily be washed away. Photography of wounds is an ideal and practical way of recording evidence that enables later examination by others.

### Surgically Altered Wounds

After firearm wounds are surgically altered, such as by debridement or suturing, they may lose many or all of their characteristics, making subsequent interpretation difficult or impossible. The initial examination notes may be all that subsequent evidence can be based on.

Some deductions about entry and exit, and therefore direction of fire, may be made from internal examination when bullet fragments are present or when bone is involved in the wound track. Splinters from bone fractures may be displaced in the direction of the bullet tract. In gunshots perforating the skull, entry and exit fractures typically have different appearances. As a bullet perforates the two tables of bone that comprise the cranium, it lifts a circular rim of bone off and away from the table on the side of the direction of travel, leaving a beveled rim. Thus, entry gunshot fractures are beveled on the inner skull table, whereas exit fractures are beveled on the outer skull table.

## Clothing

Clothing may significantly modify the appearance of firearm wounds on the body by trapping some components of firearm discharge. If ignored, erroneous conclusions may be made from the examination of wounds on the body. The examination of clothing should be an integral part of the examination of any firearm wound.

## See Also

**Ballistic Trauma, Overview and Statistics**

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# Sharp and Cutting-Edge Wounds

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## Introduction

Sharp-force injuries are those injuries by any weapon or implement with cutting edges or points (e.g., knives, scissors, glass). The injuries may be classified into either incised, where the cutting edge runs tangentially to the skin surface, cutting through skin and deeper anatomical structures, or stab, where the sharp edge penetrates the skin into deeper structures. An incised wound is generally longer than it is deep, whereas a stab wound is deeper than it is wide. Forces required to cause sharp injuries and the effect of such injuries are variable as a very sharp pointed object may penetrate vital structures with minimal force. The same implement may be capable of causing both stab and incised injuries, and a victim may present with a mixture of the two. Some injuries are not capable of being divided clearly into the stab or incised category, but may exhibit features of both.

## Incidence

Generally injuries most frequently seen in those survivors and fatalities of sharp-force injuries are caused by implements such as knives and less commonly broken glass, although any type of agent with a sharp edge or point can cause such wounds. The type of implement varies between countries and cultures and in certain settings other implements such as axes or machetes (which may combine a sharp or sharpish edge with a heavy weight and blunt surfaces) may be used. These may produce injuries that have both sharp-force and blunt-force elements – the term "chop" wounds is sometimes applied. Sharp-force trauma, mainly resulting from the use of knives, is a common cause of nonfatal injury and is seen increasingly in emergency and trauma centers. In England and Wales the most common method of killing remains killing with a sharp instrument (2002–2003) – 27% of homicide victims were killed by this method. The sites of injury in a study of wounds from penetrating injuries in the 1990s from Glasgow showed a range of sites of wounding, with head, chest, and arms predominating (Table 1).

## Wound Characteristics

Stab and incised wounds are generally differentiated by the fact that stab wounds are deeper rather than wider because of the mode of contact with the body, namely thrusting the knife by one means or another into the body. Incised or stab injuries are caused by the knife moving tangentially across the skin surface. This definition is of use when the dimensions of a wound can be properly assessed, for example, at autopsy. In the living victim, treatment within hospital may not properly document the size of wound prior to exploration or closure, or the depth of wound following exploration such as laparotomy or thoracotomy. Interpretation of such injury can become difficult. Figure 1 shows a scar following a stab wound to the neck. The operation notes did not detail the depth of penetration, no major structures were damaged, and persistent bleeding was shown to originate from a small unnamed artery. The line indicates the original stab wound.

The operation scar which extended the initial stab wound obscured detail, and no documentation had been made of the preoperative wound characteristics. Such issues become very relevant in court cases where a charge of attempted murder may be argued on the perceived depth of penetration of a knife (and by inference the force used to create the wound). It is in situations such as this that proper documentation of injury, pretreatment, within the nonforensic primary care and trauma settings, can be extremely helpful.

It should also be appreciated that a knife, glass, or other object or fragment with a sharp edge is capable of producing a cleanly cut wound resulting in a stab or an incision. Perhaps the most common error that nonforensic personnel make is using the term laceration (skin splitting or tearing after blunt-force injury) for an incised or stab wound when describing a "cut" which they have treated. "Cuts" may

**Table 1** Distribution of wounds by body region

| *Body region* | *Percentage of all wounds* |
|---|---|
| Head (face and scalp) | 22.3 |
| Neck | 6.5 |
| Shoulders | 2.7 |
| Chest | 22.3 |
| Abdomen | 12.4 |
| Groin | 1 |
| Thighs | 7.9 |
| Buttocks | 4.9 |
| Arms | 19.9 |

Modified from Bleetman A, Watson CH, Horsfall I, Champion SM (2003) Wounding patterns and human performance in knife attacks: optimising the protection provided by knife resistant body armour. *Journal of Clinical Forensic Medicine* 10: 243–248.

**Figure 1** Scar following a stab wound to the neck (line indicates site of wound, remainder of scar is due to surgical intervention).

be divided into those caused by blunt-impact injury – lacerations – and those caused by sharp implements or edges – "incisions" or incised-type and stabs. The distinction between incised wounds, stabs, and lacerations is of the greatest importance medicolegally as causation (blunt impact or sharp implement) is often the key to the outcome of a case. Although in clinical treatment terms this is a minor issue, it can be extremely relevant in the medicolegal and forensic setting. Lack of understanding of the difference and its significance between lacerations and sharp-force wounds is probably the most common mistake made by nonforensic doctors at all levels when providing statement or reports for courts.

Heavy implements with a sharp surface such as an axe or machete result in a combination of cutting injuries associated with crushing of underlying tissue and frequently fractures if there is underlying bone. Sometimes, however, a lacerated wound is the predominant component rather than a clean-cut wound.

## Lacerations versus Sharp-Force Cuts

Lacerations are caused by blunt-force impacts compressing and splitting the skin, or occasionally by shearing force. Lacerations most commonly occur where underlying bone is prominent – classically at the orbital margin. After treatment, that is, suture or gluing, it is often impossible to distinguish between a laceration and an incised wound, which is why adequate documentation before treatment is essential. The most significant difference that can distinguish between lacerations and incised wounds is that incised wounds have clean distinct edges. Lacerations may have macroscopically clean and distinct edges, but not under magnification. Generally lacerations have irregular or macerated edges – residual skin bridging (particularly at the ends) – and may have other features of blunt-impact injury associated, e.g., swelling, reddening, and bruising. Figure 2 shows a small laceration with associated swelling and irregularity of the wound edge after a punch to the face.

**Figure 2** Small laceration with associated swelling after punch to face.

**Figure 3** Fingers of a male after having broken a window with a punch with his hand.

## Incised Wounds

Incised-type wounds may be caused by anything with a sharp edge, including knives and broken glass. If glass breaks at the time of impact, multiple cuts from sharp glass shards may be seen. Figure 3 shows the fingers of a male arrested for breaking into a house, having broken a window with his hand. The illustration shows multiple small incised wounds.

Incised wounds crossing irregular surfaces may be irregular in depth, but their linearity will assist in confirming causation. Figure 4 shows the dorsum of a hand across which a sharp knife had been drawn.

Assaults with broken glasses or bottles are commonly seen in emergency medicine, maxillofacial, and plastic surgery clinics. The characteristics of such injury are multiple irregular incised-type wounds of variable depth and severity. Figure 5 shows a male who had a broken bottle thrust in his face. The wound edges are all clean with no skin bridging, confirming that sharp edges caused these injuries.

Figure 6 shows another typical “glassing” injury after treatment and suture: the wounds were much more superficial and irregular. This particular injury was caused when an intact glass was thrust to the side of the face, breaking on impact.

**Figure 4** Dorsum of a hand and fingers across which a sharp knife had been drawn.

**Figure 5** Male who had a broken bottle thrust in his face.

Figure 7 is another example of the type of injury seen when an intact glass object is impacted on the face, breaking on impact. The periorbital hematoma and the cut indicated by the arrow which is more likely to represent a laceration is caused by the (blunt) impact of glass striking, and the multiple incised-type wounds are caused by the pieces of broken glass after breakage.

**Figure 6** Typical ‘‘glassing’’ injury after treatment and suture.

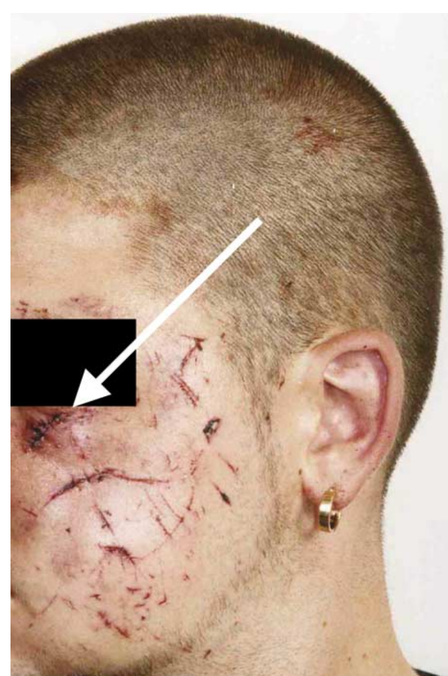

**Figure 7** Face of a male after an intact glass object broke on impact on the face.

With glassing injuries it is extremely important to try and identify from witness accounts and examination of the scene whether the glass or bottle was broken prior to impact, or on impact. Issues such as these become extremely important in court cases where intent (to maximize injury) may be determined on the interpretation of the injury patterns.

Sharp blades may have features of their own which give rise to a patterned appearance. Figure 8 illustrates the sutured incised wound of a male who alleged he had been assaulted with a serrated bread knife. This was confirmed by review of the injury where a repeated regular pattern could be observed along the length of the scar, which matched exactly with the serration pattern on the bread knife used in the attack.

Heavy weapons with sharp blades (e.g., meat cleavers, machetes, swords) are capable of causing major injury with damage to soft tissues and bone.

A mixture of blunt and sharp injury may be present and lacerations and incised wounds may be evident. Slash wounds ("slicing" or "striping") may be caused by the above implements with the intention of killing or simply disfiguring. Often the face is the target. Stanley knives, razor blades, and other very sharp instruments may be used, creating clean cuts that can be repaired surgically but leave clean scars. Figure 9A shows a scar that was repaired surgically from a wound in which a sharp blade was used. The continuity across irregular surfaces indicates that pressure must have been applied throughout the length of the injury.

Figure 8 Sutured incised wound after assault with a serrated bread knife.

Figures 9B and 9C show the initial appearance of a wound caused by a single blade slash cut across the face and the subsequent appearance after suture. Clearly there is a difference in emotive value between the two injuries and it is for the forensic examiner to make clear to the court the seriousness or otherwise of injuries that are sustained during assaults.

Figure 10 shows scarring following a serious assault with a machete about 1 year previously. The victim did not attend hospital and simply dressed the wounds until healed.

Death and loss of body parts may be the result of chop wounds. Compound fractures have been described – the term "bony laceration" has been used, although "bony incision" may be a better term.

Certain incised wounds have particular medicolegal relevance. These are incised wounds to the neck, wrist, and specific wounds to other parts of the body.

## Incised Wounds in Specific Sites

### Neck

Incised wounds to the neck are generally either homicidal or suicidal and only occasionally accidental. Accidental wounds are seen particularly in traffic accidents where such injuries are caused by fragments of glass.

The distinction between homicidal and suicidal wounds can be difficult and sometimes unascertainable at autopsy alone. It is essential before an



Figure 9 (A) Scar caused by a sharp blade that was surgically repaired. (B) The initial appearance of a wound caused by a single blade slash cut across the face and (C) the subsequent appearance after suture.

**Figure 10** Scarring following an assault with a machete about 1 year previously.

opinion is given that account is taken of the circumstances surrounding the deceased's movements shortly before death, his/her personal history, and a thorough examination of the scene of discovery of the body.

There are a number of characteristic features in terms of appearance and distribution of incised neck wounds that may be of assistance to the pathologist in making the distinction between self-infliction or attack by an assailant. When made by right-handed individuals, self-inflicted injuries normally begin high on the left side of the neck and pass downward across the front to end on the right side. They are deeper at their origin and then tail off on the right. Such wounds may also be horizontal, lying across the front of the neck. They are usually linear and clean-cut, since the skin is likely to be put under tension. Separate shallow wounds, "tentative" or "hesitation" wounds, are strongly indicative of self-infliction. There may be associated incised wounds to the wrist or occasionally elsewhere. There may be evidence of healed self-harm scars indicating previous attempts at self-harm. Some self-inflicted incised wounds may be extremely deep, extending as far as a and leaving score marks on the cervical vertebrae.

As a rule, homicidal wounds do not have the more organized "planned" appearance of self-inflicted wounds and are unaccompanied by tentative injuries, but may be frequently accompanied by incised wounds that are difficult to interpret without accompanying obvious self-inflicted injuries. Generally, homicidal wounds are more haphazardly placed on the neck and, in some cases, have more irregular edges. In addition such wounds tend to be deeper, although this is by no means invariably so. Accompanying stab wounds may also be present on the neck and other parts of the body, as well as defense cuts to the backs of the arms and hands. There may also be noncutting injuries to the body which may have contributed to the cause of death.

Accidental incised wounds may be caused by glass in road traffic accidents. Such wounds are frequently accompanied by numerous small abrasions from glass fragments and particles of glass may be found in wounds if carefully searched for.

### Wrists

Multiple and commonly parallel incised wounds to the ventral aspect of the wrist and lower forearm are typical of self-inflicted injury as a means of deliberate self-harm. They frequently accompany other self-inflicted cutting wounds to other parts of the body and often old healed wounds may be evident. Although the victim may be aiming to sever a major artery in the wrist, usually the resulting wounds are more superficial. Incised wounds to the dorsal surface of the wrists are occasionally seen in cases of self-inflicted injury but, depending on their number and distribution, they may well be defensive injuries.

### Other Sites

Planned incised wounds to various parts of the body, including the face and trunk, may well form part of torture, or of cultural rituals. It is important to distinguish these in those still living by inquiring of the individual, and in fatalities asking friends, family, or cultural experts to determine whether they are relevant to the death.

## Stab Wounds

Forensic pathologists and physicians are frequently asked to determine the degree of force used in homicidal and nonfatal stabbing. It is almost impossible to quantify in a precise way and therefore a more qualitative approach may be used. Generally, an impact with greater force is more likely to produce severe injury than an impact of lesser force.

There are a large number of factors or conditions that need to be taken into account when assessing injury severity. These factors range from and influence the movement of the knife up to the point of impact with the skin and from the skin to the point of termination and withdrawal from the body. These phases must be considered in conjunction with: (1) the properties of the knife; (2) the way the assailant delivers the blow, in terms of speed and direction; and (3) the movement or reaction of the victim to the assault. It is important to convey to the nonforensic investigator that this is a dynamic process that changes moment by moment. Table 2 summarizes the main factors to consider when assessing force required.

It was previously believed that, once the skin had been pierced, unless the knife impacted against bone, virtually no resistance was offered by the internal soft tissues, including the major organs. More recent work has suggested that the scenario is more complex than previously appreciated. It appears that once the skin has been pierced, significant resistance may be offered by the internal organs and other soft tissues. Once the knife has impacted on the skin and even after piercing it, there still needs to be a firm hand on the knife to push the weapon further into the body, because it has been slowed down by the resistance offered by the skin. In an accidental stabbing or where a knife has been thrown, less penetration into the body is to be expected. In the case of accidental stabbing, it is much more likely that, once resistance is offered by the skin, then there would not be a follow-through thrust, as in a deliberate movement. To produce such a further deliberate movement, the weapon would need to be anchored or held firmly. To produce impalement on to a knife there would need to be enough momentum by the victim moving toward the knife and it would need to be fixed firmly in some way. When a knife is thrown at a person, the main resistance will be by the skin, causing significant loss of its kinetic energy. Because there would be no follow-through, penetration into the body may not be deep because of the further resistance of the internal tissue.

Generally the best approach to assist those investigating such wounds is to advise that the force required is in the following range – weak, weak/moderate, moderate, moderate/severe, or severe.

**Table 2** Main factors influencing outcome of stabbing

| *Factor* | *Additional comment* |
|---|---|
| *Intrinsic properties of knife* | |
| Shape of knife | Including length, extent of blade, single blade/double blade/serrated blade, sharp tip, round tip, hilt? |
| Sharpness of knife | Razorsharp? Degree of sharpness? |
| Weight of knife | |
| *Delivery of blow by assailant* | |
| Velocity of thrust | Is force kept up throughout thrust? |
| Type/direction of thrust | Overarm, underarm? |
| *Movement of knife up to point of impact over which victim has influence* | |
| Clothing | Amount of clothing, body protector? |
| Movement of victim | Towards, away from, deflecting? |
| *Movement of knife through skin into body* | |
| Skin resistance | |
| Underlying organs | Fat, muscle, body cavity, bone, solid organs, e.g., liver? |
| Movement of organs | On respiration? |

### Wound Assessment

In a case involving sharp-force trauma, assessment of the injuries should take into account the following:

- the number of wounds
- their location and relationship to each other
- their character.

## Characteristics of Surface Wounds

Assessment of stab wound characteristics will frequently assist the forensic examiner in identifying the type of implement involved, its shape, size, and any possible individual features such as a broken or bent blade tip or anomalous serrations on the blade. Additionally review of possible implements will allow a determination of whether an implement was capable of causing the injury described. Figure 11A shows a piece of glass alleged to have created the wound seen on the thigh in Figure 11B. The depth of the wound was measured at operation and, even allowing for compression, the piece of glass was too wide at all relevant points to have been responsible for creating the wound seen in Figure 11B. The crime-scene officers were asked to look for and were able to identify the weapon that had caused the injury.

Stab wounds on the surface of the body may show a wide variety of morphological characteristics, depending on the type of implement used, cutting surface, sharpness, width, and shape of the blade. Most stab wounds seen in the UK result from knives with a single sharp-edged blade. Occasionally, broken glass, screwdrivers, and other pointed objects are used. Most stab wounds caused by knives tend to have clean-cut edges with one or both ends appearing pointed. If the blade is single-edged the nonpointed end may be either squared off or split (fishtail) in appearance. Figure 12 shows an example of a "fishtail" caused by a single-sided blade, although there is evidence to suggest that a double-edged blade moving

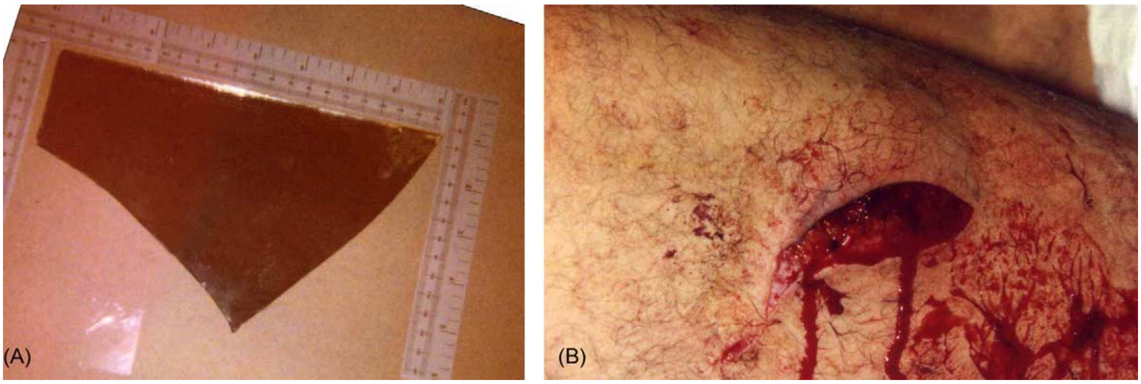


**Figure 11** (A) A piece of glass alleged to have created the wound (B) seen on the thigh.

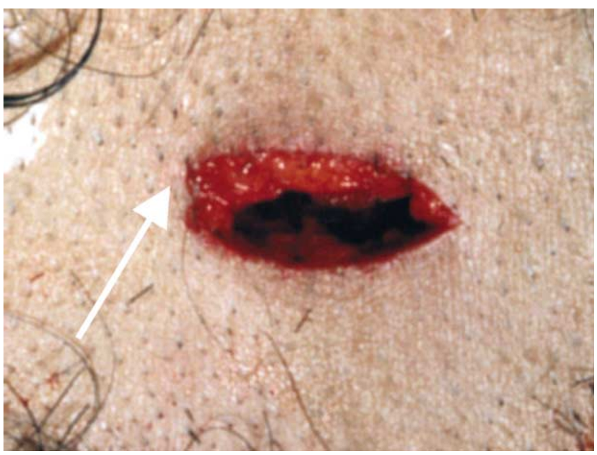

**Figure 12** A ''fishtail'' caused by a single-sided blade.

**Figure 13** A tangential stab wound to the crown of the head with underlying scoring of the cranium.

with rotational force in the wound may have created a similar appearance.

Figure 12 shows a stab wound caused by a knife with a single cutting edge. The right side of the wound is caused by the cutting side of the blade and the more ragged square/fishtail end, indicated by the arrow, is from the noncutting side.

A wound overlying bone, especially over the skull, requires care in its interpretation. It is not unusual to find a laceration of the skin resulting from a blunt impact having clean edges and a very similar superficial appearance to an incised or stab injury. The reason for this is that the skin, being close to a bony surface, becomes easily stretched during impact, thus tending to split cleanly. A thorough exploration of the wound to detect bridging tissue as one would observe within a laceration is essential. With sharp-force trauma one may see scoring by the weapon on the outer table of the skull. Figure 13 shows a tangential stab wound to the crown of the head with underlying scoring of the cranium. This can be confirmed at autopsy but may not be able to be confirmed in a living victim, and the differentiation between a laceration and an incised wound depends on accurate assessment of the cut itself and absence of associated blunt injury. However, with a "chop" wound it may be almost impossible to determine in the living.

Bruising may also surround the wound as a result of impaction by the hilt of the knife. Sometimes the wound may show abraded edges or a clear hilt pattern.

Often wounds show a notch or change of direction along the margin on the skin. This is caused by relative movement of the knife and the body during the stabbing action, thus causing the exit track of the wound to be slightly modified. Figure 14 shows a stab wound showing a slight central notch on its upper margin. The lower margin shows "shelving," with underlying tissue visible. Such wounds give the investigator an indication of the direction of the track of the wound.

Figure 15 shows a stab wound with a central notch giving the appearance of a V-shape, again caused by the dynamic movement of assailant, victim, and knife.

**Figure 14** A stab wound showing a slight central notch on its upper margin.

**Figure 15** A stab wound with a central notch.

## Other Information

There are a number of factors to assess in determining the mechanism of injury. Assessment of clothes has been referred to in relation to injuries caused by deliberate self-harm. In assault cases, careful examination of the defects of the items of clothing by a sharp weapon such as a knife and matching these up with the wounds on the victim can help in assessing the number of times the victim has been stabbed and the direction of the stab (Figure 12). Where possible – this is generally easier in the deceased victim than the living where clothes may have been cut off or discarded during first aid or resuscitation – the forensic examiner should take the opportunity to examine the clothing and the various tears produced by a knife, in conjunction with the wounds found on the body and the implement supposedly used. The number of cuts in clothes may not correspond to the number of wounds on the body. This may be for a number of reasons, including that the weapon may impact on an outer garment but not reach the skin, clothing may be folded, the knife may cause more than one cut from the same thrust, and clothing at the point of impact may not be present, for example, it may have been pulled away from its normal position for various reasons.

## Assessment of Wound Tracks

As with assessment of many injuries, detailed and accurate assessment is done better in the deceased victim than the living victim because treatment and repair may obscure information, and nonforensic personnel have different agendas when documenting the type of injury. Although the characteristics of a stab wound on the surface of the body give a great deal of information, as discussed above, it is desirable to examine the track of a particular wound, which can be done at autopsy, or to attempt to describe it anatomically in the living survivor.

Ideally the following factors should be determined or commented upon:

1. the direction of impact on to the body
2. the depth of an injury resulting from stabbing
3. the force used to inflict the injury, taking into account the various structures injured
4. injured structures and their bearing on morbidity and mortality
5. in cases of multiple stabbing, to assess which surface wounds are responsible for which internal injuries.

The depth, or more accurately, the length of the track of the wound may give some guidance as to the depth to which the blade of the knife has penetrated. Nevertheless, it should be appreciated that a number of factors affect the estimation of the length of the track, which first, is only an approximation and second, depending on the site, may be valueless in correlating with the length of blade that has penetrated the body. This is particularly the case with abdominal and neck wounds. In chest wounds one must allow for the elasticity of the ribs, especially in younger subjects.

Figure 16A shows external injuries following multiple stab wounds on the left side of the chest. The probe indicates the initial entry through the arm then to the chest wall. Figure 16B shows the track of the wound continued into the upper lobe of the left lung.

## Outcome of Injury

The forensic examiner needs to be able to interpret first, the injuries seen and second, the potential for

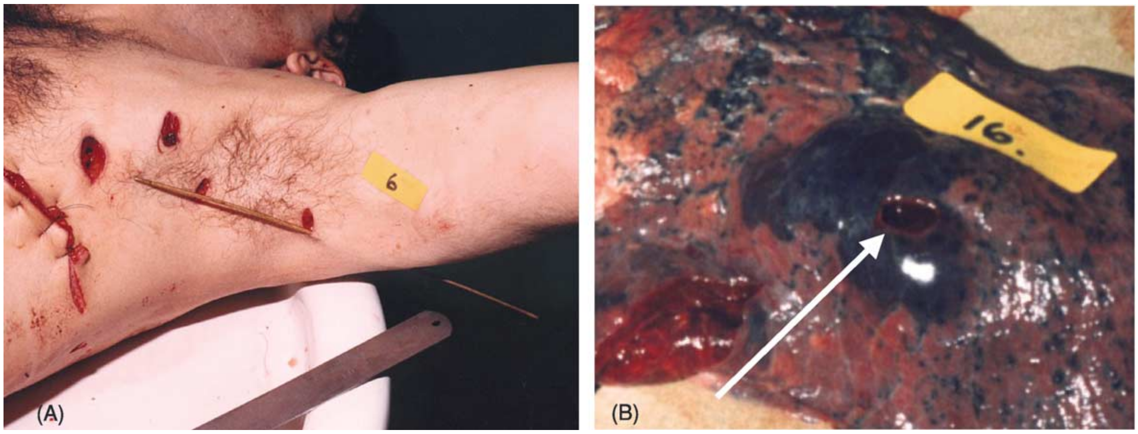


**Figure 16** (A) External injuries following multiple stab wounds on the left side of the chest; (B) the track of the wound continued into the upper lobe of the left lung.

injury that could have or might have been the outcome in both living and deceased. Table 3 identifies the potential outcome of even single sharp-force or stab traumas required to take into account the various possible effects of sharp-force trauma, including the impact of medical intervention on the overall outcome and possible contribution to morbidity and mortality. The list below is not intended to be comprehensive but includes the more recognized effects of sharp-force trauma – acute, subacute, and chronic.

Subacute and chronic complications include:

- infection
- loss of or diminished function
- aneurysm
- dissection
- ischemia
- fistula
- diaphragmatic hernia
- adhesions
- chronic inflammation.

**Table 3** Potential effects of sharp force trauma

*Acute effects include:*
- Hypovolemic shock from blood loss
- Tamponade
- Direct effect of injury to organ function, e.g. heart, spinal cord
- Air embolism
- Asphyxia from airway obstruction from hematoma
- Aspiration of blood
- Pneumothorax
- Hemothorax

*Subacute and chronic complications include:*
- Infection
- Loss of or diminished function
- Aneurysm
- Dissection
- Ischemia
- Fistula
- Diaphragmatic hernia
- Adhesions
- Chronic inflammation

## Defense Wounds

Certain types of injuries may be described as "defense" injuries. These are injuries that are typically seen when an individual has tried to defend him/herself against an attack, and are the results of instinctive reactions to assault. When attacked with blunt objects most individuals will attempt to protect their eyes, head, and neck by raising their arms, flexing their elbows, and covering the head and neck. As a result the exposed surfaces of the arms become the impact point for blows. Thus the extensor surface of the forearms (the ulnar side) may receive blows, as may the lateral/posterior aspects of the upper arm, and the dorsum of the hands. Similarly the outer and posterior aspects of lower limbs and back may be injured as an individual curls into a ball, with flexion of spine, knees, and hips to protect the anterior part of the body.

In addition to the above, in sharp-force attacks another natural reaction is to try and disarm the attacker, often by grabbing the knife blade. This results in cuts to the palm and ulnar aspect of the hand. On some occasions the hands or arms may be raised to protect the body against the stabbing motion, resulting in stab wounds to the defense areas, which in some cases may be through and through because of the sharpness of the blade. Figure 17 shows the palmar and dorsal surface of a hand and the sutured through and through cut where the victim had put his hand palmar surface out to ward off a knife attack. Note that the alignment is the same, confirming that this was from a single stab.

**Figure 17** The palmar and dorsal surface of a hand after a knife attack.

**Figure 18** Injuries to the palms and ventral surfaces of the fingers.

Figure 18 shows injuries to the palms and ventral surfaces of the fingers. Such wounds indicate that the victim tried to grab hold of the weapon between all the fingers with the thumb in apposition, or predominantly between the forefinger and the thumb.

In the latter situation care should be taken to differentiate between injuries caused by the knife slipping through the hand of the assailant holding a knife thus injuring his/her own hand, or from a genuine defense injury suffered by the victim.

The number of defense wounds tends to increase as the number of stab wounds to the victim increases and defense wounds in stab wound cases may be present in about 40% of victims.

## Homicidal versus Suicidal Stabbing

The assessment of any stabbing case requires great attention to detail, particularly where there is a possibility that the injuries may be self-inflicted. In the living victim it is easier to determine a relevant history but in fatalities there may be times when the two categories are difficult to distinguish on pathological grounds. The circumstances, appearance of the scene, and any background information play an important role in resolving the problem and the autopsy findings should all be examined, taking into consideration all these factors. Table 4 summarizes some of the factors that may differentiate between the two categories.

## Summary

Sharp-force trauma may present in many different ways, with both living and deceased victims. Living

**Table 4** Factors to assist in the differentiation between homicidal and suicidal stabbing

| *Factor* | *Homicide* | *Suicide* |
|---|---|---|
| *Scene* | | |
| Signs of disturbance | Likely | Very unlikely |
| Knife near body | Unlikely | Almost always |
| *Body* | | |
| Clothing pulled above wound | Unusual | Very common |
| Stab through clothing | Very common | Unusual |
| Single or very few deep wounds seen | Can be any number from one upwards | Common |
| Multiple deep wounds | Common | Uncommon |
| Body laid out neatly | Uncommon (unless restrained) | Common |
| Irregularly placed multiple wounds | Very common | Uncommon, tend to be in single region |
| Tentative wounds | Not seen (unless torture involved) | Common |
| Defense wounds | Common (almost half of cases) | No |
| Additional fresh marks of self-harm | No | Sometimes |
| Old marks of self-harm | Sometimes | Common |
| Location of injury in site accessible to reach | Possible | Commonly, chest, abdomen, neck, and wrist |
| Other types of injury (e.g., blunt impact) | Possible, particularly if there was a struggle | Unusual unless unrelated |

victims are able to provide accounts of what happened, but the characteristics of the injury may be poorly documented. For deceased victims the characteristics of the injury can be documented clearly, although the account of what happened may be lacking. In each case of sharp-force trauma, from the most minor to the most serious, accurate documentation, detailed review of available history, and interpretation of the findings with an understanding of the mechanism of injury will enable the investigators and courts to come to the most appropriate determination of outcome.

## See Also

**Deaths:** Trauma, Head and Spine; Trauma, Thorax; Trauma, Abdominal Cavity; Trauma, Musculo-skeletal System; **Deliberate Self-Harm, Patterns**; **Injury, Fatal and Nonfatal:** Blunt Injury; **Suicide:** Etiology, Methods and Statistics

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