SHARP EDGED AND POINTED INSTRUMENT INJURIES

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July 26, 2011

Introduction

In this article we will primarily discuss those injuries produced by sharp-edged instruments, incised wounds, and pointed instruments with a sharp-edge or edges, stab wounds. This will be followed by a discussion of chop wounds and those instruments without a sharp edge, but have a blunt point such as found on screwdrivers and barbecue forks. Impaled injuries will be discussed. Mechanism and manner of death will then be reviewed. Throughout this article there will be a brief discussion of terms, such as 'cardiac tamponade,' and cellular structures such as neutrophils in order to enhance understanding.

Lastly, there is considerable space devoted to a discussion of the chronological histological features for dating of incised or stab wounds, the purpose of which is to show there is sound scientific evidence for the histologic dating of these injuries.

Incised Wounds-General Information

An incised wound is one produced by the pressure and friction of an object with a sharp edge against tissue. Objects which can produce such injuries are straight edge razor, knives, glass, swords, axes, hatchets, meat cleavers, and bayonets. Typically, incised wounds are made with a slashing or cutting motion and are longer than they are deep. Although the length and depth of the incised wound depends upon the motion in using the instrument, the force applied, the sharpness (or dullness) of the instrument, and the nature of the tissue being incised also play a role.

Fig. 1. Master Barbers Straight Edge Razor

Fig. 2. The above figure is a full size Army KA-BAR Straight Edge Knife.

Fig. 3. Army Bayonet

Non-iatrogenic incised wounds fall into three categories: accidental, non-accidental, self-inflicted and those incurred during an assault (homicide). Most incised wounds are accidental, generally occupational related or occurring within the home, such as kitchen-war-wounds; they are superficial and usually involving the hands. Another source of accidental incised wounds and lacerations are those produced in a motor vehicular accident. Such incised wounds are usually produced by broken glass, are often deep, irregular and large, usually involving the scalp, face, neck, forearms and hands.

Fig. 3. The above figure is a laceration due to striking the steering wheel in an MVA.

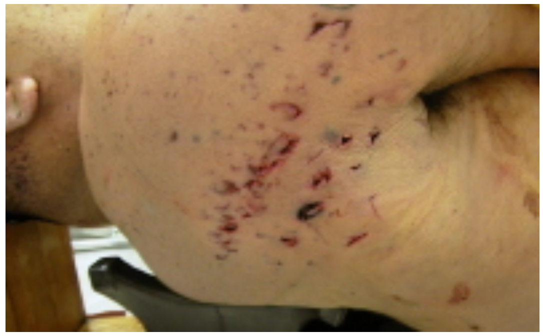
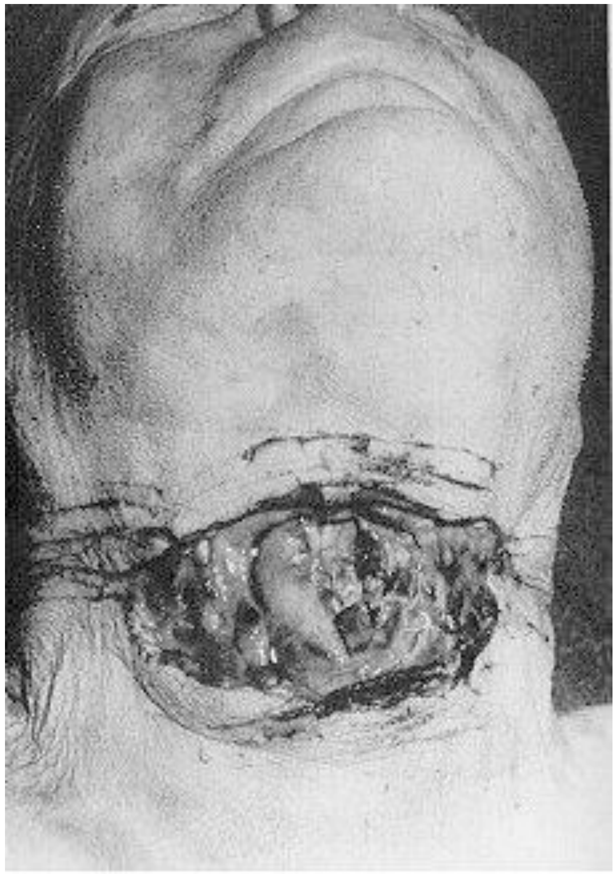


Fig. 4. These are multiple superficial dicing injuries from the passenger-side window involving the posterior and inferior-lateral aspect of the right shoulder.

Non-accidental, self-inflicted incised wounds are those produced during the commission of a suicide or self-mutilation. One of the most common sites for self-inflicted incised wounds is the neck, although, one must never forget, incised wounds of the neck can be the result of a homicide. However, with close inspection of the injuries to the neck, certain distinguishing features will suggest to you the manner in which they were produced. Often when a person commits suicide by cutting their throat, hesitation, superficial incised wounds are made before the fatal deep incision, however, this is not always the case as is shown in the illustration below. If the person is right handed, you will often find that they begin the incised wounds higher up on the left side of the neck, bringing the incised wound down across the neck, such that it ends in the lower aspect of the right side of the neck. This observation applies both to the hesitation incised wounds, as well as the fatal cut. Another observation that is often noted is that in the fatal incised wound, it will often be deeper on the left side of the neck, often involving the left common carotid and internal jugular vein and sometimes the trachea. However, as the sharp edge instrument is brought across the neck it becomes progressively shallower. Should the person be left handed, the above description is simply reversed. Often in a homicide, there are no hesitation incised wounds and those cuts inflicted are more horizontal than diagonal.



Suicidal cut throat.

Fig. 5. Note the hesitation incised wounds above and lateral to the lethal cut.

Suicidal razor cut to the throat.
Gresham: Color Atlas of Forensic Pathology, 1975.

Fig. 6. The above is a photograph of a suicide with a single incised wound.

Along with incised wounds of the neck, those who commit suicide will not uncommonly show hesitation incised wounds of the wrists and forearms. Occasionally, superficial incised wounds of the wrists or forearms will be seen in cases of self-mutilation.

Fig. 7. Superficial incised wounds of the wrist that can be seen in self-mutilation or as part of the picture of a suicide with the definitive incised wound involving the neck.

Fig. 8. Multiple superficial incised wounds of the forearms with extension to the wrist.

Fig. 9. Multiple superficial incised wounds of the abdomen in a case of self-mutilation.

Homicidal incised wounds are often associated with incised wounds of the hands and forearms, which are referred to as defensive injuries. These defensive cuts are induced by the victim attempts to deflect or crab the slashing knife motion of the assailant. Consequently, the victim will often have multiple incised wounds on their forearms, the palms of their hands, and the anterior (volar) surfaces of their fingers.

Fig. 10. Multiple defensive injuries primarily to the palm of the right hand.

Fig. 11. Multiple defensive injuries to the volar surfaces of the right 5th and 4th fingers.

Defensive injuries can also be seen on the lower extremities. Such injuries suggest the victim was lying on the ground during the assault and was using their legs for defensive purposes. Such wounds on the lower extremities are usually seen in females and suggest a sexual component to the assault. Remember, in such cases examine the vagina, rectal and oral cavities for spermatozoa, prostatic acid phosphatase and DNA. Remember, often those who commit suicide will have multiple, usually superficial, incised wounds on the anterior (volar) surface of their wrist and/or forearms before they inflict the fatal incised wound of their neck. Typically, these cuts are analogous to the hesitation incised wounds of the neck, and they are on the anterior surface of their wrist and/or forearms. In contradistinction to these self-inflicted incised wounds, those induced by an assailant are much deeper and can be on the extensor (posterior) surface of the forearm, as well as the volar surface. Also, deep incised wounds of the palms are generally not a feature of suicide. Another point to keep in mind, is that self-inflicted wounds of the anterior surface of the wrist and forearms may be associated with incised wounds of the ankles.

On occasion, you may observe additional incised wounds of the victim of a homicide over-and-above what has been described. Not uncommonly these additional incised wounds may have little or no bleeding associated with them. There are a number of reasons why these types of incised wounds are inflicted.

There are instances, especially if the assailant is in the state of deep emotional rage, in which the act of killing the person does not satisfy the assailant's rage. In such instances, these additional cuts show no pattern and manifest themselves in their disregard of purpose and their violence, or-if-you-will, their expression of overkill.

Fig. 12. Violent assault with a machete.

Fig. 13. Machete

Fig. 14. Deep incised wounds of the hand, wrist, and forearm when victim attempted to ward off a violent knife attack.

A classic example of this type of homicide was the murders of Nicole Brown Simpson and her friend, Ronald Goldman on June 13, 1994. One of the reasons O. J. Simpson was considered a suspect was the overkill that was manifested by the multiple stab wounds of Nicole's neck, to the point of near decapitation, her cervical vertebrae were nearly severed; this indicated severe rage of the assailant. Another example of violent overkill is the victim, who is a homosexual and is murdered by their estranged lover. Often in these cases it is not feasible to discern which incised and/or stab wound came first, and typically, there is no pattern.

There are also instances in which such injuries, whether having been inflicted antemortem, agonal or postmortem, do suggest a pattern. Such would be the case of an estranged partner, who may believe they have been deceived and humiliated by their partner, which can lead to mutilation or imputation of the external genitalia of the unfaithful partner or unwanted rival. Having said this, we all must never forget, that such injuries can be inflicted by someone with profound psychological issues, who takes great pleasure in inflicting mutilating injuries, often with a pattern, or if you will, a signature. The injuries you may see in such homicides, besides mutilation of the genitalia, are amputation of the breast, evisceration of the abdomen and pelvic organs, cutting off of the ears, removal of the eyes, cutting out the tongue and amputation of the fingers, toes, hands, feet, upper and lower extremities. What you need to remember, whether mutilation of the genitalia occurs singularly or in association with other evidence of mutilation, you must examine the wounds for seminal fluid; if the latter is present, the appropriate laboratory test must be accomplished. Another feature that can be apart of these mutilating injuries is evidence of urination on the victim.

Remember, any body fluid or secretion that contains nucleated cells contains DNA that can be isolated and analyzed. Even secretions such as tears and ear wax contain nucleated cells. DNA in urine comes from epithelial cells that line the bladder and ureters. A small number of cells are fluffed off every day, and with the techniques that are available for DNA typing today, especially PCR, DNA profiles theoretically can be obtained from a very few number of cells. The issue here is whether enough surviving cells can be swabbed from the dried urine stains on the body to obtain a DNA profile. In any event, any dried stain on the surface of the body should be swabbed and an effort made to extract DNA.

On a rare occasion the assailant may carve a figure or some other design on the victim. Such incised wounds serve as a signature. As has been pointed out before, sometimes the pattern of the injuries and how they have been inflicted, i.e., conveying the impression they have been inflicted by the same instrument, serve as a form of a signature. Although, dismemberment will be discussed later on in this article, there are occasions in which there is a deliberate attempt to disfigure the victim in hopes of preventing identification; as an example is the Ruxton case.

Dr. Buck Ruxton was born in Bombay on March 21, 1899. His original name was Bukhtyar Rustomji Ratanji Hakim, which he later changed to Buck Ruxton. In 1930 he moved to the UK and began practicing as a GP in Lancaster. He was described as being very diligent, well respected by his patients, and known to wave his fees when he believed his patients could not afford to pay them. He lived at 2, Dalton Square, which is still a location for practicing doctors, with his common-law spouse Isabella ("Belle") Kerr and their three children.

Fig. 15. This is a photograph of Dr. Buck Ruxton. Fig. 16. Isabella ("Belle") Kerr

Fig. 17. The above is their home at 2, Dalton Square, Lancaster, UK.

Isabella was an outgoing woman who enjoyed socializing with the Lancaster's elite and was a popular guest at functions. Dr. Ruxton, unfortunately, was described as being emotionally unstable and obsessively jealous, became convinced that she was having an affair, though no evidence of such an affair was ever found.

Dr. Ruxton became increasingly jealous of Isabella's popularity, which allegedly on occasion led to exploding fits of rage within the confines of their home. Ultimately, his emotional instability and obsessive jealousy overwhelmed him, and on September 15, 1935, he strangled Isabella with his hands. Due to the fact he could not dispose of her body before she would be discovered by their housemaid, Mary Jane Rogerson, he suffocated her too. Dr. Ruxton then proceeded to dismember and mutilate both bodies, which included removal of the eyes, nose, lips, and fingertips in an attempt to hide their identification.

Various human body parts were found over a 100 miles north of Lancaster, dumped in Gardenholme Linn, a stream running into the River Annan, which is crossed by the Edinburgh-Carlisle Road, 2 miles north of the town of Moffat in Dumfriesshire, Scotland. They were found wrapped in newspapers, which included the Daily Herald, dated August 6 and 31, 1935, Sunday Graphic, dated September 29, 1935, and the Sunday Chronicle on September 29, 1935, by Miss Susan Haines Johnson, who was visiting Edinburgh.

Unfortunately for Dr. Ruxton, one of the newspapers he had used was a special 'slip' edition of the Sunday Graphic that was sold only in the Morecambe and Lancaster areas. Inspector Jeremiah Lynch of Scotland Yard, who had been called in to assist in the investigation, investigated the subscription list, which greatly assisted in tracking Dr. Ruxton.

When Dr. Ruxton was initially questioned, he denied ever being in Scotland. However, while he was in Scotland disposing of the remains, his car had been stopped by a police officer who made a record of the registration number in his pocketbook. This evidence was used at the subsequent trial.

The bodies were identified using fingerprint techniques, forensic anthropology to superimpose a photograph over the x-ray of a victim's skull, and forensic entomology to identify the age of the maggots and thus, the approximate date of death. This was one of the first cases where such forensic evidence was successfully used to convict in the UK.

Dr. Ruxton was arrested at 0720 hours on October 13, 1935, and charged with initially with the murder of Mary Rogerson; he was subsequently charged on November 5, 1935, with the murder of Isabella. His trail started on March 2, 1936, and went for 11 days. The trial ended on March 13, 1936, when the jury returned a verdict of 'guilty' and Mr. Justice Singleton sentenced him to death. Despite the gruesome nature of these murders, a petition urging clemency for Dr. Ruxton, collected over 10,000 signatures. However, the Court of Criminal Appeals dismissed Ruxton's appeal on April 27, 1936. Dr. Ruxton was hanged at Strangeways prison, Manchester on the morning of May 12, 1936.

There are occasions when incised wounds, typically of a superficial nature, are purposely self-inflicted, with the sole purpose to gain attention or to deceive.

Fig. 18. Multiple superficial incised wound in a case of self-mutilation.

One of the early recognized experts on this subject matter was Sir Sydney Alfred Smith, a renowned forensic scientist and pathologist. Dr. Smith served as the Regius Professor of Forensic Medicine at the University of Edinburgh from 1928 to 1953. One of Dr. Smith's areas of interest were self-inflicted incised wounds. It was his opinion that such self-inflicted wounds were unusually wide, almost invariably superficial, such that the skin is often not perforated, and commonly they are made in parallel lines or are crossing one another. In his experience, it was rare that the person inflicting these injuries upon themselves was satisfied with a single incised wound. According to Dr. Smith, these wounds were are commonly on the lateral surface of the upper arm, anterior surface of the forearm, the anterior and lateral surfaces of the thighs, the anterior surface of the chest and abdomen, and in men who are bald, they can be found on the top of their head.

Fig. 19. Multiple self-inflicted, superficial incised wounds of the abdomen.

What is interesting is they will often cut their clothing, but this is done separately from the injuries to the surface of their skin considering the fact the cuts in the clothing do not coincide with those of the skin.

One of the things you must never forget, is that because the injuries are numerous or obviously would have caused great pain when inflicted, does not mean they could have not been self-inflicted. One of the observations I have made over my career as a Forensic Pathologist is the absolute tenacity of those who have decided to commit suicide; it simply is not confined by rational limits. For example, one person struck himself on the top of his head with an axe more than 80 times, succumbing to exsanguination from a cut through the superior sagittal sinus. An elderly women amputated both of her feet by cutting through her ankles, she then amputated her left hand at the wrist and finally stabbed herself in the abdomen. A window cleaner in the UK committed suicide by stabbing himself repeatedly in the groin with a jumbo souvenir pencil, that was described as being quite blunt. When his body was found there was a large amount of blood throughout his room, the jumbo pencil was found beside him with much blood on it and the stereo was still playing. At first, both the police and the East

Sussex Coroner had great doubts that this was a suicide as evidence by the Coroner's statement: "It is a mystery to me, if you were choosing to take your own life, that's not the way you would do it." "It seems to me that it can't have been a single stab wound. He seems to have worked on it. The pencil was so blunt." A bed ridden man, who was in his eighties, stabbed himself 24 times to the full depth of the four inch blade of his pocket knife. Following stabbing himself, he wiped the blade so there was no visible blood and than hid the pocket knife beneath his mattress before he bled to death.
What all the above examples demonstrate, is that the only objective pathological evidence by which suicide can be excluded, is that the location or direction of the wound or wounds are such, they could not have been self-inflicted.

Macroscopic Appearance of Incised Wounds

In contradistinction to contused, crushed or lacerated injuries, an incised wound is typically associated with relatively little damage to the adjacent tissues. It is the characteristic smooth edge of the wound that separates an incised wound from a laceration.

Fig. 20. Incised wound, note the sharp smooth edges.

Fig. 21. This is a severe triceps laceration of the left arm. Note the irregularity of the edges of the wounds and undermining.

Fig. 22. Laceration of the tongue. Note the irregularity of the wound edges.

Undermining may be present, as shown in Fig. 21, which in an incised wound indicates the direction from which the slashing stroke was made. What is not a feature of an incised wound is soft tissue bridging between the sides of the incised wound. A sharp edged instrument incises and divides tissue rather than crushing and tearing seen in a laceration, which causes strands of tissue bridging the depths of the wound.

Fig. 23. The arrows point to tissue bridges within the depths of this laceration.

The other important point to remember is incised wounds typically do not have abraded margins as do lacerations.

Fig. 24. Note the abrasions next to the lacerations.

There is another very pragmatic issue you need to be cognizant of and that is the length and depth of an incised wound does not aid you in identifying the sharp edged instrument used to inflict the injury. An incised wound measuring 5 inches in length could have been produced by a sharp edged instrument (razor, knife, etc.) of any length. Although, classically, incised wounds produced by a sharp edged instrument produces no macroscopic evidence of an abrasion or contusion at its margin and are regular in conformation, an incised wound produced by a dull edge sharp instrument, especially one in which the cutting-edge is irregular or has a defect, can produce an incised wound with irregular wound edges with abrasions and/or contusions. However, what helps you differentiate this type of incised wound from a laceration is there is no evidence of soft tissue bridges in the depths of the wound.

There are some instances in which a single incised wound is broken-up into segments, separated by none involved skin. This occurs when the skin affected by the edge of the sharp instrument is not perfectly flat, but is folded, i.e., the surface of the skin presents in peaks or valleys, or if-you-will, is wrinkled. In such instances the edge of the sharp instrument passes across the peaks of the skin folds, not touching the valleys. There are also instances in which the edge of the instrument causes the skin to form folds before incising the skin; Vince DiMaio refers to these as "wrinkle wounds."

The last thing I want to bring to your attention is the overall configuration of an incised wound may not be linear with closely approximated wound margins. The actual configuration of the incised wound is dependent on whether the edge of the sharp instrument was parallel, transverse or oblique to the direction of alignment of the collagen fibers in the skin; this alignment is referred to as Langer's Lines.

Langer's lines, also called cleavage lines, is a term used to define the direction within the human skin along which the skin has the least flexibility. These lines correspond to the alignment of collagen fibers within the dermis. They were first given detailed attention in 1861 by Austrian anatomist Karl Langer (1819-1887), though he cited surgeon Baron Dupuytren as being the first to recognize the phenomenon. Langer punctured numerous holes at short distances from each other into the skin of a cadaver with a tool that had a circular-shaped tip, and noticed that the resultant punctures in the skin had ellipsoidal shapes. From this testing he observed patterns and was able to determine “line directions” by the longer axes of the ellipsoidal holes. Knowing the direction of Langer’s lines within a specific area of the skin is important for surgical operations, especially cosmetic surgery. Usually, a surgical cut is carried out in the direction of Langer’s lines, and incisions made parallel to Langer’s lines generally heal better and produce less scarring. Sometimes the exact direction of these lines is unknown, because in some regions of the body there are differences between different individuals. Also, the lines described by Kraissl differ in some ways from Langer’s lines, especially on the face. Directional changes of Langer’s lines have also been known to occur within the course of a person’s lifetime.

Fig. 25. This illustration shows the general outlay of Langer’s lines.

If an incised wound occurs parallel to Langer’s lines it will tend to be narrow in configuration with the wound edges being more closely approximated than one in which runs across or oblique to Langer's lines. In the latter instance, you can expect the wound edges to be further apart with the configuration of the incised wound being more oval than linear with the wound edges being pulled apart and everted. The orientation of stab wounds relative to Langer's lines can have a considerable affect upon the presentation of the wound.

It should be pointed out that Kraissl's lines differ from Langer's lines in that while Langer's lines were defined in cadavers, Kraissl's lines have been defined in living individuals. Also, the method used to identify Kraissl's lines was not traumatic.

Cuts/Slashes

Originally, I was not going to include this as a separate category of incised wounds due to the fact some would argue it is redundant to do so. However, some well known Forensic Pathologist, such as Bernard Knight, have cuts and or slashes as a subdivision of incised wounds. Typically, such incised wounds occur as the result of gang fights or barroom brawls, with the sharp edged weapon being swung in an arc, which can be horizontal, diagonal or vertical so that when it contacts the victim it slices through the skin and underlying tissue.

Generally, these slashes are longer than they are deep, often deeper at the initial point of contact becoming more shallow as the slash nears the completion of its contact with the victim. Not uncommonly you will see an associated tail, or if you will, a shallow scratch following in line with the distal end of the incised wound, as the sharp edged instrument is drawn across the skin.

As Bernard Knight points out, be careful in your reconstruction of altercations. We unconsciously tend to visualize the altercation as the victim and assailant are static, with only the sharp edged weapon moving in an arc. This is often not the case. Typically altercations are fluid, dynamic with both the victim and the assailant moving, including their extremities, which may have a different motion than their bodies. Consequently, there are a myriad of angles and possibilities of contact between the victim and the assailant thus, be careful of over simplification of how events unfolded.

For the most part slashes tend to be somewhat shallow by their very nature, tending not to involve underlying organs; usually involving the upper extremities, face, neck, anterior and lateral surface of the chest and abdomen.

Fig. 26. Slash produced by a knife. Note the trailing edge on the left side of the chest.

For the most part, the ribs protect the heart and lungs, and the skull the brain in slash-type injuries. Slashes of the neck however, have the potential to be fatal due to involvement of the vessels, larynx and or trachea. Should morbidity or mortality occur as a result of these injures it usually will be due to blood loss.

There is another form of slash injuries, which you need to be cognizant of and that is those produced by broken glasses or bottles. If a broken glass or bottle is used in an assault, deep incised wounds, often irregular in conformation can be produced. On occasion, due to dagger-like configuration of the edges of the broken glass, you may see stab-wound-like injuries along with the slashes. Sometimes an intact bottle is used as a blunt instrument. In such cases, especially if the person is struck in the head and the bottle breaks, you may see a laceration, contusion, abrasion and incised wounds all in a single injury.

There are instances in which a body is found floating in water or has washed up on a beach, which will show multiple slashes. In such cases you will need not only to identify the causation of the injuries, but also were they before or after death.

Fig. 27. Cuts due to broken glass.

Fig. 28. Multiple sharp edged incised wounds due to propeller blades.

Fig. 29. Multiple sharp edged slashes, which initially appear to be analogous to those produced by propeller blades or perhaps slashes from a sword or machete, with the body being disposed of in the sea. In actuality, these slashes are due to a shark attack.

What is of a great help in determining whether the injuries were before death (antemortem) or after death (postmortem) is noting the presence of blood in the soft tissues next to the incised wounds. If you find hemorrhage into these tissues than clearly you are dealing with antemortem injuries. However, the absence of such hemorrhage may not necessarily mean the injuries are postmortem as Fig. 29 demonstrates. This victim was alive at the time of the shark attack, the absence of blood in the incised wounds is due to her prolonged immersion in water, which simply washed the blood out of the wounds, thus creating the impression of a postmortem injury.

Stab and Penetrating Wounds-General Information

Stab wounds are incised wounds that are deeper than they are wide generally caused by a sharp pointed instrument, which penetrates the skin and underlying tissue. They can be the result of someone thrusting a sharp pointed instrument into the victim or the result of the person falling against a pointed object. The exact nature of the wounding instrument may sometimes be ascertained by examination of the wound, however, although stabbing wounds tend to be deeper than they are wide, a simple rocking or lateral movement of the victim may enlarge the entry, thus the external appearance of the wound may not resemble the cross-section of the weapon.

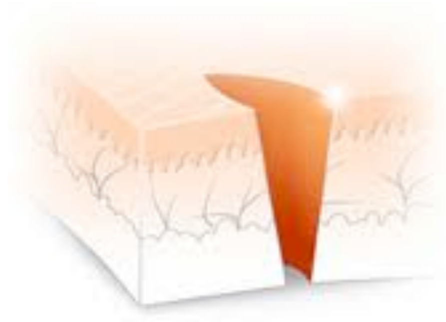


Fig. 30. Illustration of a stab wound showing the classic feature of greater depth than width with sharp edged margins.

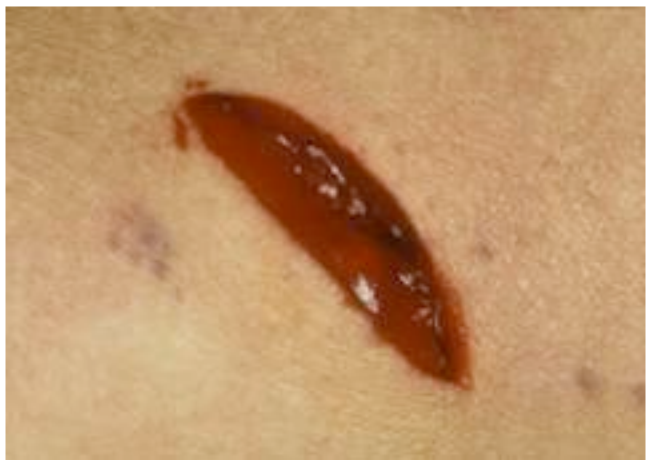


Fig. 31. This is a stab wound from a victim of an assault. Remember, the external appearance of this wound may not resemble the cross-section of the weapon.

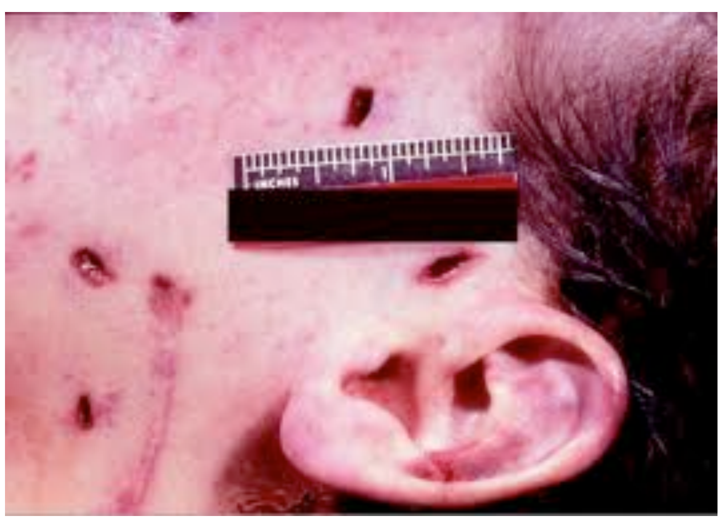


Fig. 32. Multiple stab wounds from a screwdriver. Note the squared off ends.

In the case of a person being found dead with one or more fatal stab wounds, be very cautious in rendering an opinion how the fatal injuries occurred. As suggested above, suicide by stabbing is not uncommon, with the victim, on occasion, hiding the weapon that he used to induce the fatal injuries. The point to be made here is that multiple stab wounds does not negate a suicide. Multiple stab wounds involving the chest and abdomen can be self-inflicted and even accompanied by an effort of deception to create the illusion of a homicide. Also never forget, the scene can be modified by a friend or member of the suicide victim's family, including removal of the sharp-edge instrument thus, creating the appearance of a homicide. Likewise, the scene can be modified, including hiding the weapon by the perpetrator of a homicide, thus creating the appearance of a suicide. One of the things you need to be mindful of is members of the family coming upon a suicide of a loved one, may choose to modify the scene due to feelings of guilt, embarrassment, and or concerns of insurance money.

There are instances in which the weapon used either in a homicide or suicide, may be so slender that the defect on the surface of the skin is easily overlooked. Not only may the external evidence of a stab wound be inconspicuous, there may be little or no evidence of external bleeding. Objects, which can produce such inconspicuous, but non-the-less fatal injuries are hat pins, knitting needles, skewers, stilettos, ice picks and three cornered files.

In homicides by stabbing, most of the stab wounds involve the left chest. Why this is often the case is open to conjecture; it may very well be that the majority of people are right handed thus, when facing their victim, the arc of their right arm would carry the weapon into the left chest area.

Fig. 33. The above is an ice pick.

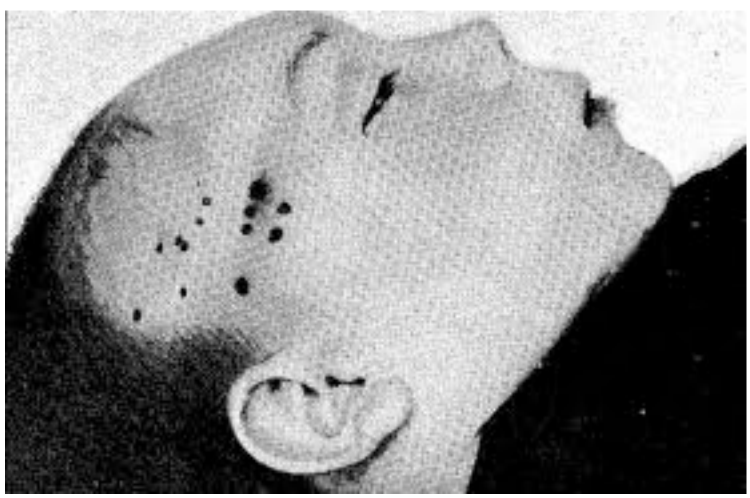


Fig. 34. There are multiple stab wounds to the right side of the head. Some will describe these as puncture wounds. These wounds suggest those done by an ice pick. There multiplicity in of themselves does not necessarily mean this is a homicide.

Fig. 35. This stab wound is consistent with being done by a nail, ice pick or needle. Some will refer to these as puncture wounds.

There are several fundamental principles you should keep in mind when analyzing stab wounds:

1. **Position and Number:** This observation will help you decide whether the stab wounds are self-inflicted or the result of a homicide. Remember, multiplicity in of itself does not mean you are dealing with a homicide. Ultimately, that decision is made by an assessment of all the evidence in the case. Multiplicity however, does suggest the emotional level or the degree of intensity that the person acted under when stabbing them self or the assailant was under at the time of the assault. Each stab wound should be photographed, described and placed on a body diagram.

2. Shape of the Stab Wound: The external appearance of a stab wound is in part determined by the cross-sectional configuration of the weapon. However, the alignment of collagen fibers within the connective tissue of the dermis of the skin plays a significant role in the configuration of the stab wound. Within the skin, as previously discussed, collagen fibers are arranged in a definitive pattern of parallel flowing lines throughout the body. These lines are referred to as Langer's lines. When the longitudinal axis of a stab wound is parallel to the arrangement of the collagen fibers of Langer's lines, the stab wound appears narrow and long. If however, the longitudinal axis of the stab wound is perpendicular to the collagen fibers of Langer's lines, the stab wound will gape and the edges will be pulled apart by the collagen fibers, causing an oval or circular short wound.

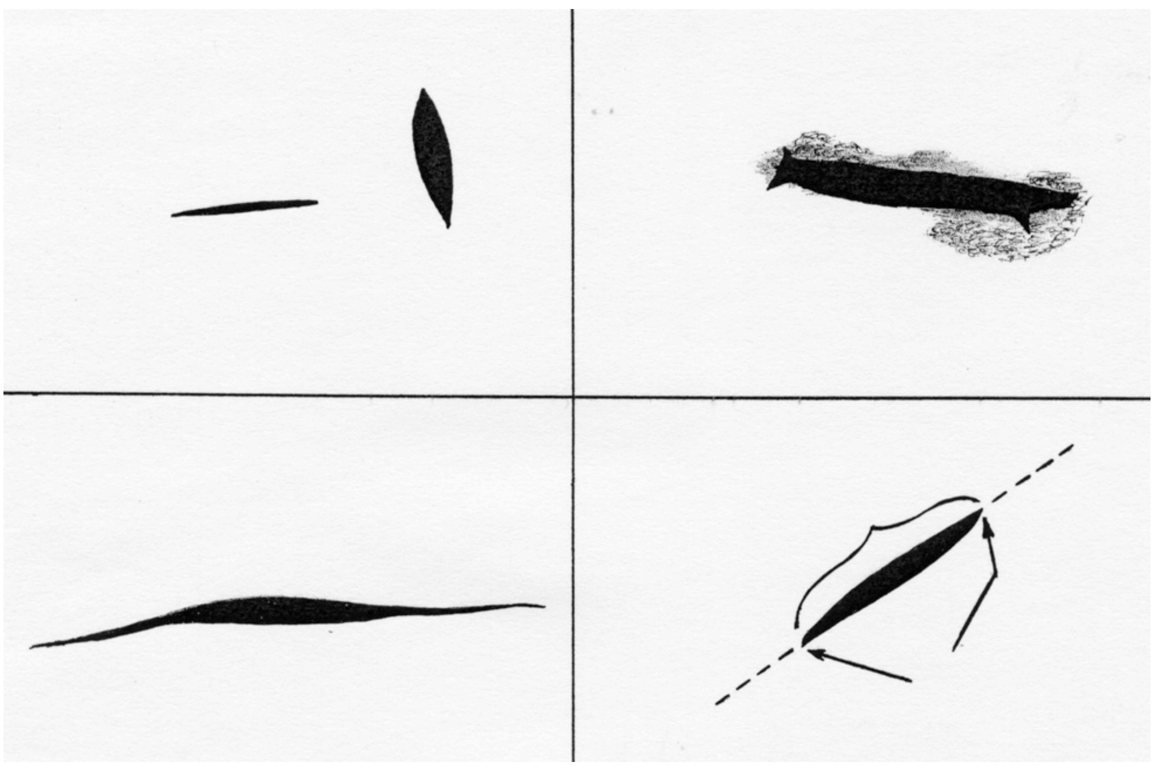


Fig. 36. Diagram of stab and incised wounds. Upper left stab wounds, the more oval is perpendicular to Langer's lines, whereas the slit-like defect is parallel to Langer's lines. The upper right is a chop wound, which will be discussed later in this article. The lower right shows a stab wound with a bracket defining the margin or edge, whereas the arrows denote the angles or ends. The dashed line defines the longitudinal wound axis. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Before continuing, it is important to draw a distinction between the collagen fibers of Langer's lines and the elastic fibers that are present in the dermis and epidermis. Although, elastic fibers give connective tissue such as blood vessels, lungs and skin properties of elasticity and resilience, they are not believed to play a substantive role in the configuration of stab wounds. Elastic fibers are major insoluble extracellular matrix assemblies that give connective tissues resilience, permitting long-range deformability and passive recoil without energy input. These properties are critical to the function of arteries, which undergo repeated cycles of extension and recoil, and to the lungs, skin and all other dynamic connective tissues. This elastic fiber function complements collagen fibrils, which impart tensile strength.

These fundamental principles must be kept in mind when examining a stab wound. A single-edged knife wound can appear to have been inflicted by a double-edged blade due to this distortion. A further example would be the effects of Langer's lines on the appearance of stab wounds made by an awl (a pointed tool for making holes in wood or leather) or an ice pick in which due to the tearing of the collagen fibers, which can occur at right angles to their plane, what would be a circular wound takes on an elliptical or slit-like appearance.

There are also other factors, which can determine the appearance of stab wounds, one of which is the movement of the victim, the result of which can cause the appearance of the edges of the wound being somewhat serrated, when the weapon used did not have a serrated edge. It is not only movement of the victim, which can affect the shape of the stab wound, but also how the weapon was thrust into the victim. For example, should the weapon be thrust in and then partially withdrawn, but thrust in again along a different track, the external appearance of the stab wound will be altered producing the so-called compound stab wound. When the depths of a compound stab wound are analyzed you will find more than one track. If the weapon is thrust in, completely withdrawn, but in doing so the cutting-edge of the weapon is extended along one angle of the stab wound, thus extending the wound superficially, giving one angle of the stab wound a tail, thus giving a teardrop configuration to one end of the stab wound.

Fig. 37. This is a gaping stab wound, which is difficult to determine if the angles are sharp or blunt. However, the image below, will show what occurs with re-approximation of the wound edges. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 38. Re-approximation of the wound edges of the above image. Such re-approximation allows one to determine the upper angle is blunt, whereas the lower has an acute angle consistent with a single-edged instrument. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 39. This is a gaping stab wound with abrasions near the upper angle. The presence of such abrasions is consistent with having been inflicted by the handle of the knife or other sharp-edged instrument. Note each angle of the stab wound is sharp, which is consistent with a double-edged instrument. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 40. This image is of a compound stab wound, which shows two intersecting stab wounds. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

If the blade of the weapon is thrust in, and while still in, the blade is pulled in the the direction of the cutting-edge thus, causing an elongated track and skin wound. In short, the resulting skin wound gives the appearance of having been accomplished by a much larger weapon than that which was used.

Another mechanism by which the external skin wound can appear far larger than the weapon used is by thrusting the blade in and using the point of the blade as a fulcrum, the cutting-edge of the blade is pulled toward the narrow angle it produces. This motion leads to a track which is narrowest at its deepest point and widest at its most superficial point. Should the blade be twisted when it is thrust inward or as it is withdrawn, or for that matter both when thrusted in and withdrawn, the edges of the stab wound will be irregular and large.

One of the fundamental points to remember is the most common cause of large, irregular stab wounds is not the assailant twisting the knife in the victim after thrusting the blade into them, but is due to the victim moving as the blade is being removed. Be careful of embellishing, let the wounds of the body speak for themselves. Some have advocated using "scotch tape" to approximate the edges of a gaping stab wound to give you a better understanding of the configuration of the stab wound while the knife was still within the wound track and before the collagen fibers exerted their effect. This is certainly a reasonable technique to use. However, as demonstrated in Fig. 37 and 38, all you need to do is simple approximate the wound edges with your fingers and photograph the result.

There are a few fundamental points about the shape of stab wounds and the sharp edged instruments that cause them that you need to remember. Wounds inflicted with certain weapons will have very characteristic markings. As an example, sharp-edged instruments with a hilt or quillion create distinctive markings.

The hilt of a sword is its handle and consist of a guard, grip and pommel. The guard in-of-itself, may contain a cross-guard. The guard protects the user's hand from the opponent's sword, and prevents the user's hand from sliding up onto his own blade. The grip is the actual handle of the sword. It is usually made of wood or metal, and often covered with shagreen leather, shark skin or rubber. Shagreen leather is a type of leather or rawhide consisting of rough untanned skin, formerly made from a horse's back or that of an onager (wild ass), and typically dyed green. Today, shagreen is commonly made from the skins of sharks and rays. The word itself is derived from the French (*chagrin*) and is related to (*sagrin*), which is derived from the Turkish (*sagrilecagri)* meaning, 'rump of horse' or the prepared skin of this part of the horse. The pommel is the counterweight at the top of the handle. The purpose of the pommel is to provide a balance that the user of the sword finds comfortable.

There is another term that you may see used in regarding a sword or rarely a dagger and that is ‘ricasso.’ The ricasso is the blunt section of a blade, just forward of the guard, possibly protected by a smaller guard. On great swords, the ricasso provides a third hand position, permitting the user’s hands to be further apart for better leverage.

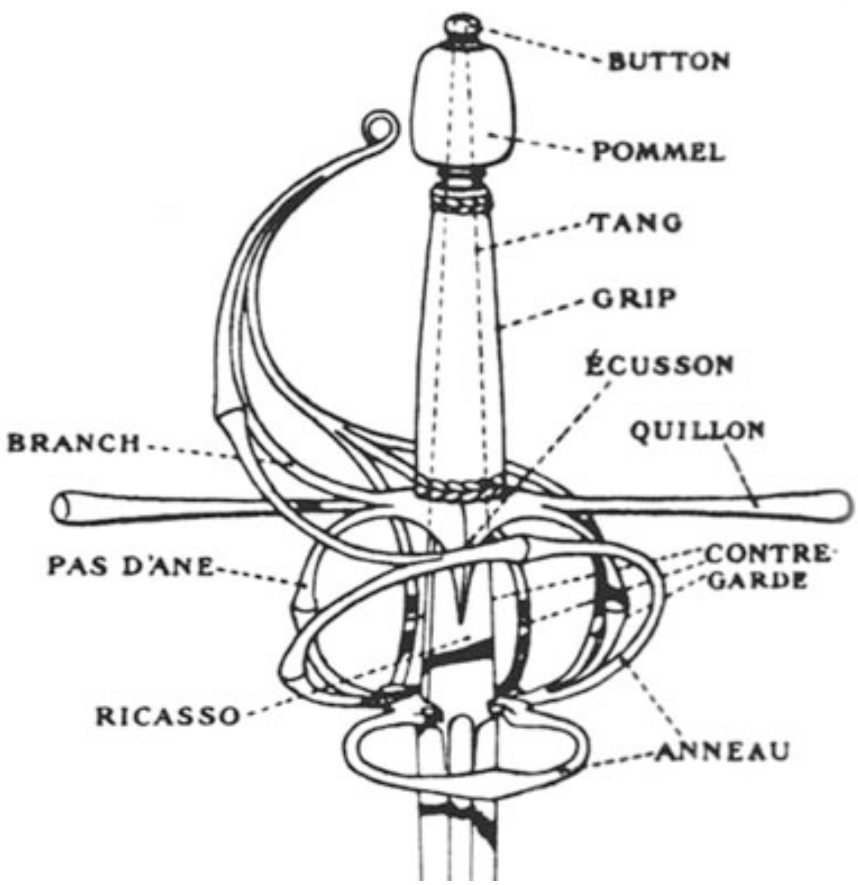


Fig. 41. These are the parts of the hilt of a sword.

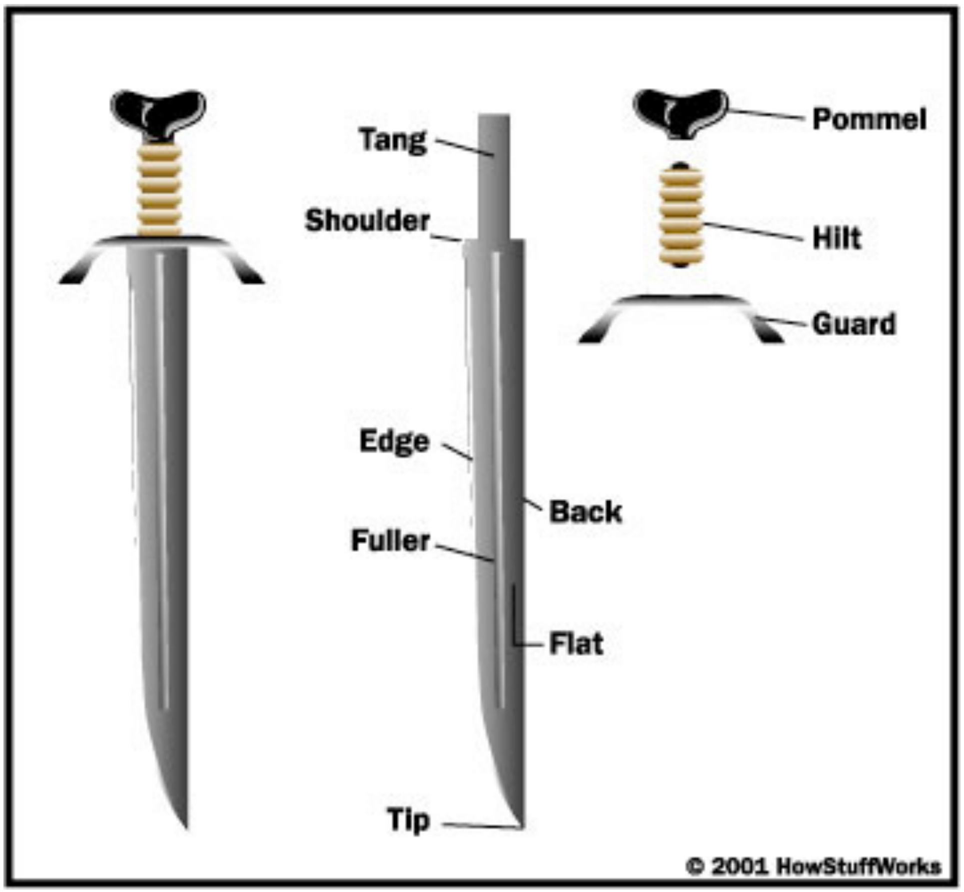


Fig. 42. Another illustration of the parts of the handle of a sword.

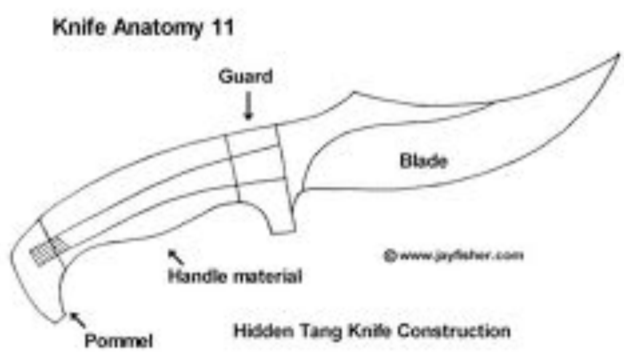


Fig. 43. This illustration depicts the anatomy of the handle of a knife.

As you can see in Fig. 41, quillions are cross-guards that are found on swords and some knives such as daggers. They consist of a bar of metal, which is at right angles to the blade, and is placed between the blade and the hilt. The quillion prevents the person who is using the sword from punching shields while swinging the weapon, thereby protecting the user's hand. It also prevents other blades from sliding down onto the hand or wrist of the person using the sword during combat.

Fig. 44. This is an example of a Quillion Dagger.

If a sharp-edged instrument has been used with considerable force, a contusion may be seen next to the wound itself. Such a contusion also gives you information as to the considerable force that was used on thrusting the blade into the victim. Should you observe an abrasion-contusion coupled with double circular or near circular small defects, this will suggest a weapon such as a two-prong barbecue fork or a 4-tined dinner fork.

Fig. 45. A stab (puncture) wound complex produced by a barbecue fork with 2-tines. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 46. A superficial wound complex produced by a 4-tined dinner fork. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 47. Note the abrasions near the upper angle and the contusion to the left of the upper lower margin of this double sharp-edged stab wound. (Sharp Force Injuries, J. Prahlow, MD, and S. CIna, MD, Medscape, Mar 29, 2010)

3. **Width (minimal and maximal):** As discussed previously, if a knife is thrust into the the skin so that its long axis is parallel to Langer's lines, the width of the skin wound will be narrow and slit-like because its edges are not subjected to lateral pull by

Fig. 48. Narrow and slit-like stab wound. The left angle has a squared-off appearance and would therefore be described as being "blunt," whereas the right angle come to a point and is therefore described as being "sharp." (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

severed collagen fibers. However, if the weapon is inserted through the skin so that its long axis is perpendicular to Langer's lines, a gapping wound develops, one in which its width exceeds the thickness of the blade. If the same knife is inserted in an oblique plane, as compared to the plane of Langer's lines, the resulting defect is wider than the former, but narrow than the latter.

Fig. 49. This is a gapping stab wound due to the blade entering oblique to perpendicular to Langer's lines. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

The above factors clearly suggest that the estimation of blade width and thickness should be accomplished with abundant caution when basing the estimation on the size and shape of the skin defects. What may be of some help in estimating the blade width and thickness is to examine the underlying viscera that may have suffered a defect, such as the heart, liver, spleen or kidneys. Of these organs, the liver spleen and kidneys may give you a better indication of the width and thickness of the blade, albeit its distal end; this is especially true in a tapered blade. Be careful however, of your interpretation of stab wounds going through intercostal muscles. A stab wound on the anterior surface of the chest may be narrow and slit-like if its long axis is parallel to Langer's lines, however, the defect in the underlying intercostal muscles may gape widely because of the retractive effect of the muscle fibers. Having said this, if the sharp-edged instrument penetrates or perforates bone or costal cartilage, such as that of the sternum or the ribs, this may provide you with the best evidence for the cross-sectional characteristics of the weapon. The fragments within the

Fig. 50. Stab wounds of the sternum of a decomposed body. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

penetrated bone are minute, which is one of the reasons you X-ray the deceased prior to doing an autopsy. X-rays are not only routinely done in all gunshot wound cases, but should also be done in incised and stab wound cases, as well as blunt force trauma cases. If possible, the cut surface of a knife injury to either bone or cartilage should be examined using a dissecting microscope, which not only may reveal minute fragments of metal, but also tool marks from the sharp-edged instrument used in the assault. These minute fragments can prove to be very important

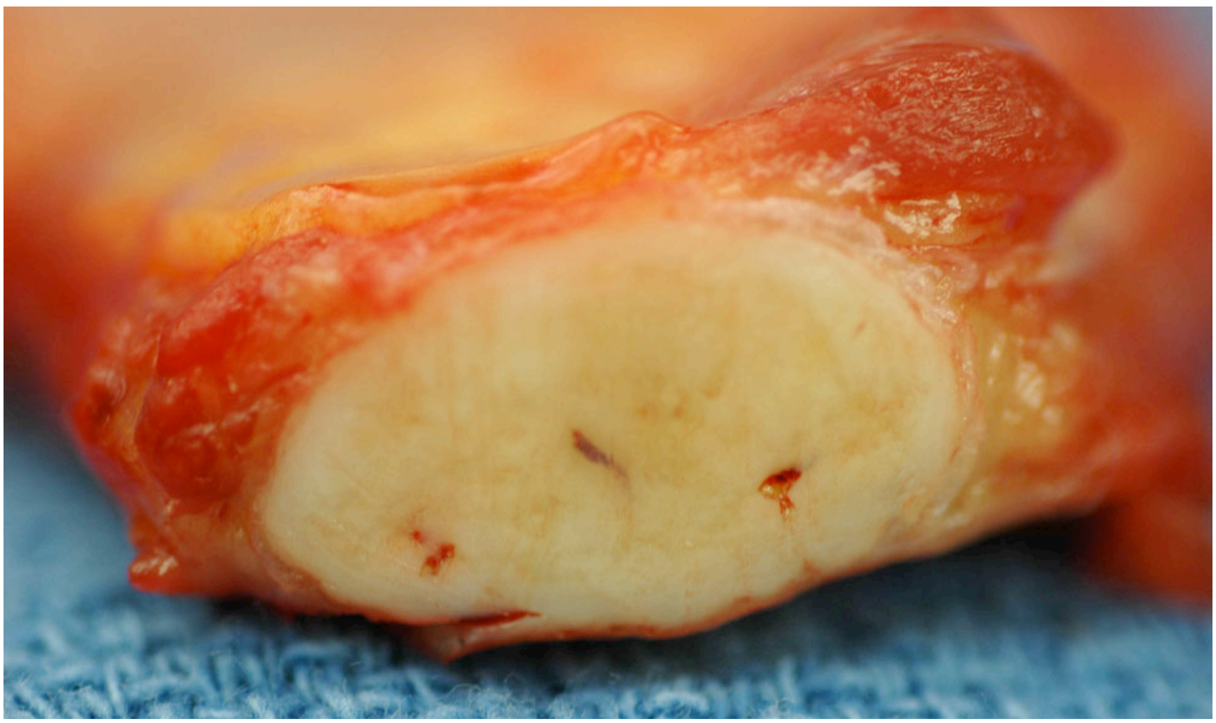


Fig. 51. A stab wound of the anterior cartilaginous portion of a rib. Examination of the cut surface using a dissecting microscope may reveal tool marks that can be compared to the suspect weapon. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

toward the resolution of your case. These minute metal fragments can be subjected to electron microprobe analysis or spectrochemical analysis as to their metallic composition, which can be compared to the metallic composition of the weapon. Other test that can be employed are X-ray diffraction analysis (Debye-Scherrer-Hall pattern X-ray diffraction), density measurements, radiation tests, neutron activation analysis, and directional crystallization analysis.

One of the very pragmatic reasons you want to do X-rays on incised and stab wound cases before starting the autopsy, is there are occasions when the tip or a substantive portion of the sharp-edged instrument used in the assault, broke off and remains within the defect.

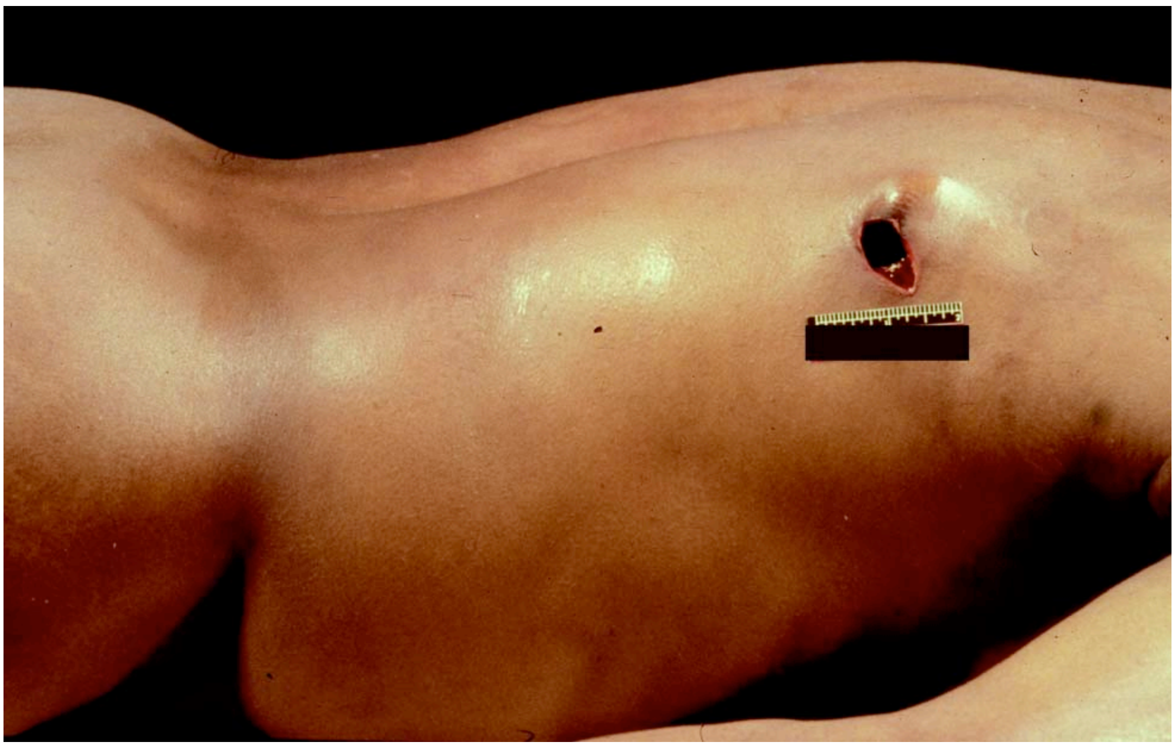


Fig. 52. Stab wound with broken blade remaining within victim. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

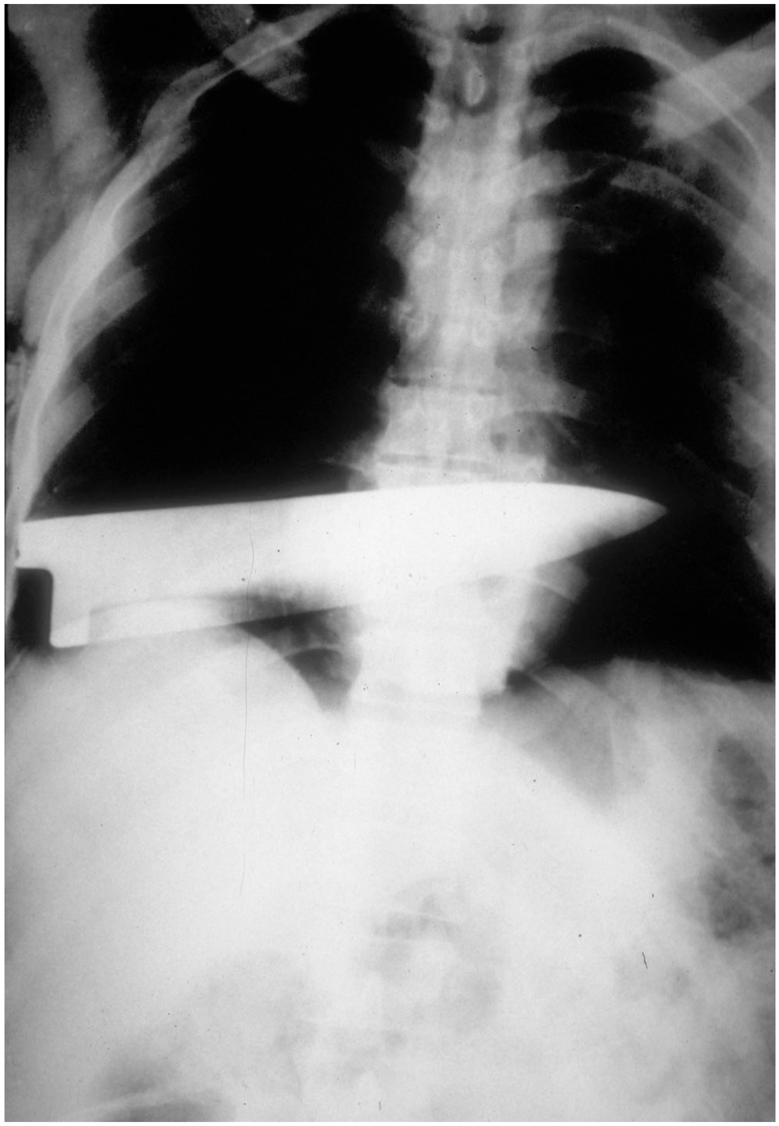


Fig. 53. X-ray of the above deceased showing a retained knife blade. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

FIg. 54. Broken-off blade removed from the deceased at autopsy. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

4. **Length of Track (depth):** The depth of each stab wound should be measured and recorded in inches. Although, I much prefer to use the metric system, I have found that for the most part, police officers, attorneys, insurance investigators, fire marshals and jurors are somewhat confused with metric system.

   There is another point you need to be cognizant of and that is when probing a wound track to determine its length be careful, you do not want to inadvertently increase its length. By determining the length you will add definition to the expression “the stab wound is superficial or it is a deep penetrating stab wound.” On the surface one would think that by determining the length of the wound track you are giving an indication of the minimal length of the weapon. However, you must bare-in-mind the track length determined, is in of itself fraught with complications when drawing a relationship between its length and the length of the weapon. For example, at the time of the stabbing, the victim may have been in a position quite different from the supine position they assume on the autopsy table. Due to the usual movement of the torso and extremities through a variety of different planes in an altercation, the resulting wound track or tracks lengths may be much greater than that of the blade of the weapon.

   Another point you need to be cognizant of is compression of certain parts of the body, most especially the abdomen, which may have occurred during the stabbing. Such compression is easily accomplished, especially if the assailant is using a dagger with a quillion, which allows compression of the chest or abdomen, so that a much deeper penetration occurs than would seem possible on examination of the blade. Also, remember the blade of the weapon may not have been thrust in to its full length thus, the wound track will be less than the length of the blade.

When testifying as to length of the blade, which inflicted the stab wounds, speak in terms of possibilities or probabilities, suggesting the length of the stab wounds examined are consistent with the shown weapon. What is important, do not speak definitively. What can be of help is if there are several stab wounds, in many respects the more the better, because they will provide you with more data in determing length and width of the blade of the weapon. Also, multiplicity of stab wounds may provide you with information as to the position of the victim and assailant at the time of the stabbing.

What also may be of some help to you in determining the length of the blade of the weapon is the work of Conor, Blectman and Duddy, who published data in *Injury* in 1998 concerning organ to skin distance. They determined there was no significant difference between the minimum skin to organ distance for males and females. The following table gives the minimum, maximum and mean skin to organ distances of the listed organs.

Distance from Skin to Organs (mm)

	Pleura	Pericar-dium	Liver	Spleen	Kidney	Thoracic aorta	Abdominal	Femoral
Minimum	10	15	9	12	19	31	65	13
Maximum	48	45	36	39	79	93	102	25
Mean	22	31	19	23	37	64	87	18
Standard Deviation	7.9	7.1	6.3	7.0	13	15.1	10.3	3.9

Above Table: Forensic Pathology, 2nd ed, V. DiMaio, MD and D. DiMaio, MD, CRC Press, p. 189, 2001.

It is important to remember when using this information that the distances listed in the table may exaggerate the distance the blade of the weapon needs to reach an underlying organ due to the fact when the blade is thrust in it may compress the involved skin and soft tissue. Thus, the length of the blade need not be as great as the distance from skin to organs determined.

5. **Single-edged Blade, Double-edged Blade and Serrated Blade:** One of the most significant determinations that must be made, along with width, thickness and length of the blade, is whether the blade was single-or double-edged or serrated.
   If the victim has been stabbed with a single-edged blade, they will have an acute angle at one end of the stab wound, with the other end being blunted or squared off.

Fig. 55. Single-edged blade

Fig. 56. The above is an image of a stab wound due to a single-edged blade. The lower end has a sharp angle, whereas the upper is squared off. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

However, it is well known that stab wounds produced by single-edged blades often have acute angles at both ends. How a single edged blade can produce acute angles at both ends is believed to occur for two reasons. The first is that the initial penetration by the point of the knife creates a defect with an acute angle at both ends. As the blade of the knife continues to proceed deeper into the tissues, that end of the defect in contact with the cutting-edge obviously remains at an acute angle. However, the opposite end of the defect, which is in contact with the non-cutting surface does not impart its shape to that end of the skin defect. All that the non-cutting edge does as the blade is plunged deeper into the defect is to tear the skin and underlying tissue along the original acute angle. Where this changes, is if the stab wound runs parallel to Langer's lines, than one end will have an acute angle and the other will be blunted or squared off. In this particular case the width of the blunt end of the stab wound will represent to a substantive degree the width of the non-cutting edge of the knife.

The second reason why a single-edged blade can produce acute angles at both ends is because many single-edged blades have a cutting-edge on the back of the knife (non-cutting edge) at its tip.

Fig. 57. Single-edged blade with cutting-edge on the back side towards the tip.

Thus, as the blade is thrust inward, and at the same time, pulled slightly back so that the non-cutting edge is not contacting the skin, you will not see a blunt or squared-off-end.

If the victim is stabbed with a double-edged blade, the resulting stab wound will show two sharp (acute) angles, one at each end.

Fig. 58. Double-edged blade

Fig. 59. Stab wound produced by a double-edged blade. Note acute angles at each end. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

A serrated blade is commonly used on saws and on some knives or scissors. It is also referred to as a dentate, sawtooth, or toothed blade. The serrated blade has a cutting-edge that has many small points of contact with the material being cut. By having less contact area than a smooth blade, the applied force at each point of contact is relatively greater and the points of contact are at a sharper angle to the material being cut. This causes a cutting action that involves many small splits on the surface of the material being cut, such as the skin. Cuts made with a serrated blade are typically less smooth and precise than cuts made with a smooth blade.

Fig. 60. Serrated blade. Note the sawtooth appearance on the cutting-edge.

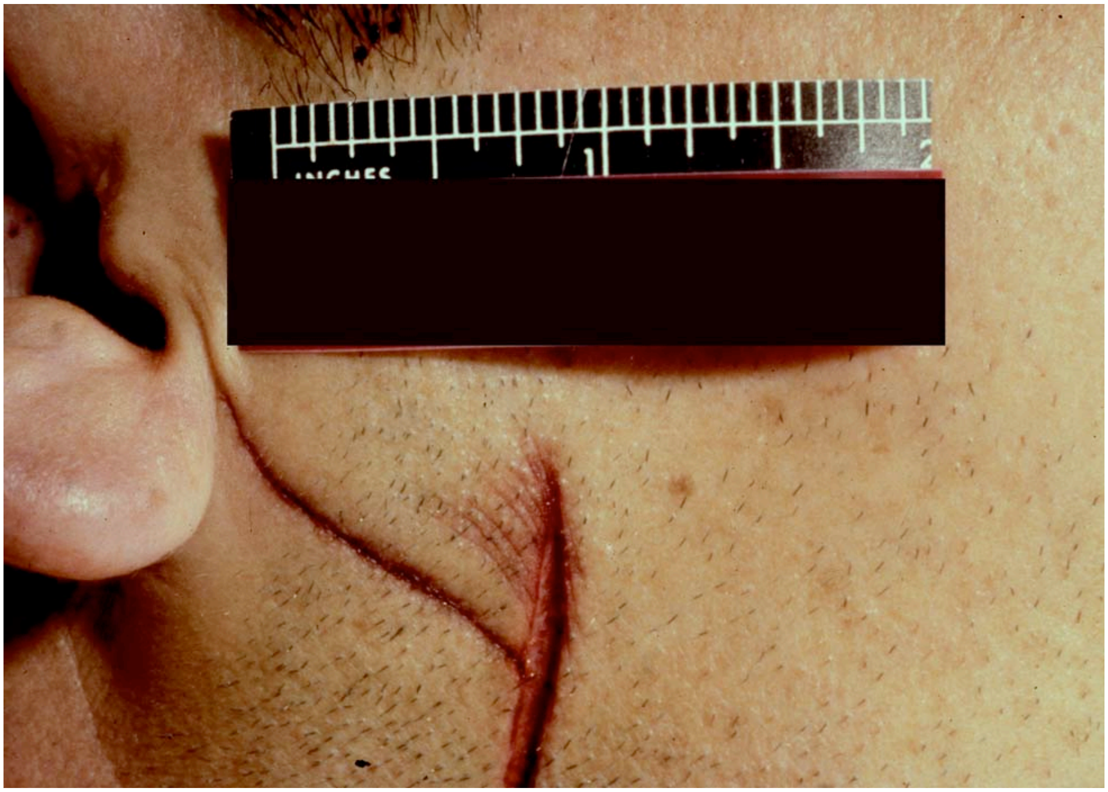


Fig. 61. This stab wound of the right cheek has a superficial curvilinear incised wound that trails away from the posterior margin toward the ear. Note the multiple, parallel, superficial incised wounds extending from the margins, superior to the longer incised wound. The presence of these marks are consistent with having been produced by a weapon with a serrated edge. (Sharp Force Injuries, J. Prahlow, MD, and S, Cina, MD, Medscape, Mar 29, 2010)

The point of this discussion is you may not be able to determine whether a single-edged or double-edged blade accomplished the stab wounds, especially if there are only a single or a few stab wounds. If there are multiple stab wounds, and a single-edged blade was used, than the classic blunted or squared off end will be seen at one end and an acute angle will be seen at the other end. When this is the case, unless there is other evidence, make certain the investigating law enforcement agency understands that within a reasonable degree of probability, only one weapon was used.

Before we leave this subject, there are some stab wounds which will have a blunted or squared off appearance at both ends. This occurs if the knife used has a ricasso, which is the flat section of the blade located at the junction of the blade and the knife's bolster or guard.

Fig. 62. Note the blunted or squared off appearance at both ends in a stab wound produced by the flat section of the blade at the junction of the blade and guard (Lower right stab wound immediately next to the guard).

Fig. 63. (1) is the blade, (2) handle, (3) point of knife, (4) cutting edge, (5) grind, which is the cross section of the blade, (6) spine, which is the thickest part of the blade, (7) fuller, the groove which lightens the blade, (8) ricasso, barrier between the blade located at the junction of the blade and the knife's bolster or guard, (9) guard, the barrier between the blade and the handle, which protects the hand from an opponent, (10) the end of the handle or butt, and (11) the knife's handle or butt may allow a lanyard to be used to secure the knife to the wrist, or a portion of the tang to protrude as a striking surface for hitting or glass breaking.

As previously discussed, between the guard and the cutting-edge of a knife, there may be a very short segment in which both edges (cutting and non-cutting) are squared-off or if-you-will blunted. Thus, if the blade is thrust in its full length, both ends of the stab wound will be blunted or squared-off as shown in Fig. 62. The one is squared-off by the non-cutting edge and the other by the ricasso or guard.

One last point to remember is that most knives sold in this country are single-edged.

6. **Relationship Between the Weapon and Wound:** The fact that the appearance of a weapon "Fits" with a stab wound is not proof that the weapon caused the injury; it only means that it could have caused the injury. Having said that, the appearance of

a weapon which does not “Fit” with the wound removes it from consideration. For example, the blade of a knife that is seven-eights inch wide at a point two inches from its tip means it could not have produced a stab wound five inches deep, whose maximum skin dimension is one quarter inch. A knife with a thick blade that is squared off to a flat surface on the edge opposite the cutting-edge, can be identified from the stab wound showing a double right-angled end to the skin defect. Often, on close examination you will see each end showing a ‘fish tail’ appearance.

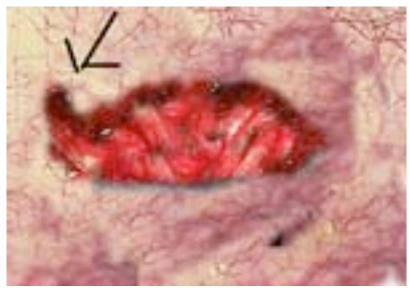


Fig. 64. Fish tail appearance to a stab wound caused by a knife with a thick blade.

If a knife has a serrated back edge, such as that of a Bowie-type or ‘Rambo’ style knife, the edge of the wound next to the serrated back edge will be markedly irregular or ragged. Should such a knife be thrust into the victim at an oblique angle, the edge of the wound next to the serrated back edge will show serrated abrasions.

Fig. 65. Damascus Bowie Knife with serrated back edge.

Fig. 66. Rambo style knife with serrated back edge.

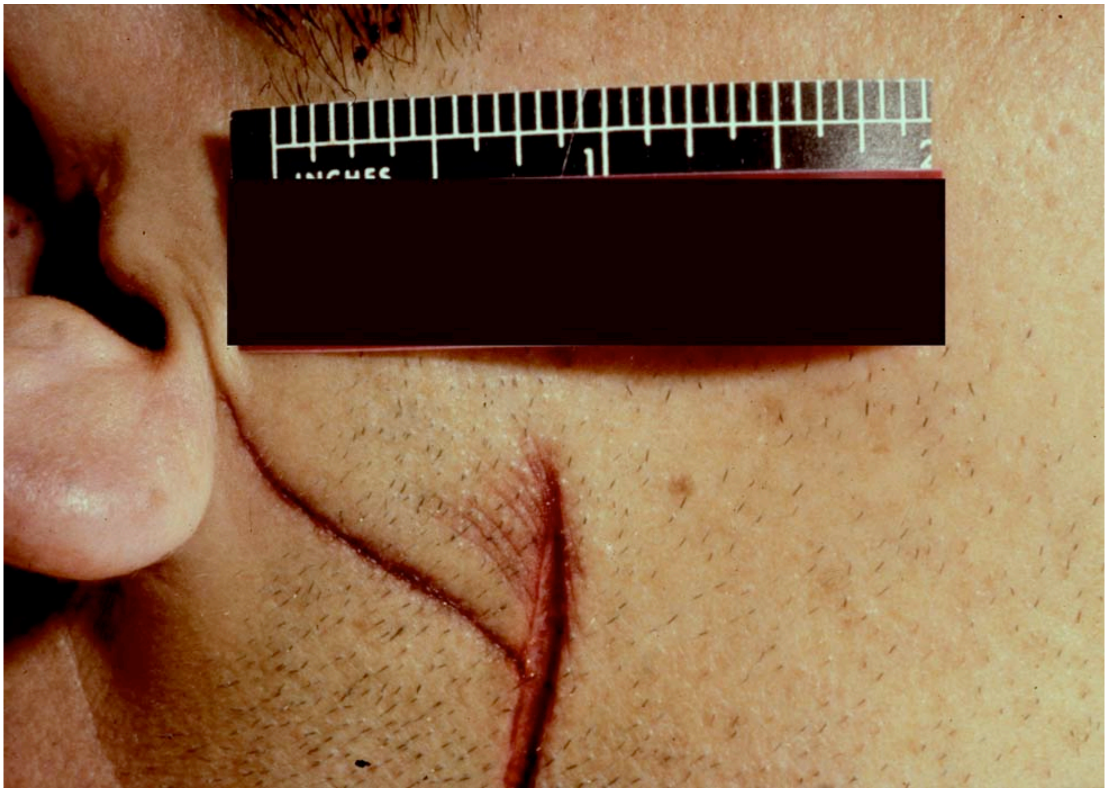


Fig. 67. Note the multiple, parallel, superficial incised wounds extending from the stab wound margins, superior to the longer incised wound. The presence of these types of incised wounds indicates injuries produced by a blade with a serrated edge. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Stab wound produced by tapered blade will typically show a width which is analogous to the level that the blade is thrust to.

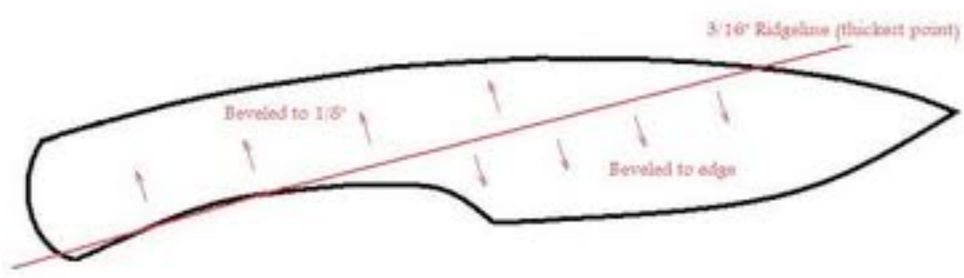


Fig. 68. Tapered blade

Movement of the knife within the produced track can change the configuration of the stab wound, such that the resulting stab wound will have an appearance which is quite different from the suspect knife. For example, thrusting the knife into the skin and underlying soft tissue parallel to Langer's lines will produce a stab wound that has the appearance of being consistent with the suspect weapon. However, should after the knife has been thrust into the victim, under the same scenario as just described, but the assailant and or the victim's movement 'rocks' the blade of the knife, thus changing the configuration of the stab wound, the resulting wound will have an appearance, which is not consistent with the suspect weapon.

In order to establish a relationship between the stab wound and a weapon, it is very important that the suspected weapon be available at the time of the autopsy. On the surface, this may appear to be absurd to mention this, but in my years of experience there have been occasions where the investigating agency did not bring the weapon to the autopsy, and were somewhat put-out we wanted to see the weapon before beginning the autopsy.

The weapon must be examined, photographed and appropriately measured. In addition to looking for fingerprints, fragments of blood and tissue must be noted. It is the responsibility of the Forensic Pathologist doing the case to make certain all appropriate laboratory test, most especially DNA, be accomplished. It is only after the weapon has been throughly examined with all appropriate specimens taken for analysis that it can be compared to the stab wound or wounds. What is not appropriate is to insert the blade of the suspected weapon into the wound or wounds and photograph it, before the stab wounds have been measured, placed on a body diagram, described, and photographed. It would be absolutely unacceptable to insert the blade of the suspected weapon into a stab wound before examining it for tissue or blood.

One of the problems Forensic Pathologist come across in examining gunshot wounds, incised and stab wounds at the time of autopsy is that surgery has been performed on the victim, which often complicates the interpretation of these wounds. It is not uncommon during surgery for the configuration of these wounds to have been modified. The wounds may have been enlarged during exploration, excised during debridement, or sutured. It is important in these circumstances the Forensic Pathologist review the admission and operative notes for descriptions or to see if photographs have been taken before surgical intervention. It is also very important the Forensic Pathologist talk to the surgeon involved in the case.

Fig. 69. This is an image of a previously sutured surgical incision after the sutures have been removed and the surgical margins have been re-approximated by using superglue. The defect above the left side of the scale is a stab wound. Note it has been incorporated into the surgical incision, and was not recognizable with the sutures in place. The horizontal defect above the right side of the scale also appears to be a stab wound; however, this defect had been produced by emergency personnel during the placement of a chest tube. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

There are two things Forensic Pathologist should consider when reaching their conclusions. First, do not reach any conclusions or express an opinion in a dogmatic fashion as to the identification of the suspected weapon, unless you have unequivocal objective anatomic and other evidence that support that conclusion. Secondly, when expressing an opinion in the court room or elsewhere, whether a particular weapon was the weapon responsible for the wounds, it is best, if the objective evidence supports it, that statements such as, “It could have been” or “its appearance and configuration are consistent with the weapon, which produced the injuries I observed in the victim.” What you do not want to do is to embellish or create science to support a dogmatic conclusion, which is not supported by objective evidence. This can cause not only embarrassment in the court room and publicly, but can also tarnish your professional reputation.

7. **Direction:** With close examination of the external surface and wound track of a stab wound you often can ascertain the direction from which the blade entered the body. Having said that, stating definitively the position of the assailant is another matter, especially if there is only a single or few stab wounds. This is because both the assailant and the victim may have been in movement. This line of thought also applies to examination of cuts in clothing. Altercations are rarely static. As Bernard Knight points out, a stab wound which enters the upper part of the left side of the chest and proceeds at an acute angle downwards, does not mean the assailant was taller or positioned above the victim, thus, delivering a downward blow. The victim may very well have been bending forward or crouching, when the assailant used a horizontal arc relative to the floor, thrust the knife into the left side of the chest or the victim. As pointed out above, the Forensic Pathologist will be able to determine the direction of the wound relative to the axis of the body; it will be the witness statements that will tell him the positions of the assailant and victim.

Fig. 70. The clothing of the victim should be examined not only to correlate the defects in the clothing with those on the body, but also to look for trace evidence. It is also possible that the defects in the clothing may give you some idea as to the nature of the

weapon used. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

The determination of direction the blade takes through the planes of the body is accomplished through a careful layered dissection of the wound tracks, beginning at the external surface defect and concluding at the distal end of the track. This is best accomplished by examining each stab wound, recording each ones dimensions, length, width and depth, placing each on a body diagram and photographing. Following the external examination, each stab wound is dissected from its external surface to its termination. This same concept applies to gunshot wounds. It is only after all measurements have been made and track directions have been determined do you begin with the internal examination.

It is only by using this method can you accurately describe the direction of each stab wound, i.e., from front to back or back to front, from lateral to medial or medial to lateral and from head to foot or foot to head. Often I will also try to give the angle the blade passed through the planes of the body. To do this you need to have good comprehension of the anatomy of the body, and use diagrams, which accurately depict the location of surface anatomical landmarks and if possible the location of internal organs.

One of the things that can help you in determining the direction the blade of the knife took on entering the body is careful examination of the margins of the stab wound. Specifically you are looking for patterned abrasions and or contusions, which have been caused by the guard of the knife; if the blade entered the surface of the body perpendicularly then the resulting patterned abrasion and or contusion induce by the guard will be symmetrical. If however, the blade is thrust into the surface of the skin at a downward angle, the patterned abrasion and or contusion will be above the stab wound; likewise, if the blade is thrust into the victim at an upward angle, the patterned abrasion and or contusion will be below the stab wound.

In those stab wounds, which are induced by the blade entering obliquely, such as from the right, the patterned abrasion and or contusion will be on the right; If the blade comes obliquely from the left, it will be located on the left.

Another examination of stab wounds, which can be of help in determining direction is looking for 'undercutting,' such that the subcutaneous tissue is visible below the edge of the wound. If the plane of the blade is perpendicular to the surface of skin, no such shelving will be seen at the sides of the wound.

Fig. 71. Note the soft tissue beneath the lower margin assumes a more oblique plane suggesting the direction of the thrust of the blade was left to right at an oblique angle, thus exposing the underlying subcutaneous tissue. This also accounts for the abrasions by the guard or quillion being more severe to the left of the upper angle and why the contusion appears to the left of the lower margin. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

8. **Force Required:** The question that every Forensic Pathologist must address in either cases of blunt force traumatic injury or stabbings is "How much force was used." As one would suspect this question cannot be answered in absolute terms. It is a question however, that often plays a key role in the perception the prosecution and defense wish to convey in the presentation of their case in the court room. The prosecution when presenting this aspect of their case will not uncommonly use expressions such as 'violent,' 'frenzied,' or 'extreme force.' The defense will adopt

a position the victim unfortunately fell against the weapon, with the blade of the knife being only held against them, thus sustaining the stab wound. Another scenario is the blade of the knife was held against the victim and because the victim moved, the blade accidentally penetrated the skin and underlying soft tissue. The actual determination of how much force was applied is for the most part subjective. Although, it is true that research has been done, such as that by O'Callaghan *et al.* who determined the amount of force required to penetrate the skin and underlying soft tissue. They determined it took 11.1 lb. with a range of 7.9 lb. to 12.4 lb. to penetrate the skin, subcutaneous tissue and muscle. They further broke the required force down for each of the respective tissues, for subcutaneous tissue and muscle, 7.8 lb.; for muscle, 8.4 lb. and for fat 0.5 lb. Although, O'Callaghan's group does provide definitive units of force, what you need to ask yourself is what meaning do these measurements have to the judge or jury; in actuality, probably nothing. What is far more effective is to use expressions of force, which are based on common knowledge, such as 'slight pressure,' 'moderate force,' 'considerable force,' and 'extreme force.' The expression 'extreme force' can rightly be use when the blade of the knife has penetrated bone or the dagger was thrust into the victim causing a patterned abrasion and or contusion produced by the guard or quillion. When trying to ascertain the amount of force required to inflict a stab wound there are some general concepts to keep in mind:

a. It is the sharpness of the tip of the blade, which is most important in penetrating the skin, not the cutting-edge of the blade.

b. It is reasonable to conclude that a blade with a cutting-edge analogous to a razor will require less force to induce a stab wound than a dull pocket knife.

c. Bone and calcified cartilage require more force to penetrate than skin, muscle or subcutaneous tissue.

d. The velocity of the moving knife plays a substantive role in the force required for penetration, much more so than the mass of the knife. Remember, force varies with square of the velocity.

e. The skin over the chest is easier to penetrate as compared to the skin over the abdomen because it is stretched.

f. The skin of the elderly, although, showing poor skin turgor, is no easier to penetrate than the skin of a younger person. Skin turgor is a reflection of the elastic property of the skin. The skin of women is no less resistant to penetration than that of men.

g. This is a very important concept to keep in mind, once the skin is penetrated, with the exception of bone and cartilage, no additional force is required to penetrate the underlying subcutaneous tissue or muscle. This concept even applies to stab wounds which extend to the guard or quillion. Often the prosecutor will claim that since the length of the stab wound extended to the guard or quillion, 'considerable or extreme force' was used. This is not true. Once the tip of the blade overcomes the resistance of the skin, the blade of the knife will literally 'fall' through the underlying soft tissue with no additional force required.

h. Another point to remember, if the tip of the blade perforates the skin rapidly, it is not necessary that the handle of the weapon be held tightly in order for the tip of the blade to penetrate the underlying soft tissue. To counter the defenses claim that the victim fell against or ran into the blade, the prosecution will claim that the handle of the weapon had to be rigidly supported, such as being held against a person's hip in order for the blade to have penetrated up to the guard or quillion. This is not true. Experiments have shown this theory to be incorrect. Remember, although one may look upon the defenses claim that the victim fell against the blade as being rediculous, the prosecution does not have the right to create science to counter their claim.

i. Although calcified cartilage offers considerable resistance to penetration, uncalcified cartilage, such as that of the costal cartilage of the younger or middle-aged person offers little resistance to penetration. This is not to say that its penetration does not require more force than the adjacent intercostal muscle. Remember, thrusting of a sharp knife with 'considerable force' will easily penetrate ribs, sternum, and certain parts of the skull, i.e. squamosal portions of the temporal bones.

j. The degree of force to produce a stab wound also varies with the character of the blade. A thin slender, double-edged knife will penetrate more deeply than an equally sharp, wide, single-edged blade thrust with the same force.

9. **The Stab Wound was Inflicted by which Hand:** It is suggested when answering this question the Forensic Pathologist should be conservative. For example, the victim and assailant, although facing one another, does not lead to the unequivocal conclusion that the stab wound into the anterior-lateral left chest was accomplished by the right arm of the assailant, and that the assailant was right handed.
The assailant could have used a "backhand" swing of his left arm to produce the stab wound in the victim's anterior-lateral left chest wall. Regarding the issue the assailant had to be right handed to inflict this particular injury, in a violent assault, an assault in which there is intense emotion, you must always remember the possibility that a right-or left-handed person could have used either hand to hold the knife.
10. **Physiologic Effects of Stab Wounds by Anatomic Location:**
a. **Stab wounds of the chest:** As previously discussed most fatal stab wounds involve the left chest region. This is primarily due to the fact most people are right handed. Another point to be made, if it is your desire to kill someone with a knife, than your focus would be primarily on the heart.
In fatal stab wounds involving the chest the heart and major arterial vessels most commonly the aorta, and major venous vessels are involved. Other anatomic structures commonly involved are the lungs, bronchi, mediastinal structures and the diaphragm. A fatal outcome due to stab wounds of the lungs is uncommon if there is immediate medical treatment, unless the hilar regions are involved where there is a concentration of major vessels. The more peripheral the stab wound in the lung, the less likely there will be an immediate fatal outcome. Two of the more common findings in stab wounds of the lungs are subcutaneous emphysema and pneumothorax. Another not uncommon finding in stab wounds of the lungs is evidence of hemoptysis and blood-tinged froth and mucus in the bronchi, trachea, larynx and oral cavity often associated with blood in the nares. Generally, in fatal stab wounds of chest with involvement of lungs, there is also involvement of the heart.
If the stab wound occurs immediately to the left of the sternum, it will typically involve the right ventricle. As the stab wound occurs more laterally into the left anterior chest wall, it will involve left ventricle. One of the things you need to keep in mind

is if the stab wound of the left ventricle involves the left anterior descending coronary artery, than even with rapid medical intervention, these stab wounds are fatal. However, stab wounds of the ventricles, more left than right, are not always fatal. Interestingly enough, stab wounds involving the left or right atrium lead to death sooner than those of the ventricles due to the muscular contraction of the latter. Stab wounds involving the right anterior chest wall, immediately next to the sternum can involve the right atrium, right ventricle and aorta. Other vascular structures, which can be involved are the superior and inferior vena cava and the azygos veins. Should the stab wounds involve the lower chest, besides involving the heart and lungs, they can involve the diaphragm and some of the abdominal viscera. The organs typically involved are the liver, gallbladder, stomach, duodenum, pancreas, and spleen. The major vessels that can be involved are the aorta, inferior vena cava, portal vein and hepatic artery.

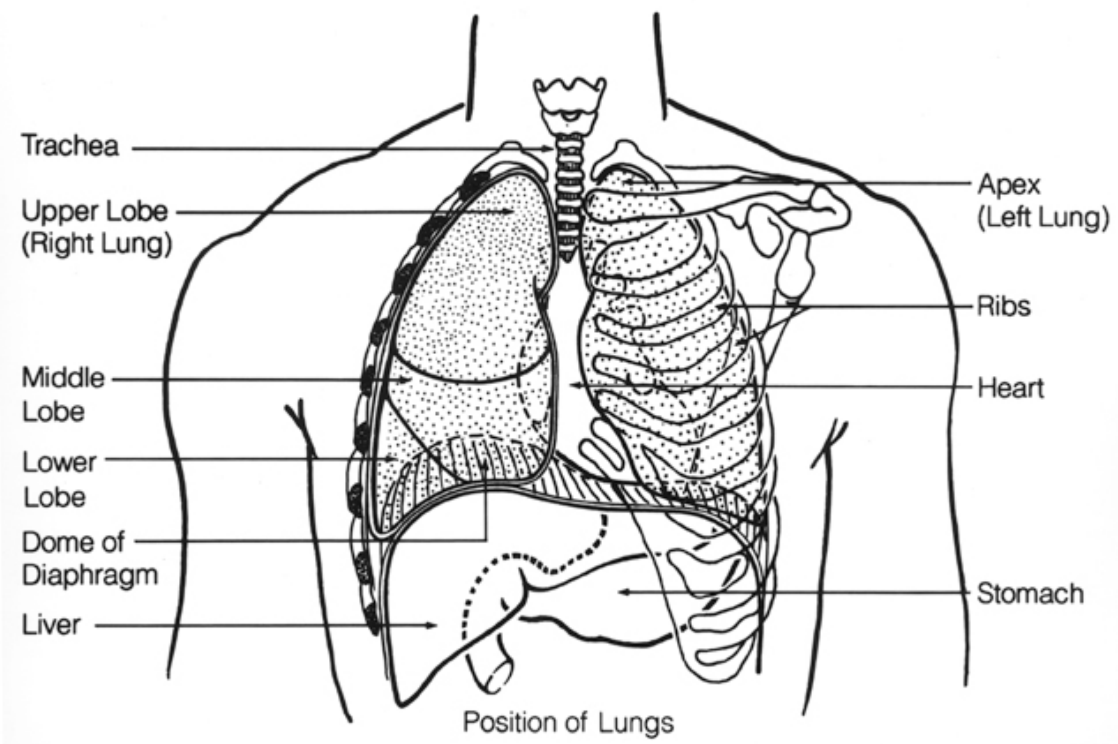


Fig. 72. The above is an anatomical drawing showing the general anatomy of the neck, chest and upper abdomen.

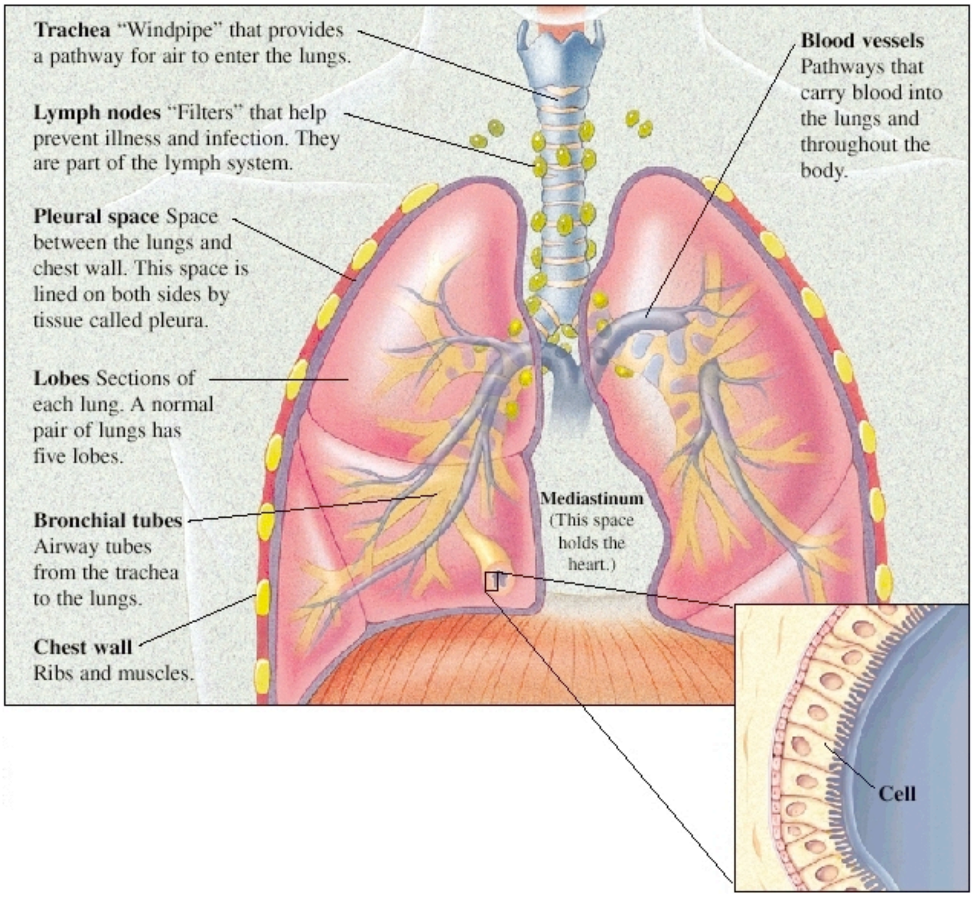


Fig. 73. This is an anatomical illustration of the respiratory system, extending from the larynx to the alveolar air sacs, including lymph nodes, blood vessels, pleural space (space within the chest that contains the lungs), lobes of the lungs (3 right lung and 2 left lung), bronchial tubes and the chest wall composed by muscle and ribs.

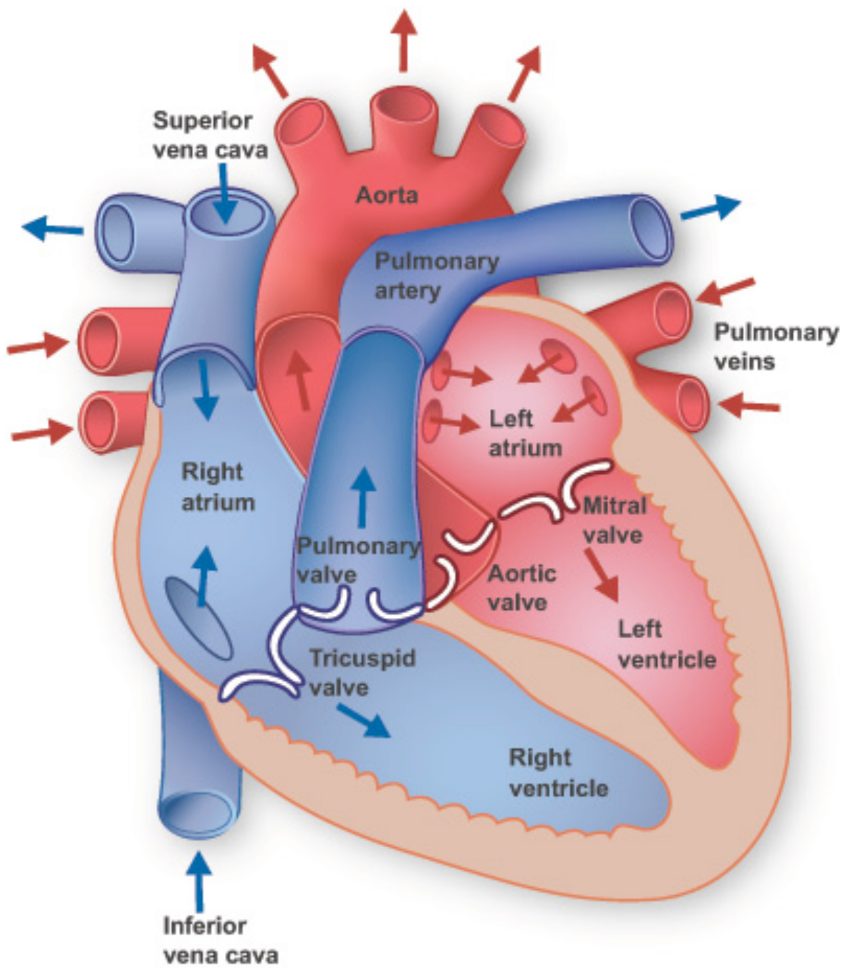


Fig. 74. This is an illustration of the heart and the major vessels.

b. **Stab wounds of the abdomen:** Stab wounds are more common in the upper abdominal quadrants as compared to the lower quadrants. Typically, according to Vince and Dominick DiMaio, only two-thirds of abdominal stab wounds enter the abdominal cavity and less than half of these lead to significant injury. When death occurs from abdominal stab wounds, it is not always immediate. The fact death occurred several days, to weeks after the stab wounds can on occasion cause the Forensic Pathologist difficulty in establishing the cause of death as being related to the stab wound. To resolve this issue there is a fundamental axiom that should be followed, “Where it not for the injury (gunshot wound, stab wound, etc.) would the victim have died.” To give you an example, I did an autopsy on an individual who had been shot several times in the abdomen during the Vietnam conflict in 1967. His death occurred some 40 years later. Reviewing the prodigious volume of medical records I could establish a link between the gunshot wounds of the abdomen in 1967 and his death in 2007; the manner of death was a homicide. Stab wounds of the upper abdomen can involve the liver, gallbladder, stomach, duodenum, pancreas, spleen, small and large bowel, omentum, aorta, inferior vena cava, portal vein, mesenteric vessels and other vessels associated with the anatomical structures named. Typically, the kidneys and adrenals are involved with flank stab wounds.

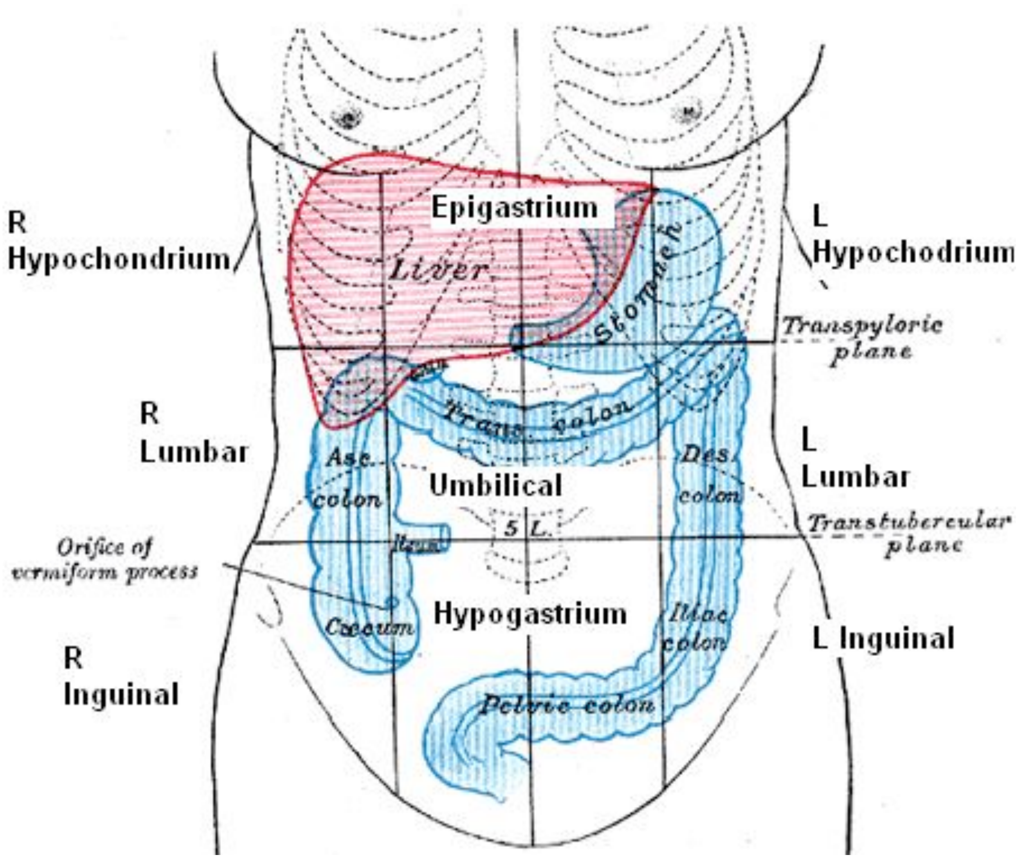


Fig. 75. When viewing the external surface of the body, the abdomen is divided up into 9 distinct anatomical regions.

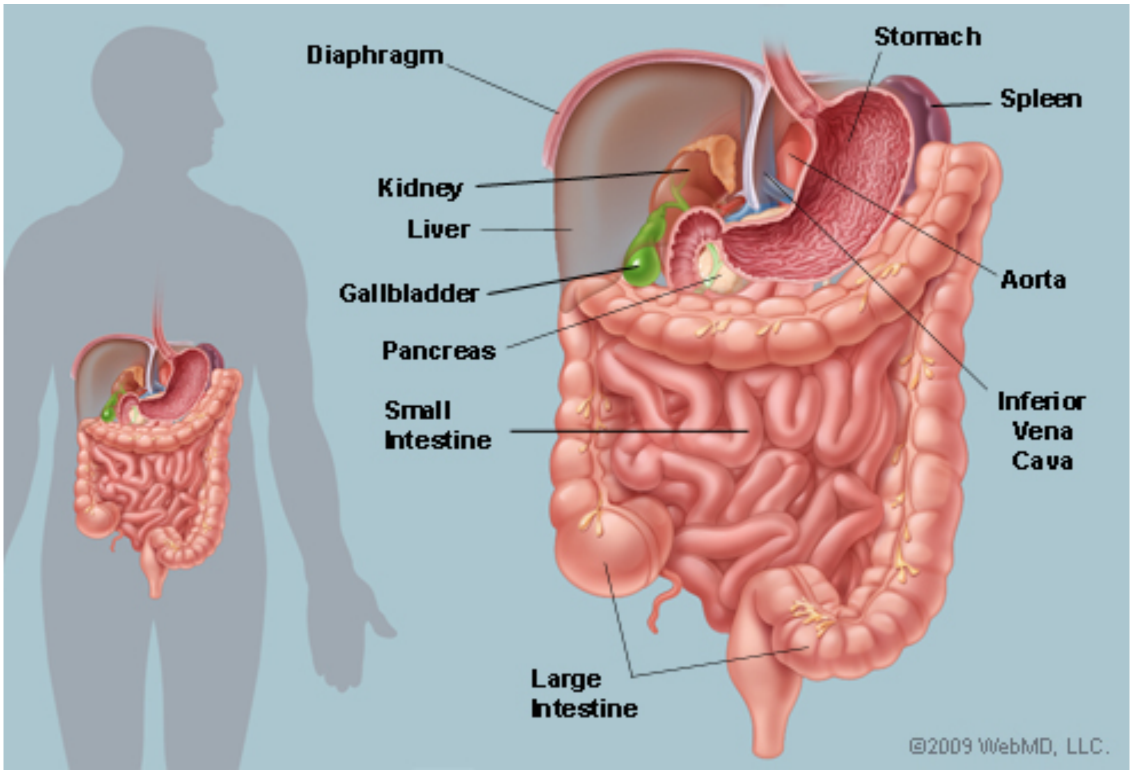


Fig. 76. This is an illustration of the major anatomical structures in the abdominal cavity.

Stab wounds of the lower abdominal and inguinal regions most commonly involve the small and large bowel, bladder, uterus, aorta, inferior vena cava, mesenteric vessels, femoral and external iliac vessels. Fatal stab wounds of the lower abdominal and inguinal regions are more common in men than women.

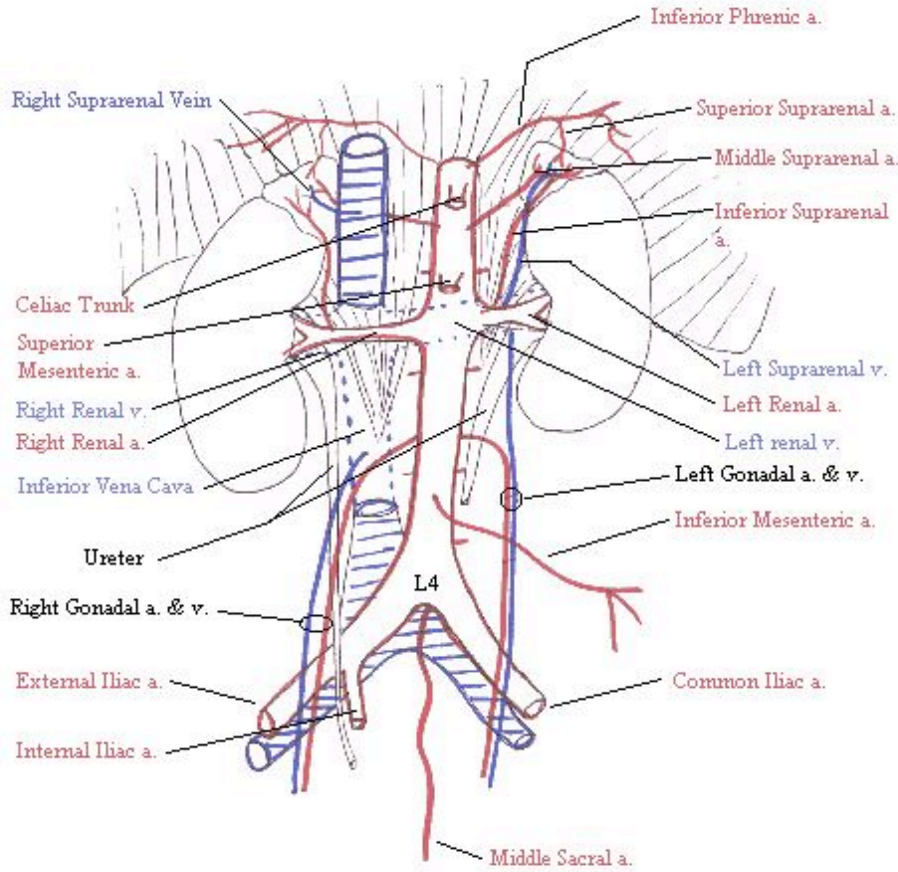


Fig. 77. Major vessels within the mid and lower abdominal and inguinal regions.

Fig. 78. The above image shows a stab wound of the inferior vena cava (shiny gray structure on the left) as well as a total transection of the aorta. (Sharp Force Injury, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

c. **Stab wounds of the neck:** These stab wounds usually involve penetration with near to complete transection of the carotid artery, external and internal jugular veins or both, and their immediate branches or tributaries. Although, stab wounds and incised wounds of the neck constitute a small percentage of homicidal deaths, when inflicted, they often result in a fatality. This is because the major vessels and the trachea and larynx are quite superficial thus, an incised or stab wound of less than one-half to one inch in depth can cause fatal exsanguination and fatal venous air embolism, or asphyxia due to aspiration of blood. The substantive fatality rate is is also because anatomically the carotid artery, external and internal jugular veins, and trachea and larynx lie near to one another and the skin. This anatomic relationship is further exacerbated should the neck be hyperextended.

Deaths from stab wounds of the neck need not always be immediate. Stab wounds of the neck can result in thrombosis of the common carotid artery and embolism, both causing cerebral ischemia with its attendant cerebral infarction. Stab wounds of the neck area can lead to abscesses, cellulitis and mediastinitis. An arteriovenous fistula between the carotid artery and internal jugular vein can ultimately lead to death. The formation of an aneurysm of the carotid artery can cause a delayed death following its rupture.

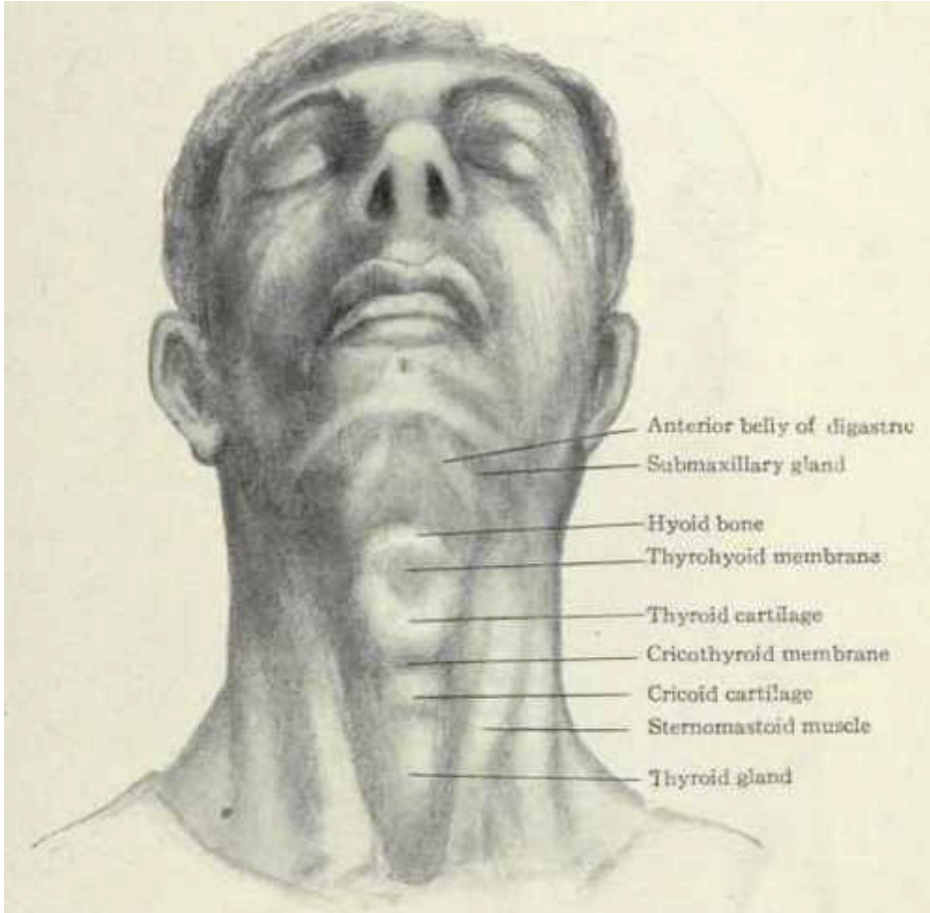


Fig. 79. External surface anatomy of the neck.

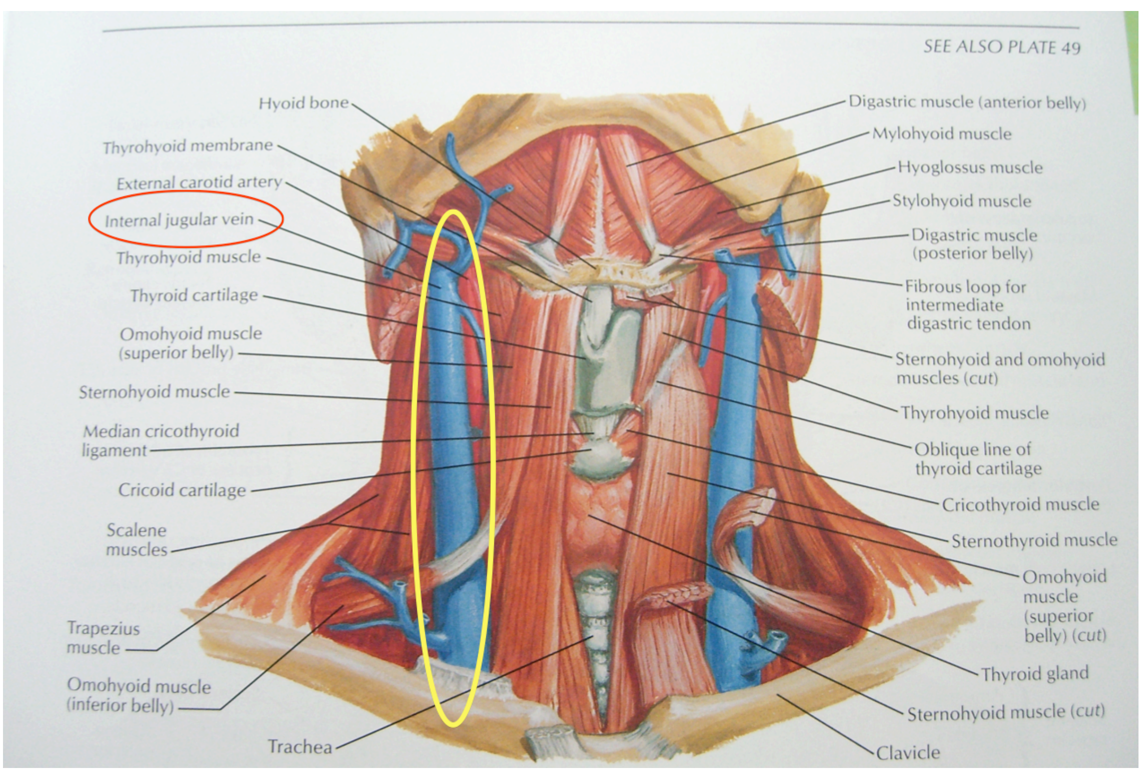


Fig. 80. The above illustration is the Internal anatomy of the neck. The structure circled in yellow is the internal jugular vein, the name of which is circled in red.

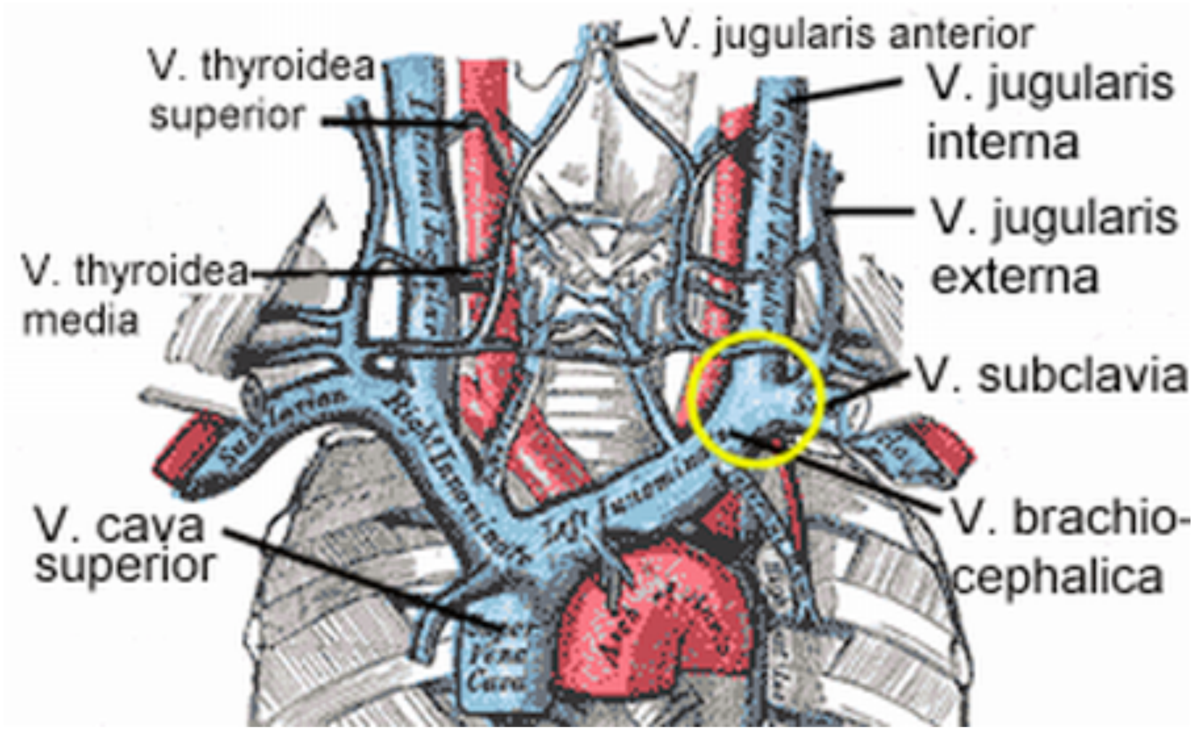


Fig. 81. This illustration depicts primarily the vascular structures of the neck and mediastinum.

Fig. 82. Stab wounds of the neck.

d. **Stab wounds of the head and face:** Most of the knife injuries to the head and face are incised wounds as the result of slashing.

Fig. 83. An incised wound of the face as the result of slashing. Note the wound is longer on the skin surface than it is deep. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fatal stab wounds of the head typically are through the eye with involvement of the orbital wall or the squamosal portion of the temporal bone, which is the thinnest bone composing the cranial vault. However, on rare occasions the fatal incised or stab wound did not penetrate the skull, but involved a major vascular structure, such as the superficial temporal artery or one of its branches, the occipital artery at the back of the head or the facial artery of the face with death by exsanguination. Most fatal stab wounds of the head do involve penetration of the cranial vault. If such a stab wound is associated with an immediate fatality it generally is due to penetration of the squamosal portion of the temporal bone with penetration or perforation of the middle meningeal artery within its groove. Although not common penetration of the top of the head with involvement of the longitudinal groove, may penetrate the contained superior sagittal sinus.

More often, the stab wound to the head is not immediately fatal with many of the victims being hospitalized. There are cases, in which the victim has walked or run away from an altercation, not realizing they have been stabbed in the head with penetration of the brain. This is because stab wounds of the brain are “low velocity” injuries as compared to a missile, consequently, they are not characterized by the same degree of cerebral destruction as the latter. In essence, there is no associated conical cavitary lesion as seen in missile injuries due to their velocity. Remember, the energy imparted to an organ as a result of a missile is due to velocity square and not its mass. Thus, a stab wounds destruction is limited to the track the sharp-edged instrument produces.

There are also cases in which the person has been hospitalized, with multiple injuries, one of which was not picked up. This is especially true in those who have a crop of hair or the entrance to the brain was through the orbital plate of the frontal bone or cribiform plate of the ethmoid bone, with the stab wound having occurred in the upper or medial aspect of the upper eyelid next to the supraorbital margin.

Some of these victims have eventually died due to continued intracranial bleeding or infection. This is why when examining the head during an autopsy you take the time to inspect the undersurface of the scalp and most especially the external and internal surfaces of the calvarium and floor of the skull. The other thing to keep in mind is that the actual defect in the skull from a sharp-edged instrument will coincide with the width and thickness of the blade of the weapon.

Fig. 84. Stab wound of the upper left forehead with exposure of the squamosal portion of the left frontal bone. There is no evidence of penetration of the cranial vault.

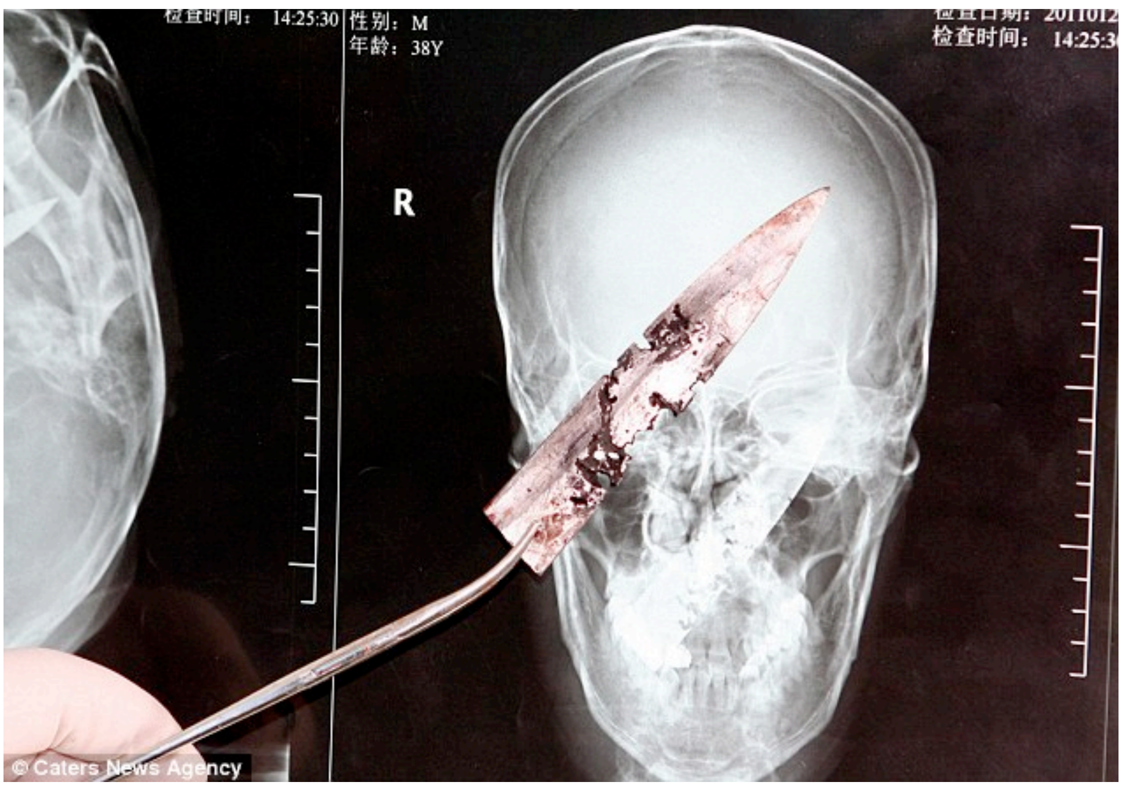


Fig. 85. Stab wound of the head with retained broken blade.

e. **Stab wounds of the spine:** Stab wounds of the vertebral column with involvement of the spinal cord are uncommon. The type of injury that the vertebral column and spinal cord sustain is dependent on the sharp-edged instrument used and the degree of force applied. The two most involved areas of the vertebral column and spinal cord are the cervical and thoracic.

The spinal cord is especially vulnerable to stabbing when the vertebral column is flexed in the cervical and thoracic regions. This is because with flexion of the neck and back, the spinous processes of the cervical and upper thoracic vertebral arches separate; thus, allowing easier penetration of the blade of the weapon into the vertebral canal with involvement of the spinal cord. The degree of flexion of the lower thoracic and lumbar vertebrae is not nearly as great as the upper thoracic vertebrae, consequently the spinous processes still overlap to a degree making penetration to the vertebral canal difficult.

If there is evidence on external examination of the body of stab wounds to the posterior midline, x-rays should be taken before starting the autopsy. It may well be that a fragment of the blade of the weapon may be within the wound track.

As previously discussed, it is also possible that minute fragments of metal can be found in the wound track, most especially if bone is involved. These minute fragments can subsequently be analyzed as previously elaborated.

The entire spinal cord should be removed, examined and photographed before placing in formaldehyde. Following fixation the cord should be serially sectioned and those portions of the cord penetrated should be examined with a microscope.

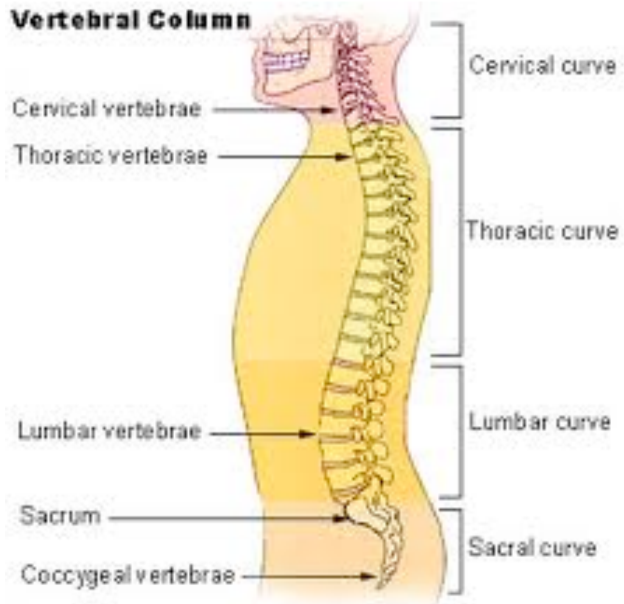


Fig. 86. General anatomy of the vertebral column.

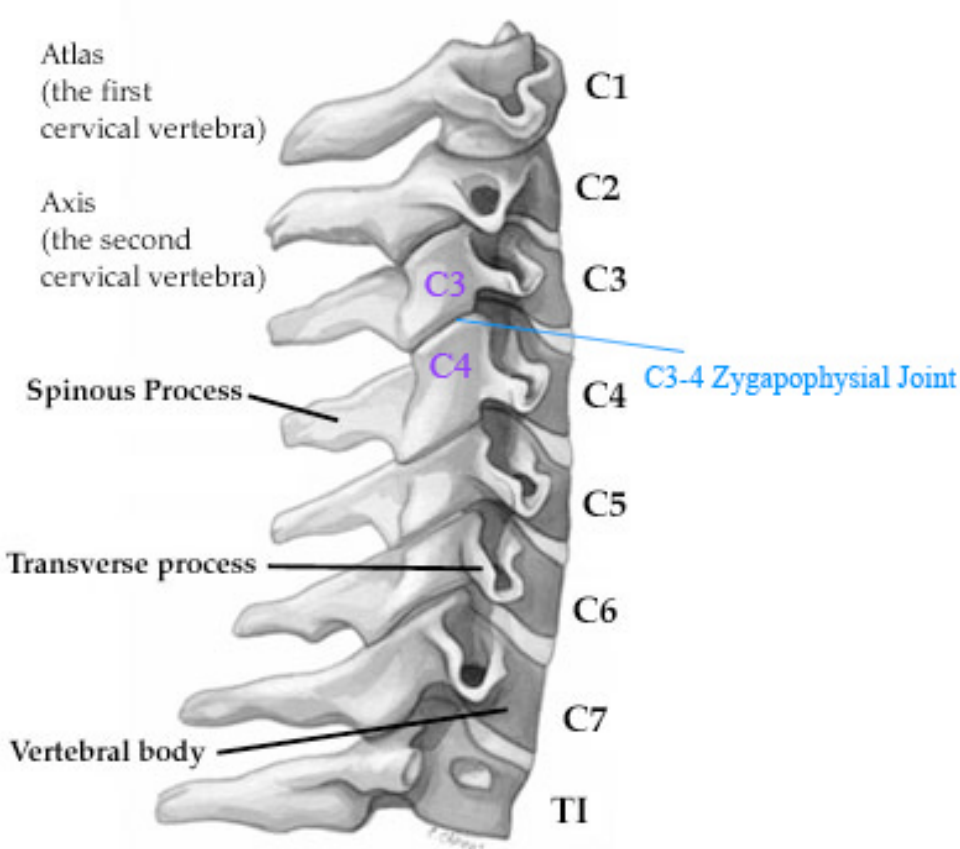


Fig. 87. Anatomy of the cervical vertebrae.

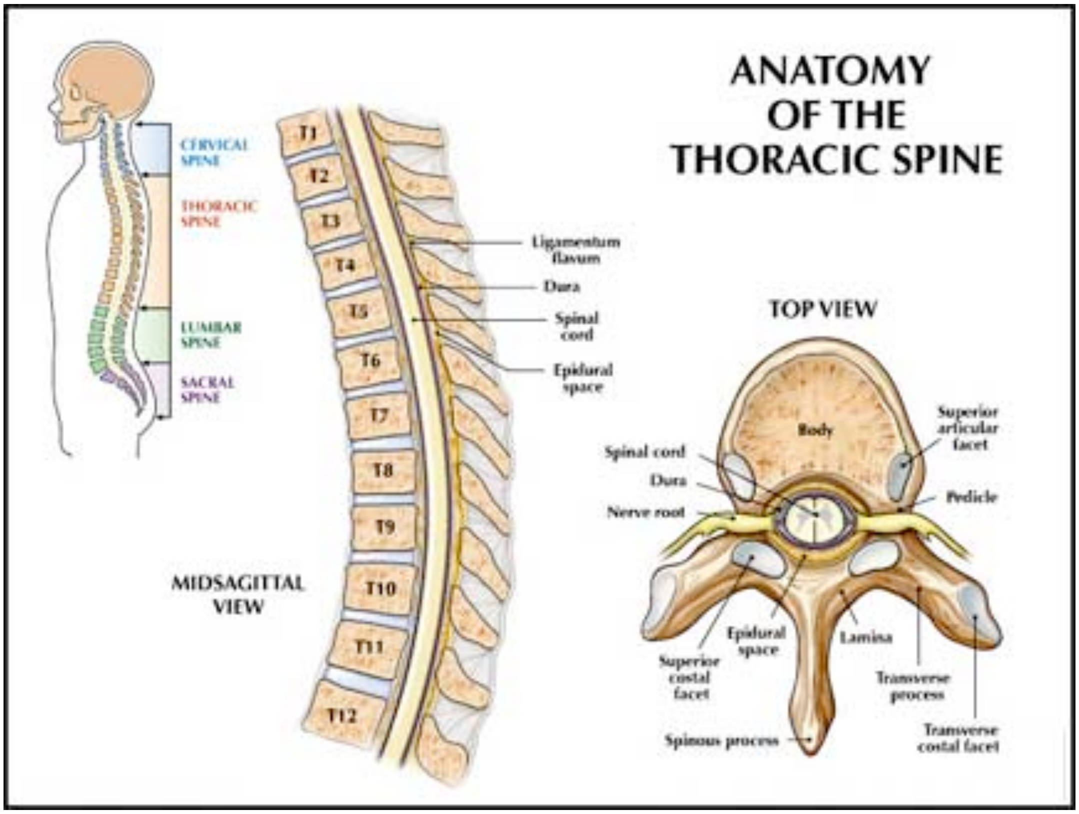


Fig. 88. Anatomy of the thoracic spine.

Fig. 89. The above picture is that of a young Russia woman who was the victim of a purse snatcher, who thrust a knife with a 6 inch blade into the posterior midline at the base of her neck. She was totally unaware she had been stabbed, until she got home and her parents saw the knife protruding from the base of her neck. She was immediately taken to the hospital.

f. **Stab wounds of the extremities and axillae:** Stab wounds that involve the supra- and infraclavicular areas with penetration or severing of the subclavian arteries are analogous to penetration or severing of the external iliac or femoral arteries of the lower extremities. Unless immediately treated these injuries can lead to death as the result of exsanguination. Likewise, stab wounds involving the brachial, ulna and radial arteries of the upper extremities unless immediately treated can lead to death from exsanguination, as is true of stab wounds of the popliteal and tibial arteries of the lower extremities.

Stab wounds of the axillae can penetrate or sever the axillary artery or vein leading to exsanguination unless immediately treated.

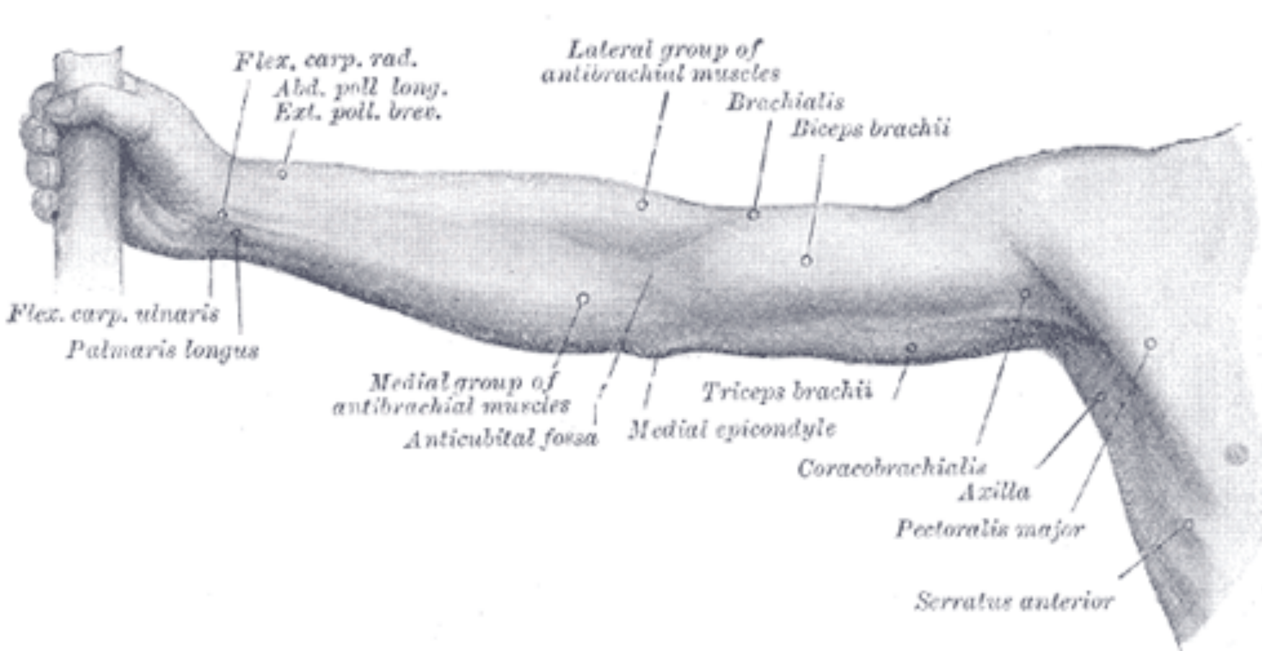


Fig. 90. Surface anatomy of the right upper extremity.

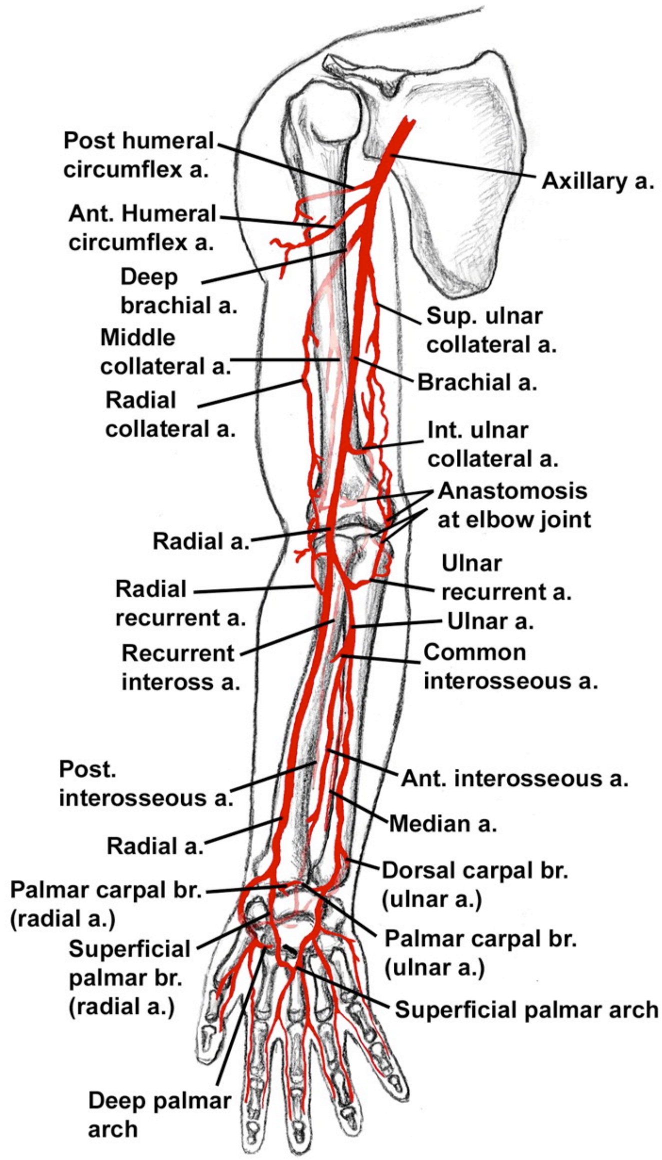


Fig. 91. Arterial supply of the upper extremity: The ulnar artery supplies the superficial palmar arch, which is the major source of blood to the digits. The radial artery supplies the deep palmar arch, which in turn supplies the dorsal arches of the hand.

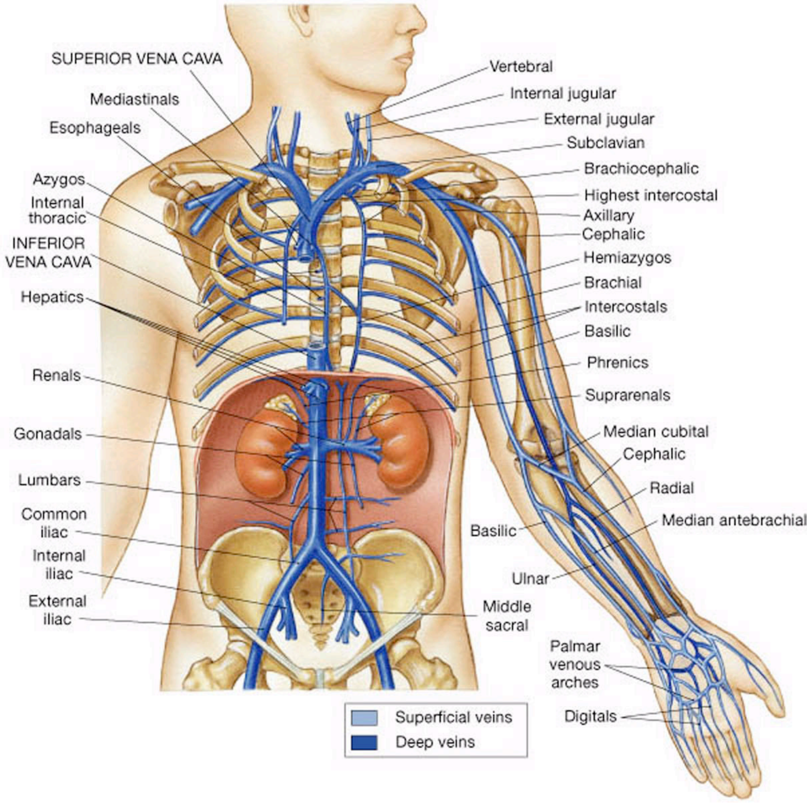


Fig. 92. Superficial and deep veins of the upper extremity.

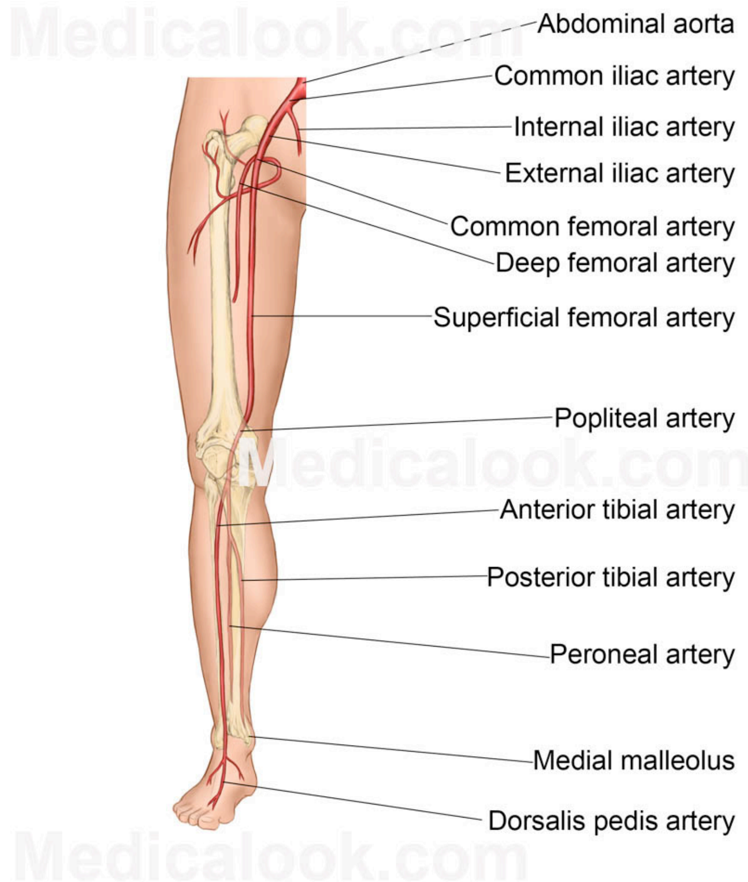


Fig. 93. Arteries of the lower extremity.

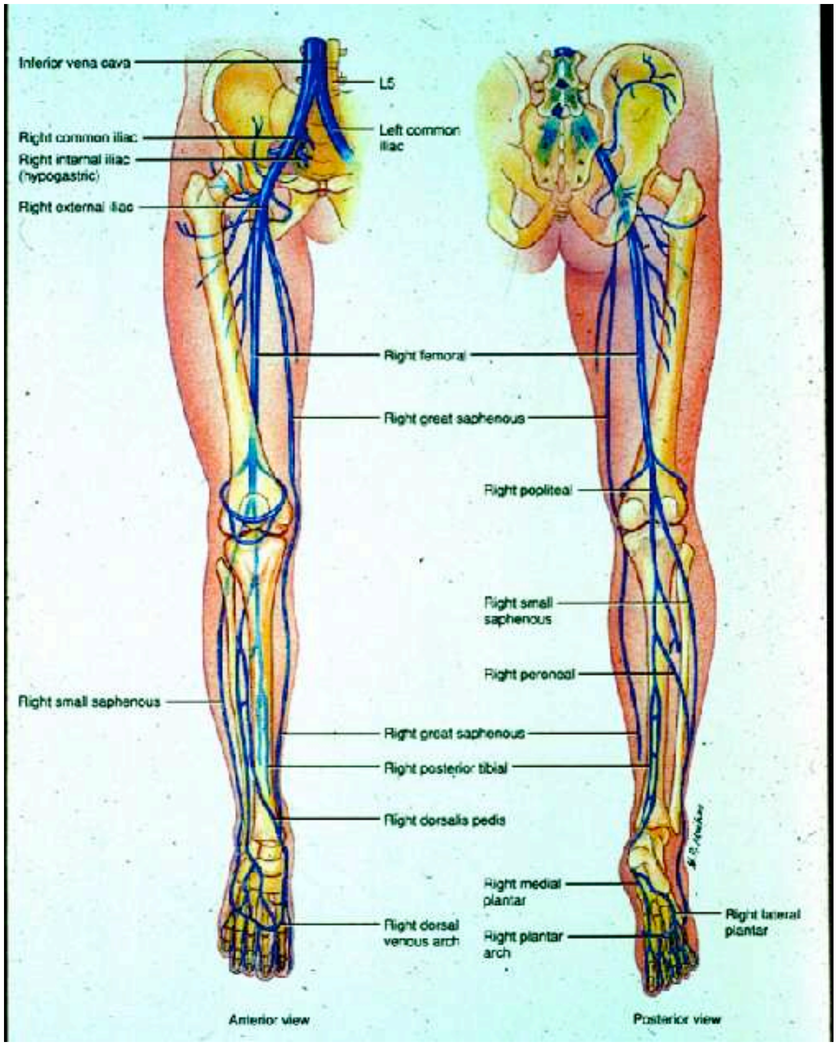


Fig. 94. Deep veins of the lower extremity

11. **Rapidity of Death:** How soon the victim died following receipt of the incised or stab wounds is a common question poised by the police or prosecutor. This can be a very difficult question for the Forensic Pathologist to answer definitively. There are instances however that can lead to an instantaneous death as would occur with a stab wound of the brainstem or upper cervical cord, especially with a blade of substantive width. Having said this, not all stab wounds of the brain will cause an instantaneous death as has been previously discussed. A stab wound of the frontal, parietal, temporal or occipital lobes, unless there is involvement of a major blood vessel, will give rise most definitely to morbidity and unless immediately treated

eventually death, but it does not lead to instantaneous or immediate death.

It is also feasible that the victim may have a virtual instantaneous death with a stab wound of the cervical or thoracic cord to the level of T6. Such a stab wound could induce an immediate autonomic dysarrhythmia, which would induce an acute cardiac arrhythmia leading to sudden cardiac arrest.

Although, stab wounds of the heart can cause death within a few minutes, as is the case with stab wounds of the aorta, this is not always the case as previously discussed. Stab wounds of the left ventricle can, in a rhythmic way, be partially sealed during systole, thus delaying the amount of blood collecting within the pericardial sac and possibly extension into the pleural cavities or mediastinum. Such a delay can allow the victim to travel some distance after being stabbed, eventually colapsing and dying due to pericardial tamponade and or hemomediastinum and hemothorax.

The rapid accumulation of as little as 100 ml of blood in the pericardial sac can lead to death as the result of the external pressure exerted by the blood in the pericardial sac preventing blood in normal amounts to enter the atrial and ventricular cavities. There are a couple points you need to be cognizant of. First, stab wounds of the right ventricle will lead to death sooner than those of the left ventricle due to the thinnest of its wall, thus even during systole, it is not as effective at retarding loss of blood through the stab wound as is true of the left ventricle. Furthermore, stab wounds of the atria lead to death sooner than those of the ventricles due to the marked thinnest of their walls thus, having no ability to retain loss of blood from the respective atrial cavities. As previously discussed, there is one exception to all of this; if the stab wound involves the left anterior descending artery, death will occur rapidly due primarily to failure of perfusion of much of the left ventricle.

A stab wound of the aorta, although not causing an instantaneous death, can lead to unconsciousness in as little as 20 seconds and death within a few minutes from exsanguination. However, should the stab wound only penetrate the wall of the aorta, it may rupture several minutes, hours or days later. The other major arterial vessels, as noted above, can over a matter of minutes lead to death. Typically, the larger the artery, the more rapid death occurs from exsanguination. Also, penetration or severing of venous vessels can cause exsanguination, but not as quickly as the penetration or severing of similar sized arteries. There is an interesting caveat when it comes to penetrating or severed arteries, some, due to the elastic fibers in their walls, will retract at the severed end, which may retard to a degree the loss of blood thus, delaying exsanguination.

Another factor when assessing the rapidity of death is you must take into consideration the age of the victim, as well as existing medical conditions. Clearly, a person in their 80s cannot survive multiple traumatic injuries, stab wounds or otherwise, as can a much younger person. A victim with a cardiac and or respiratory disease has less of a chance surviving multiple traumatic injuries as would a person without these abnormalities. This concept however, does not apply to very evident life threatening injuries, such as a stab wound of the brainstem or of the heart with severing of the left anterior descending artery.

In commenting on the rapidity of death, it is best the Forensic Pathologist speak honestly as to the scientific accepted physiologic processes that came into play based on the incised and or stab wounds the victim sustained; most of all do not embellish or create science.

12. **Amount of Movement Following the Incised and or Stab wounds:** Often the Forensic Pathologist is asked by either the law enforcement agency investigating the case, or the prosecutor or defense council, “Did the victim collapse where the assault occurred or could they have walked or run from the assailant.” There are occasions were a “trail of blood” is found at the scene. It must be remembered the trail could have been made by the victim or the assailant. In either case, the origin of the blood must be determined hence, the necessity of collecting samples for identifying the blood is human, the blood group and if possible DNA. The victim’s clothing, as well as the victim himself should be examined for stab and incised wounds and evidence of blood streaks either on the clothing or person. These observations, although very fundamental and basic are easily overlooked. For example, if the victim was stabbed while he is on the floor, and remained there, the streaks of blood will usually run down the side of his body. The information that can be obtained from these fundamental observations point to the necessity of examining the body at the scene,

taking the necessary photographs, and again, examining the body at the morgue, first with clothes on, than clothes off, but the body has not been washed, and again after the body has been washed with appropriate photographs taken at each phase. The answer to the question as to the capability of the victim to either walk or run away from the assailant is in a major part determined by the severity and multiplicity of the incised and or stab wounds and most especially the underlying organs and major vessels involved.

Another issue which will arise is the existence of potential adverse medical conditions, such as congestive heart failure, atherosclerotic and or hypertensive cardiovascular disease, cardiac arrhythmias, chronic obstructive pulmonary disease, etc. As has been discussed previously, a stab wound of the left ventricle with perforation of the left anterior descending coronary artery, of the aorta, or left or right atrial wall, will not allow the victim to travel far due to the rapidity of death. However, a stab wound of the left ventricle, without involvement of the left anterior descending, in a young person with no preexisting cardiac or respiratory abnormalities, may be able to walk or run several blocks before collapsing. The issue is how much blood did the victim lose per unit of time. The greater the blood loss per unit of time, the shorter the distance they are going to be able to travel. There is another point that needs to be made, it is not only the rate of blood being lost per unit of time, but where is the blood going. For example, stab wound of the right ventricle leading to a cardiac tamponade of 450 ml, caused a collapse in a few seconds. However, another victim with a stab wound of the left ventricle, causing a cardiac tamponade of 400 ml, lived for 10 minutes before collapsing. Much more blood was lost per unit of time from the stab wound of the right ventricle than that of the left ventricle. Remember, we are talking about a lose of 400 to 450 ml of blood. In contradistinction to this, another person committed suicide by stabbing himself in the right chest with perforation of his right lung, right leaf of the diaphragm and right lobe of the liver. He survived for 2 hours. At autopsy, 2200 ml of blood where found in his right pleural cavity (hemothorax) and 700 ml of blood was found in the abdominal cavity (hemoperitoneum).

When we speak of blood loss there are some fundamental concepts you want to remember. The loss of 1 quart (946 ml) of blood, twice the amount usually donated, can cause fainting, This is especially true in the person who has preexisting medical conditions, i.e., cardiac and or respiratory disease, etc. The loss of even more blood will invariably cause fainting. Weakness, confusion, and fainting can occur when a loss is greater than a quart and less than 2 quarts (1893 ml). Thus, the victim is not able to defend their self. At this juncture, there is another point to keep in mind and that is the victim may be so overwhelmed they cannot take action to prevent further blood loss. Thus, the victim may go on to exsanguinate from incised and or stab wounds, which if appropriately treated, they could have survived. This latter point is something the investigating law enforcement agency, prosecutors and defense council will want addressed.

13. **Stab Wounds Produced by Instruments other than those with a Sharp Edge:** Stab wounds produced by instruments which either have a dull edge or a smooth surface, but with a conical shaped point, such as pokers or a blunt chisel will show an abraded, contused, stab wound. The blunter the stabbing point, the more irregular or ragged the margin of the wound, due to the skin being split open as well as being penetrated.

    The configuration of stab wounds produced by scissors is determined by whether they are thrust into the victim past the screws or rivets and whether the scissors have a two-part blade. Typically, a stab wound inflicted by scissors causes a wound that is quite broad as compared to the stab wound produced by the blade of a knife, which is because the blades of the scissors are much thicker. If the scissors are closed the resulting stab wound will have a small "step" along one or both edges of the wound because the one scissor blade will overlap the other. If however, the scissors are open and one blade is thrust into the victim, than the appearance will be very much like that of a typical knife wound. If the other blade comes across the skin it may leave a fine linear abrasion or contusion that runs closely parallel to the wound edge produced by the stab wound. However, if the scissors are open, with the blades separated by a narrow gap, you will see two stab wounds, both with abraded edges. If the scissor blades are closed and they are thrust into the victim past the rivets or blade screws, they will produce a cross shaped stab wound with the longitudinal dimension being longer than the horizontal thus, negating confusion with the four-pointed scar of a Philips screwdriver. Those scissors with a two-part blade with the steel cutting-edge riveted to a carrier, which is continuous with the handles, can produce a stab wound that may show a notch or variation in linearity in the margin of the stab wound. Typically, closed scissors produce a "Z" shaped stab wound.

Fig. 95. Multiple puncture and stab wounds produced by scissors.

Fig. 96. Scissors which produced the puncture and stab wounds in the above image.

Fig. 97. Blood splatter pattern in case with multiple stab wounds due to scissors.

Stab wounds produced by a barbecue fork will show equally spaced patterns of 2 or 3 circular puncture-like wounds due to the prongs of the fork, each with an abraded edge.

Fig. 98. Stab wounds produced by a barbecue fork with two prongs. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Although not common, stab wounds with kitchen forks have been reported. They typically occur in patterns of 4 circular stab wounds, each evenly spaced and with abraded margins.

Fig. 99. Superficial stab wound complex produced by a 4 pronged dinner fork. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Table knives have also been used as a weapon. These knives produce a typical configured stab wound, the exact configuration of which is determined by Langer's lines. Some of these stab wounds will have abraded edges, and if inserted to the handle, a half-mooned abrasion at one end.

Stab wounds produced by screwdrivers are typically slit-like with squared ends and abraded margins if thrust parallel to Langer's lines. If the victim is stabbed by the by the screwdriver oblique to or perpendicular to Langer's lines than it will assume an oval or circular configuration with an impression of squared ends and abraded margins.

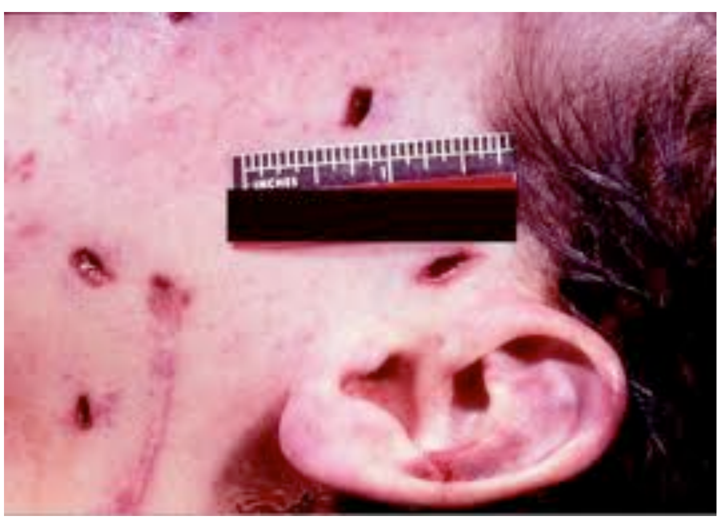


Fig. 100. The above image shows multiple stab wounds produced by a standard screwdriver. Note the rectangular shape and squared off ends with abraded margins of some of the wounds. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Stab wounds due to a Phillips screwdriver causes a very characteristic X-shaped wound with four equally spaced cuts, each with an abraded margin.

Fig. 101. Multiple superficial stab wounds produced by a Phillips screwdriver. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Suicide victims have used pens and pencils to stab themselves. Such instruments have also been used in assaults.

Stab or incised wounds produced by broken bottles are typically irregular, ragged and sometimes, semicircular with varying depths. The edges are sharp and usually have no abrasions. Generally, these stab wounds do not penetrate the pleural or peritoneal cavity. What is important is to inspect wounds produced by broken beer or wine bottles for fragments of glass. Identifying such fragments may prove helpful in identifying the particular bottle used. Incised wounds produced by broken bottles are often found on the face. They may be accompanied by fine linear incised wounds or linear abrasions resembling scratches. Typically, incised or stab wounds produced by broken bottles are the result of a homicide, however, there are cases in which a person has committed suicide using such a weapon. Rarely, these injuries are due to an accident.

Fig. 102. Note the multiple incised wounds and the irregular, ragged stab wound with no appreciable abrasions produced by a broken bottle. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

The last instrument we will consider for the production of atypical stab wounds are those due to arrows. Generally, arrows produce stab wounds on the shape of the arrowhead. The arrowhead of target arrows are round, thus they produce circular stab wounds with an appearance similar to a gunshot wound. Hunting arrows have from two to five knifelike edges. The stab wounds they produce are either X or cross-shaped, such as accomplished by a four-edged arrowhead, with sharp margins and no abrasions.

Fig. 103. Target arrowhead

Fig. 104. Hunting arrowhead

Fig. 105. Arrowhead of a push dagger

When dealing with victims of stab or incised wounds, atypical or otherwise, a careful search of the scene for potential weapons consistent with what you are seeing on the body is essential.

14. **Chop Wounds:** Large, heavy sharp-edged instruments such as an axe, hatchet, meat cleaver, machete and saber type sword produce wounds with extensive lacerations, extending deep into the underlying soft tissue, often with involvement of bone. If such injuries involve an extremity they can cause near or complete amputation. Typically, the scene shows abundant splatter of blood, which if in a room, the blood splatter will be found everywhere. What is also common is the mark variation in the size and configuration of the injuries. The size and shape of the sharp edge of the instrument, the direction and angle of the blow, the surface area of that portion of the victim's anatomy struck, its curvature, abundance of soft tissue and the presents of underlying bone all play a role in determining the appearance of "chop" wound.

Fig. 106. Kukri Machete

Fig. 107. Arabian Sabre Sword

Fig. 108. A chop wound produced by the claw end of a crowbar. The chop wounds appearance, as shown above, may also aid in determining the type of weapon used, as the wounds may take on the pattern of the weapon. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

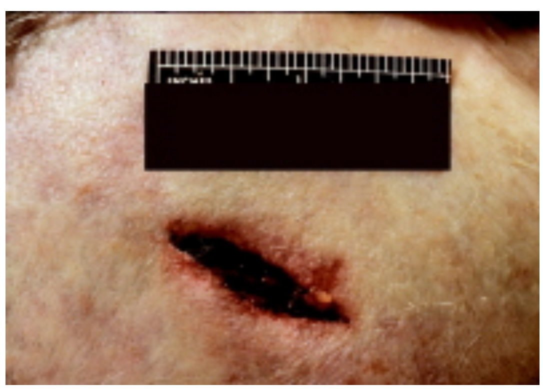


Fig. 109. A chop wound produced by a tomahawk like tool. Note the stab like injury as well as the associated marginal abrasions. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 110. Tomahawk like tool with side hammer and sharp excavation tool.

When dealing with a victim whose body shows evidence of "chop like" wounds, but are found in water or on a beach, you need to be mindful the injuries may have been caused by a boat's propellor. If the body is found in shark invested waters or on a beach near such waters, the "chop like" injures may have been caused by them (please see Fig. 28, injuries due to propellor blades and Fig. 29, injuries due to a shark attack).

15. **Impaling Injuries:** These are injuries produced by impaled objects that have punctured the skin and underlying soft tissue. Depending on the anatomical location, the puncture wound may have extended into the pleural or peritoneal cavity, with possible involvement of an organ or organs. There is typically little external evidence of bleeding due to the tamponade effect (created by the pressure of the object) thus, controlling bleeding. However, the more movement of the impaling object within the soft tissue, the greater the likely hood of bleeding from the traumatized soft tissue.

These injuries are often the result of an accident, such as a fall or motor vehicle.

There are also cases in which a person will commit suicide by jumping from a building and impaling themselves on an object such as a fence. The reverse is also true, where at a construction site, a worker will drop an object several stories above the ground, which impales someone at ground level. A car may strike the backend of a flatbed truck carrying pipes, resulting in one or more of the pipes going through the windshield, impaling the driver or passenger. Using the same flatbed truck, the driver of which may strike another vehicle resulting in his load shifting, coming forward and impaling him. There are occasions where a person is walking at their place of business, trips, and falls on an object they were carrying, such as a pen, impaling themselves. These cases are handled in the same fashion as a stabbing by a sharp-edged instrument.

Fig. 111. The above image is of a motorcyclist, who while ridding with a group of friends, was impaled by a branch, which had been kicked up by the cycle in front of him. His prognosis was described by the Trauma Surgeon as good. No pins were necessary to stabilize the fractured fibula.

Fig. 112. The victim is a six-year old Indian boy who slipped off the roof of his families home and landed on a five foot long iron rod that was left standing at a building site. He miraculously escaped major internal injuries.

16. **Mechanisms of Death:** The most common mechanism of death in incised and stab wounds is loss of blood (exsanguination), leading to hypovolemic shock. Such blood loss can occur externally or internally or both. Although, there may be evidence of minimal external bleeding, this does not in any fashion bear a relationship to the degree of internal bleeding. For example, a small slit-like defect in the parasternal region, upper left chest, may show minimal evidence of external bleeding, but produce 2000 ml of blood in the left pleural cavity due to perforation of the aortic arch.

As previously discussed, it is not necessary to lose several 1000 ml of blood to cause death. A stab wound through the pericardial sac into the heart can lead to a rapid accumulation of between 100 to 400 ml of blood, which can cause a rapid death by cardiac tamponade.

I have used the expression 'cardiac tamponade' several times in this article. Let me briefly explain what the term means. Cardiac tamponade occurs when the potential space between the pericardial sac and the surface of the heart fills up with fluid faster than the pericardial sac can stretch.

The pericardial sac forms an envelope around the heart and base of the pulmonary artery and aorta. It is deep to the sternum and anterior chest wall. The pericardial arteries supply blood to the dorsal portion of the pericardium.

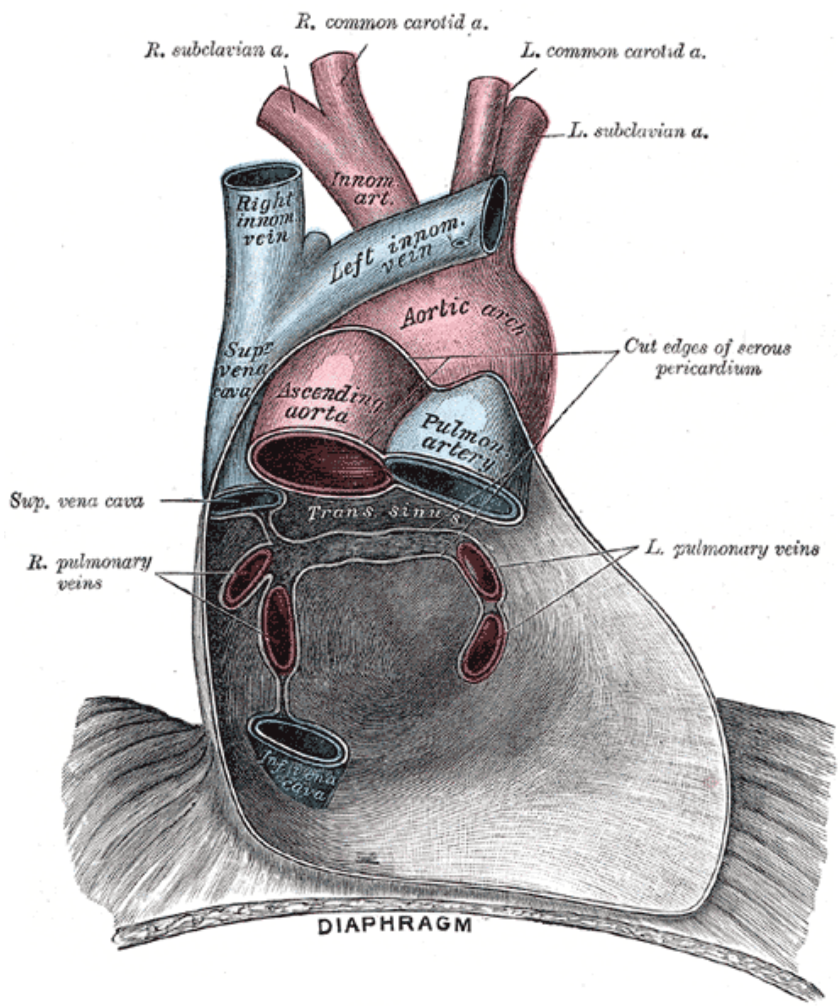


Fig. 113. The above illustration depicts the posterior wall of the pericardial sac, showing the lines of reflection of the serious pericardium on the great vessels.

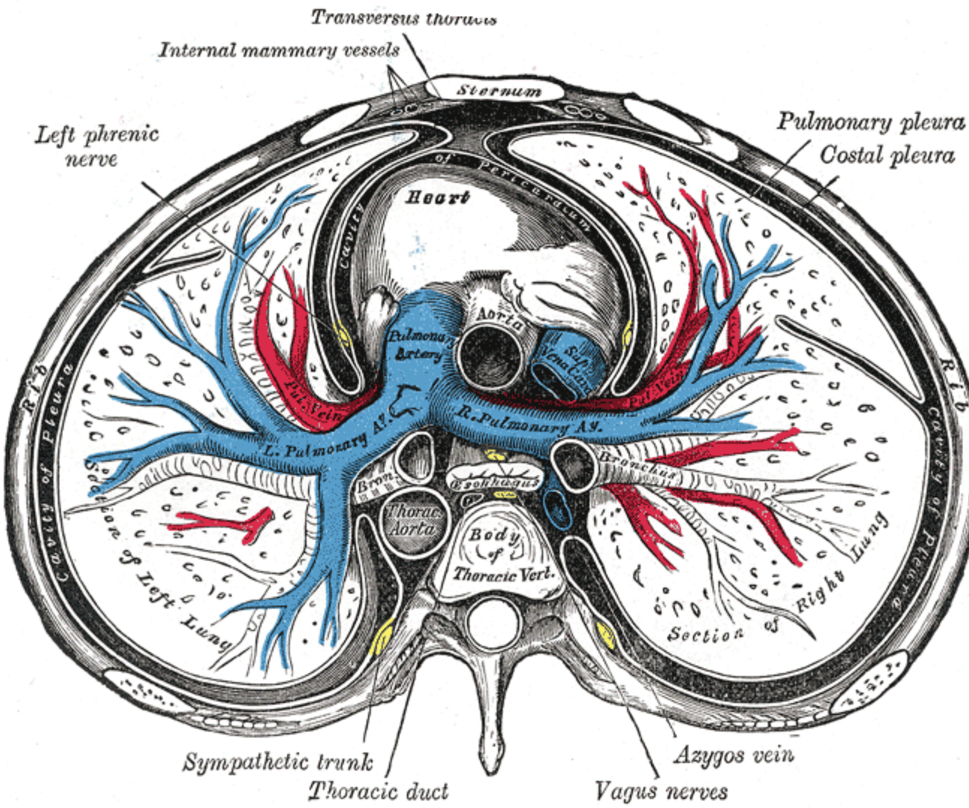


Fig. 114. This illustration if of a transverse section of the thorax (chest), showing the contents of the middle and the posterior mediastinum. The pleural and pericardial cavities are exaggerated since normally there is no space between parietal and visceral pleura and between pericardium and the heart Pericardium.

The pericardial sac is composed of two layers: the fibrous pericardium and the serous pericardium. The serous pericardium, in turn, is divided into two layers, the parietal pericardium, which is fused to and inseparable from the fibrous pericardium, and the visceral pericardium, which is part of the epicardium. The epicardium is the most superficial layer of the heart, lying immediately outside the heart muscle proper, which is called the myocardium.

The visceral layer extends from the surface of the heart to the beginning of the great vessels (aorta and pulmonary trunk as they leave the heart and the superior and inferior vena cava and pulmonary veins as they enter the heart) where it fuses with the parietal layer of the serous pericardium.

Between the parietal and visceral layers of the pericardial sac is a potential space called the pericardial cavity. It normally contains no more than 15 ml of relatively clear fluid, which lubricates the parietal and visceral layers surfaces. To much fluid within the potential space can cause pericardial (cardiac) tamponade, which means the volume of fluid is compressing the heart.

If the amount of fluid increases slowly, as in hypothyroidism, the pericardial sac is given time to expand thus, allowing it to contain 1000 ml or more of fluid before leading to tamponade. However, if the fluid accumulates rapidly, such as occurs with a stab wound of the heart or the base of the aorta or pulmonary trunk, as little as 100 ml of blood can cause a tamponade. This occurs because the layer of the pericardial sac called the fibrous pericardium does not stretch easily thus, blood rapidly entering the pericardial sac will cause the pressure within the sac to increase preventing the ventricles to expand and fill with blood during the diastolic period. Thus, with each successive diastolic period, less and less blood enters the ventricles. As the pressure within the sac increases, not only is less blood getting into the ventricles, but due to the thinness of the right ventricular wall, it collapses more than the left ventricular wall, forcing the interventricular septum into the left ventricle, leading to further decrease in the volume of blood flowing from the left ventricle. If this process is not interrupted by treatment, obstructive shock develops, which in turn leads to cardiac arrest (the heart stops beating).

Stab wounds causing between a 1000 to 2500 ml of blood to accumulate within the pleural cavities and or peritoneal cavities will cause hypovolemic shock and death due to cardiac arrest. Hypovolemic shock refers to a severe loss of blood, which prevents the heart from adequately perfusing the organs of the body, most especially the brain and heart. How much blood loss that is required to cause death is dependent on the victim’s size, presence of other injuries and existing medical diseases, such as cardiac and or respiratory disease. There is another factor, which comes into play with rapid accumulation of blood into a pleural cavity and that is mediastinal shift, which results in shifting the position of the heart to the pleural cavity opposite the one in which the blood is accumulating. This further compromises cardiac function by compressing the superior and inferior vena cava, which results in a decrease in venous return to the heart (i.e., less blood is returned to the heart) and thus a decrease in cardiac output. Along with the rapid accumulation of blood leading to a mediastinal shift, the rapid accumulation of air within a pleural cavity due to perforation of a lung or large bronchus can cause the same lethal mediastinal shift. Also

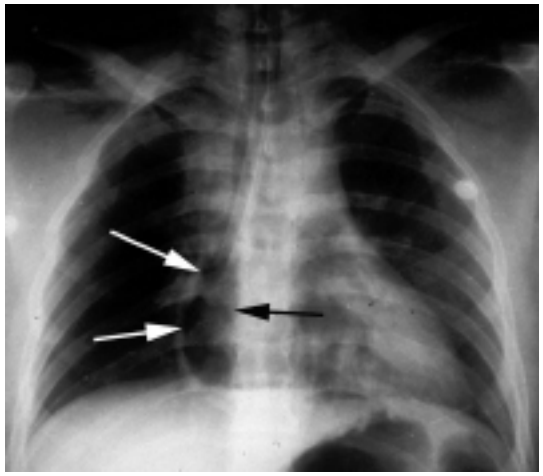


Fig. 115. This is a chest x-ray of an air embolism within the heart. Note the radiolucent (dark) area within the right side of the heart identified by the arrows. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

when a medium sized to large vein is severed, the continue beating of the heart can create a vacuum effect, which leads to air being sucked into the vein. When this air reaches the heart, a "vapor-lock" effect can occur, resulting in no more blood entering the right atrium, which ceases blood blow from the heart to the lungs and aorta. As has been previously discussed, although, missiles and knives produce wound tracks, the track formed by a missile is much larger than the slit-like wound track of the blade of the knife, due to its substantive velocity. Remember, the energy released to the tissues is the square of the velocity of the offending object, not its mass.

17. **Manner of Death:** There are three manners of death used in the determination of deaths due to incised and stab wounds: suicide, homicide and accidental death. Remember, manner of death is determined by the circumstances leading up to the death. Most incised and stab wounds are homicides. Typically, the manner of death, 'accident,' is very infrequent and thus seldom presents any difficulty in removing it from consideration. Where the issue is, is separating the manners of deaths, homicide and suicide. Without question, your greatest concern is overlooking a

homicide. A fundamental approach you may want to use is to consider all deaths as the result of incised and or stab wounds as homicides until proven otherwise. The following diagnostic features were used by Lester A. Adelson, M.D., who served as the Pathologist and Chief Deputy Coroner for the Cuyahoga County Coroner's Office, Cleveland, Ohio.

Differential Diagnostic Features In 700 Cutting And Stabbing Fatalities

Manner of Death	*Homicide*	*Suicide*	*Accident*
Incidence	80%	18%	2%
Wound Grouping	Irregular	Arranged or systematic	Vulnerable site
Target Area	Chest mainly, neck or groin	Victim's choice neck, wrists, precordium	Vulnerable site
Number of Wounds	Usually multiple (may be single)	Frequently multiple	Usually single
Hesitation Marks	Absent	Usually present	Absent
Defense Wounds	Present if victim had opportunity	Absent	Absent
Clothing	May be involved	Part usually exposed	May be involved
Non-cutting Injuries	Signs of struggle	Absent	May be associ-ated with accident
Weapon	May or may not be at scene	Usually at scene	Usually at scene
Method	Usually stabbing, but often associated with cutting	Cutting of neck and wrists Stabbing in precordium	Usually stabbing

As one can see from the above table, most stab wounds are homicides. Generally, the stab wounds are multiple and typically, do not follow a patterns, although this may not necessarily be the case in serial murders. Most of the fatal stab wounds involve the chest primarily, but other areas involved are the neck, groin and abdomen. It is also not uncommon to find many of the incised and or stab wounds to be superficial.

As seen in the above table, suicides by stabbing are unusual. Typically, the victim uses incised wounds of the neck or wrist. When the person does use stabbing as a method to commit suicide, they frequently are multiple and involve the center of the chest. On examination you will find many of the incised and stab wounds are superficial. Those fatal stab wounds are generally few, one or two. What is of interest, and this is especially true of women, they will often part their clothing, so that the act of stabbing does not include their clothes. This is generally not the case in homicides. Lastly, the instrument used to commit the suicide is typically somewhere at the scene. As previously pointed out, one of the complicating factors in scenes of suicides is their modification by loved ones, including removal of the instrument.

One of the things you need to be careful of is assuming because the incised and or stab wounds appear especially vicious does not mean the victim was assaulted thus, this is a homicide. The determination and savage methods a person will use to commit suicide has been well documented. Unless the incised and or stab wounds are mutilating and thus rendering the person incapacitated, and especially if there is evidence some or all the injuries were postmortem and thus unequivocally removing suicide from consideration. It behooves the Forensic Pathologist not to rush to judgement as to manner of death, unless he or she has irrefutable evidence that excludes all other considerations. Thorough analysis of the scene, knowledge of anatomy, and careful analysis of the stab wounds can often prevent embarrassing conclusions by the Forensic Pathologist as the following case exemplifies:

A soldier was tried by court martial for the murder of a German civilian by stabbing him in the abdomen with a sheath knife.

Fig. 116. Double blade serrated sheath knife

No witnesses were present at the time, but the cause of death and the weapon used were not in dispute. The single wound was situated above and to the right of the umbilicus with the blunt edge of the knife upwards, it had penetrated the pancreas, and the aorta, the pathologist said to a depth of four inches. This depth was used by him in assessing the degree of force used. The accused said he had acted in self-defense because the victim had him locked across his knee and was strangling him. He said he thought he "had had it," but remembering his knife which he carried, he dragged it out and pressed it against the other man's abdomen and told him to stop. As not notice was taken he gave a "shove." It was quite clear from the measurements that the knife had penetrated to the extent of the sharpest point (double edge), but there was no roughening of the upper edge of the wound such as might be expected if inflicted by the part of the knife with the serrated edge. The question to be considered was whether a penetration of 2 3/8 inches could injure the aorta; it soon became clear that if the abdominal wall was contracted it would have been possible to inflict the wound. Further, if the victim continue to apply pressure with his legs, he would tend to contract the muscles of his abdomen, and if the tip of the knife was pressed against his abdomen, he would contract his abdominal muscles even more. It is clear therefore the pathologist's opinion, whether right or wrong, was based upon a false premise.

18. **Postmortem Bleeding:** It is generally agreed that bleeding following death does occur. The issue however, is how much bleeding occurs in the postmortem period. Bernard Knight states there is little doubt postmortem bleeding occurs, however, with the exception of bleeding into the pleural or peritoneal cavities, or externally from a body part in the dependent position, in most cases the amount of bleeding is a small portion as compared to what occurred during life. This is due to tissue pressure opposing passive bleeding. Vincent and Dominick DiMaio point out that although the amount of postmortem bleeding is usually minimal, if a large vessel is incised or perforated and the vessel is in a dependent area of the body, the quantity of blood lost can be considerable. In one postmortem experiment, large vessels in the chest and abdominal cavity were incised to get some idea how much bleeding could occur; 300 to 500 ml of blood passively collected into the pleural and peritoneal cavities. Another experiment was done at the Institute of Forensic Medicine, School of Medicine, Belgrade, Serbia and Montenegro, by Nikolic S, Atanasilevic T, Micic J, Djokic V, and Babic D., published in the Am J. Forensic Med Pathology, 2004 Mar: 25 (1) 20-2. Their study objective was the amount of postmortem bleeding from postmortem cutting of the thoracic aorta, related to time since death. The amount of postmortem bleeding ranged from 100 to 1300 cm, 440.6 ± 268.1 cm on average. The time since death up to the autopsy time ranged from 4 to 72 hours, 19.4 ± 12.9 average. A statistically significant correlation between the amount of postmortem bleeding and the postmortem time interval was stated; Pearson correlation test value r = –0.461 (P = 0.000): the shorter the time interval, the larger the amount of bleeding. The formula of linear regression was estimated according to this correlation: amount of postmortem bleeding (cm) = –9.571 × time since death (h) + 626.659. This proved that the amount of postmortem bleeding (e.g. from aortic blunt rupture) could be about + 620 cm.

There is another aspect of postmortem bleeding you need to be cognizant of and that is bleeding, which occurs during transportation of the body, which obviously requires movement of the deceased. Consequently, you must note blood on the victim's clothing, within the body bag and the scene before movement. It is especially important when you are at the scene to note the amount of blood collected next to the victim, as well as on the victim's clothing before moving the body. For once the body is moved and subsequently transported, the original blood stains or patterns of blood on the clothing may be either enlarged or totally obscured.

19. **Dismemberment:** Dismemberment as we commonly use the term today is the act of cutting various body parts such as the extremities, fingers, toes, hands, feet, nose, lips, breast and external genitalia from the rest of the body. This is usually done following a homicide by the assailant for the purposes of disposing of the remains in different localities and to hinder identification. Placing a body in a solution of an acid, such as sulfuric acid is another issue and will not be discussed in this article.
The act of dismemberment is generally accomplished after the person has died (postmortem period). Postmortem dismemberment, especially if decomposition has not taken place, is recognized by the lack of bleeding and dryness of the cut surface of the body parts. You will also note, that if bone has been cut through with a sharp-edged instrument, such as a Bowie knife, axe, saw, and meat cleaver, evidence of tool marks will be seen on the cut surface. If an instrument such as an axe has been used in the cutting of long bones (femur, tibia, fibula, humerus, ulna and radius), the cut surface will have a smooth, regular quality to it. However, it not uncommonly will also show fragmentation at the edges. Bones such as the ribs, skull and pelvis, when cut with such an instrument will usually show a smooth even surface with no evidence of fragmentation. This is because these bones are membraneous in origin except the pelvic bones, which are cartilaginous bones because the are derived through a process of intra-cartilaginous ossification (endochondral ossification). Membranous bones are also known as dermal bones and the process by which they ossify is called intra-membranous ossification. In this process bones, such as the flat bones of the skull and face, evolve through a process of condensations of mesenchymal tissue and not by replacement of preexisting piece of cartilage as is the case in endochondral ossification. The frontal and parietal bones of the skull, as well as parts of the temporal and occipital bones and the mandible and maxilla, are formed by intra-membranous ossification. This process also contributes to the growth of short bones and the thickening (not the lengthening) of long bones. Bones

derived from intra-membranous ossification do not have the structural integrity of those derived through a process of endochondral ossification.

The tool marks produced by these sharp-edged instruments will appear in the form of parallel, horizontal or oblique furrows on the cut surface of the bone. These tool marks are produced by skipping of the blade. As previously discussed, examination of the cut surface of the bone using x-rays and a dissecting microscope may reveal enough of the tool marks to suggest the particular sharp-edged instrument used.

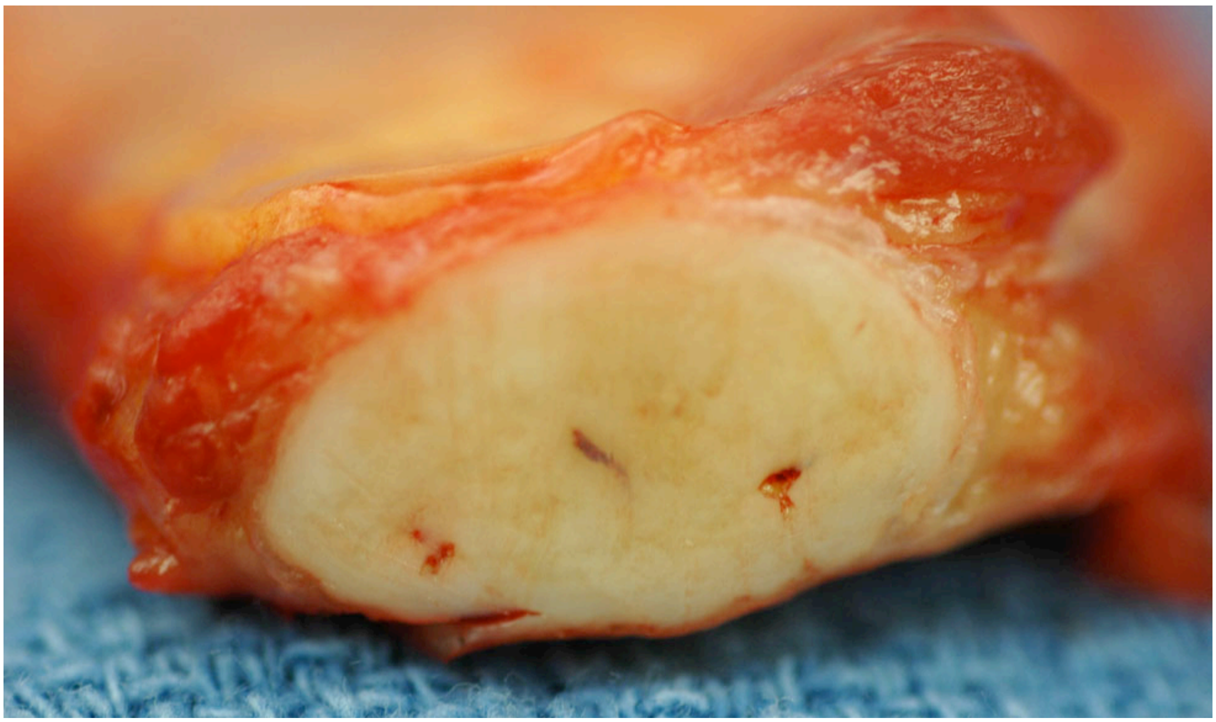


Fig. 117. This is a stab wound of the anterior, cartilaginous portion of a rib. Examination of the cut surface using a dissecting microscope may reveal tool marks that can be compared to the suspect weapon. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Should minute fragments of metal be identified, their analysis can give you information as to the metallic composition of the sharp-edged instrument use. If the weapon is identified, its analysis may allow you to state that its metallic composition is consistent with the metal fragments found on the surface of the cut bones.

Another very fundamental point to remember, is the width of the incised wounds will correspond to the thickness of the blade of the weapon used.

There are a number of other points you need to keep in mind when examining a body that has been dismembered. Dismemberment of a body can suggest some understanding of anatomy or prior experience as a hunter. An example of the latter is the case of Tami Engstrom, who was murdered by Kenneth Biros, which will be discussed shortly. Not uncommonly, there are certain aspects of the dismemberment process used by the assailant that can give you insight into their psychology. For example, evidence of ritualistic acts at the scene, such as burning of candles, religious paraphernalia, arrangement of furniture, dead animals, gives some insight into the psychology of the assailant. In some respects such acts serve as a psychological fingerprint. Jeffery Dahmer showed some aspects of this behavior. You may see evidence of piquerism (also spelled picquerism, which is derived from the French word *piquer,* which means "to prick"). Piquerism is a form of paraphilia, which is sexual arousal to objects, situations, or individuals that are not part of the normative stimulation and that may cause distress or serious problems for the paraphilia or persons associated with him. Paraphilia is almost never diagnosed in females. A paraphilia involves sexual arousal and gratification towards sexual behavior that is atypical and extreme. The term was originally coined by Wilhelm Stekel in the 1920s. Presently, the *American Journal of Psychiatry* describes paraphilia as a sexual disorder characterized by "recurrent, intense sexually arousing fantasies, sexual urges or behaviors generally involving (1) nonhuman objects, (2) the suffering or humiliation of oneself or one's partner, or (3) children or other non-consenting persons that occur over a period of 6 months," which "cause clinically significant distress or impairment in social, occupational, or other important areas of functioning."

Piquerism is also a form of sadomasochism, in which one finds sexual gratification through penetration of another person, most commonly by stabbing or cutting the body with sharp objects. Some also include the act of feeling the ripping and tearing of some sort of material or human flesh. To become sexually aroused under piquerism the most frequently targeted areas of the body are the breasts, buttocks, or groin. Keppel and Birnes suggested piquerism can serve as a unique signature in serial murders; again, it is kind of a psychological fingerprint. As an example, Dr. Keppel and his co-authors concluded in their analysis of London’s Jack the Ripper murders of 1888 that, “The injuries sustained by the victims displayed the signature characteristic of picquerism.” Another serial killer, Albert Fish, also engaged in piquerism, not only on his victims, but his own body through flagellating himself constantly with a nail-studded board and inserting needles into his groin. Technically, the insertion of needles into the groin is a form of infibulation, which is the purposeful use of sharp objects such as pins, needles, and piercings, in the genital area for sexual pleasure and pain.

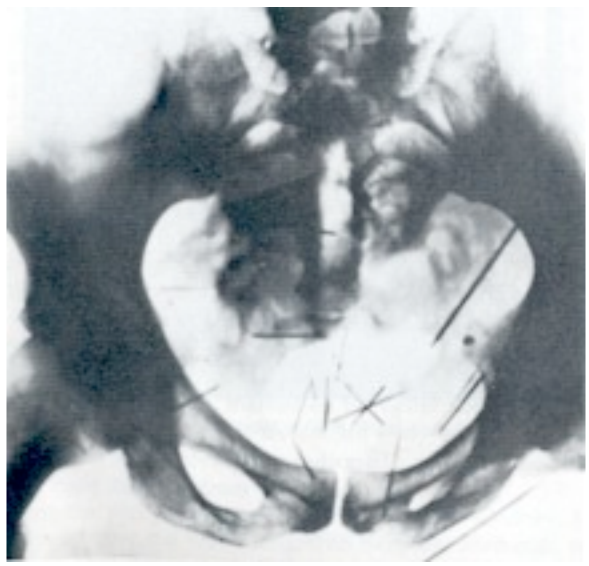


Fig. 118. This image is the x-ray of Albert Fish showing over a dozen needles inserted.

One of the other things you may see at the scene is the posing of the victim’s body by the assailant. It is felt that in those victim’s who show evidence of mutilation, including dismemberment, whose body has been posed, which has significance to the assailant, also serves as a psychological finger print.

Although rarely seen today, dismemberment can also be accomplished through tearing, pulling or wrenching a persons extremities by tying them to chains or other restraints, which are in turn attached to movable entities such as horses. Dismemberment was carried out in the Medieval and Early Modern era by chaining four horses to the condemned’s arms and legs, and having them pull the victim a part. Francois Ravaillac in 1610 and Robert-Francois Damiens in 1757 were both executed in this fashion.

Fig. 119. The Martyrdom of St. Hippolytus by Dieric Bouts depicts dismemberment used in the third century.

Dismemberment was also used as a form of capital punishment for convicts of high treason in the Korean Kingdom of the Joseon Dynasty. The Five Pains is a Chinese variation invented during the Qin Dynasty. Dismemberment is no longer used by most modern governments as a form of execution or torture, though amputation is still carried out by countries that practice Sharia Law.

There are many instances of dismemberment occurring following homicides in the modern era.

Fig. 120. The above image is an example of Dismemberment.

I would like to give you two examples of cases of dismemberment that I was personally involved with.

On the evening of February 7, 1991, Tami Engstrom left work early not feeling well from her job in Hubbard, Ohio. Before going home she stopped at the Nickelodeon Lounge in Masury, Ohio, to meet her uncle, Daniel Hivner. During the evening she had several drinks. Around 1:00 a.m. Tami decided to leave the lounge, however, her uncle took her car keys from her, because he felt she was in no condition to drive. At this point Kenneth Biros offered to take Tami out for coffee so she could sober up, after which he would bring her back to the lounge. Daniel Hivner knew Mr. Biros and agreed to his offer. Daniel Hivner waited at the lounge for several hours for them to return, which did not happen. He finally left the lounge assuming Mr. Biros had taken Tami home.

Later on that day, after speaking to Tami's uncle, Andy Engstrom, Tami's spouse, went to see Mr. Biros inquiring where his wife was. Mr. Biros told Andy that Tami had passed out in his car. He drove to an ATM in Sharon, Pennsylvania to withdraw money so he could get Tami coffee. While doing so Tami awakened, demanded she be taken back to the Nickelodeon, immediately after which she opened the door to the car and ran off. When he was subsequently asked where he had gotten the cut over his eye and cuts and scratches on his hands he explained they had occurred in separate incidents. The cut on his eye occurred while chopping wood, and his hands had gotten their injuries when he climbed through a broken window after he had locked himself out of his home. Mr. Biros lived with his mother, in Brookfield township, Trumbull County, Ohio.

His story began to unravel when Tami's ring was found on the bathroom floor by his mother. Under police questioning he initially stated he had taken Tami to see a cabin in the backyard of his house. The cabin was an ordinary concrete shed in the middle of the woods behind his home. His initial explanation on what occurred when they arrived at the cabin was "We were in the car together. We were along the railroad tracks. I touched her hand. Then I went further. I either touched or felt her leg. She pushed my hand away. The car was not stopped. She opened the door and fell and struck her head on the tracks. However, under further questioning Mr. Biros admitted he had tried to rape Tami, which she resisted. They struggled, during which he beat and stabbed her. At this point Mr. Biros disintegrated psychologically and proceeded to dismember Tami with several knives, one of which was a Bowie knife. Mr. Biros was a hunter. There was extensive blood on his clothes and shoes, as well as at the scene. Mr. Biros amputated Tami's head, right breast and right lower extremity immediately above the knee. In addition he eviscerated her small and large bowel, portions of which where still at the scene. Her uterus, bladder, rectum and anus were never found. He put her remains in several trash bags and deposited some in Butler County and the rest in Vernango County, both of which are in Pennsylvania.

During the autopsy it was evident the dismemberment took place after Tami's death. This was accomplished by noting the lack of bleeding in the cut surfaces of the neck, right breast and right lower extremity. Microscopically, there was no acute inflammatory reaction. There were multiple contusions, many of which were seen on the under surface of her scalp. These scalp contusions where found on the top of her head as well as on the lateral, front and back of her scalp. The multiplicity of these contusions did not support Mr. Biros explanation that she fell out of the car and struck her head on the railroad track. There were also stab wounds, many of which were superficial, and appeared to have been inflicted after Tami died. I was able to identify hemorrhage around the superior horn of the thyroid cartilage, as well as the hyoid bone, which was consistent with death by strangulation. The segments of small and large bowel found at the scene were subjected to DNA analysis, which proved they had come from Tami.

Kenneth Biros was found guilty at a subsequent trial and sentenced to death on October 29, 1991. He died by lethal injection on December 8, 2009.

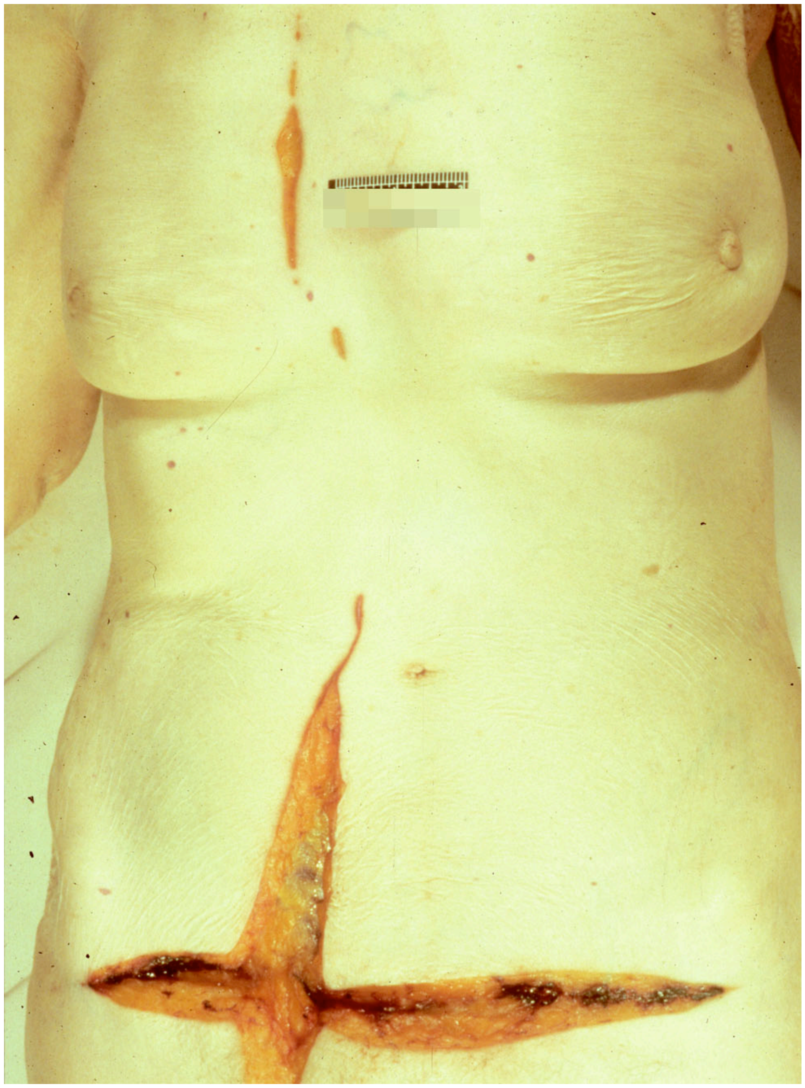


Fig. 121. The above image is from an elderly victim who was killed with sharp-edged instrument and blunt force trauma. Note the orange-yellow color to the incised wounds and the lack of bleeding. These injuries are those inflicted in the postmortem period. The appearance of these incised wounds is the same as Tami's stab wounds, which is how we knew they occurred after Tami died. (Sharp Force Injuries, J. Prahlow, MD and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 122. Kenneth Biros

Fig. 123. This is the remains of Biros's home which had been boarded up and sustained fire damage. Eventually the entire home collapsed.

The second case was that of Steven Hicks, Jeffery Dahmer's first victim. My discussion of Jeffery Dahmer will be restricted to Steven Hicks, and not include his early life or the initial 17 murder charges, which were later reduced to 15.

As we understood the psychological struggles Jeffery Dahmer was dealing with in 1978, it would appear he was psychologically disintegrating; due primarily to his homosexual desires along with his need to act out his sadistic fantasies. It was in the midst of this struggle that he picked up a hitchhiker, Steven Hicks on June 6, 1978. Steven Hicks was 19 years of age, Jeffery was 18. Jeffery invited Steven to his Father's home in Bath, Ohio. While there they had several beers. Jeffery later admitted it was his desire to have sex with Steven. At some point, Steven indicated he wanted to leave, which resulted in Jeffery bludgeoning Steven to death with a 10 lb. dumbbell, striking him in the back of his head. When Jeffery was questioned on his motive for killing Hicks he said, "The guy wanted to leave and I did not want him to go." He then took Hicks's body to the basement and dismembered him. He placed the various body parts in several trash bags and then buried them on his Father's property. Years later he dug up the trash bags and crushed the skeletal remains with a mallet on cliffs behind his Father's home. After crushing the remains, most of which were no larger than an inch in length, he stood on the cliffs and scattered the remains in an arc.

Dahmer did not murder his next victim until September of 1987. He was eventually arrested on July 22,1991 after a failed attempt to murder Tracy Edwards, who escaped from Dahmer's apartment in Milwaukee, Wisconsin. Tracy Edwards led police back to Dahmer's apartment. After arriving at Dahmer's apartment the police noted photographs of mangled bodies in his bedroom. Further inspection revealed a human head in his refrigerator, three more severed heads, multiple photographs of murdered victims and human remains, severed hands and penises, photographs of dismembered victims, acid-filled fats with several corpses, and implements for the construction of an alter of candles and human skulls were found in the closet. Seven skulls were found in his apartment. A human heart was found in the freezer.

Shortly after Dahmer's arrest he advised the Milwaukee Police Department of his his first victim. Shortly thereafter, I along with medicolegal investigators from the

Coroner's Office, members of the Sheriffs Office and Bath Police Department began a search of the Bath residence for Steven Hick's remains, some thirteen years after his murder. Examination of the basement revealed blood stains on the walls and floor using luminol.

Luminol is used to detect trace amounts of blood left at crime scenes as it reacts with iron found in hemoglobin to produce a chemiluminescence. For analysis of an area, luminol is sprayed evenly across an area, and trace amounts of an activating oxidant will cause the luminol to emit a blue glow. Usually, a solution of hydrogen peroxide and a hydroxide salt in water is used as the activator.

Fig. 124. Chemiluminescence of luminol.

To examine the property for skeletal remains we set up a grid pattern, which covered approximately 1 and half acres. For the next five days we sifted the top 6 inches of soil finding several hundred fragments of human bones and bones of birds and small animals. We found over 200 fragments of human bones, most no larger than an inch in length. During our search, we were most fortunate to have Douglas Owsely, Forensic Anthropologist with the Smithsonian Institution and the FBI to offer their services. Doug catalogued all bones, human and animal. One of the bones identified was a portion of a human cervical vertebra. On x-ray analysis it contained a defect within it's vertebral body. We were able to acquire a lateral x-ray of Steven's head and neck, which had been taken to have dental work done. The FBI was able to enhance this x-ray to a point we could see the same defect in the fourth cervical vertebra, as well as the trabecular pattern, which was also identical to the trabecular pattern in the portion of the vertebra we found. Due to this analysis, Doug and the FBI were able to conclude the remains were those of Steven Hicks.

An important point to remember is the trabecular pattern in each of our bones is believed to be unique to us. This uniqueness can be used for identification. This of course requires you have something to compare your skeletal remains with.

In May of 1992, Dahmer was extradited to Ohio from Wisconsin, where he had been found guilty of 15 counts of murder and sentenced to 15 life terms, receiving a total of 957 years in prison. In Ohio he entered a plea of guilty for the murder of Steven Hicks.

While serving his time in the Columbia Correctional Facility in Portage, Wisconsin, he was beaten to death with a broomstick handle on November 28, 1994.

Fig. 125. Jeffery Dahmer after his arrest.

20. **Recognition of Incised and Stab Wounds in Victims who have undergone Postmortem Decomposition:**

As previously discussed postmortem decomposition is the process by which the tissues of the body begin to disintegrate primarily due to anaerobic bacteria derived from the gastrointestinal tract. The bacteria largely responsible are the coliform bacilli and *Clostridium welchii.* However, other bacteria, fungi and cellular enzymes also make a contribution to the decomposition process. Since I have previously reviewed decomposition in depth, I will review the process of decomposition in a general sense so that you hopefully will better understand how decomposition modifies the appearance of incised and stab wounds.

Decomposition manifest first as a greenish discoloration to the skin of the lower abdominal wall, typically the right, which gradually spreads over the skin of the entire body. Intravascular hemolysis takes place releasing hemoglobin, which because of bacteria in the vascular system, results in the veins of the skin becoming prominent; a process referred to as marbling. This process generally begins in the skin over the shoulders and chest. The skin begins to show blister formation as well as evidence of “skin slippage,” which is due to the superficial layers of the epidermis separating from the rest of the skin. Because of gas formation as the result primarily of bacterial activity, the face begins to swell and blood stained fluid begins to flow from the nose and mouth, which is referred to as “postmortem purge.” As pointed out before, do not misinterpret this to be evidence of traumatic injury. Ultimately the whole body becomes swollen and bloated taking on a green-black color. Because of this bloating, facial features are markedly distorted, as is true of the whole body. If the body is in a place where flies can gain access there will be evidence of maggot infestation, as well as other insect activity, which further distorts anatomical features. Although, there are a number of factors which influence the rapidity of this process, the most important is temperature. Generally, the higher the temperature the faster the decomposition process takes place, the lower the temperature the slower the process. As I am sure you can understand this process can influence the appearance of incised and stab wounds.

Not only does the bloating of the body distort incised and stab wounds, but it is these very wounds that the flies are attracted to and it is were you will find initially the heaviest maggot infestation thus, virtually obliterating the wounds. If there are such injuries to the external genitalia, you will also see a heavy maggot infestation there. Even though the incised and stab wounds may have been markedly distorted or obliterated, it is important you carefully examine these sites to see if there is any evidence of such injuries.

Whatever tissues remain in the neck they should be carefully examined. Finding a fracture of the hyoid bone or superior horns of the thyroid cartilage is evidence of strangulation. At the fracture site, you may also find evidence of hemorrhage or hemoglobin staining at the fracture site supporting an antemortem injury.

The thoracic and abdominal cavities, depending on the stage of decomposition, may contain hemolyzed blood due to decomposition. The way you can determine ante-mortem hemorrhage (hemorrhage before death) is there will be evidence of a blood clot. For example, a decomposed body of a person who has died from a rupture of an acute myocardial infarction, will show blood clots in the pericardial sac. Again, this is dependent on the stage of decomposition. At this juncture in the decomposition process most organs are recognizable. The spleen, although recognizable, will be semiliquid, with the liquid being confined by it's capsule. The liver, both on the capsule and within the parenchyma will show numerous cyst due to gas formation by bacteria. In those who have been dead for several weeks, the body cavities are dry and the organs shriveled and leather-like. Even at this stage, stab wounds are readily identified. Examining the inner lining of the atrial and ventricular cavities of the heart, the endocardium, may show numerous yellow-white small nodules, which are fungal colonies. Within the abdominal cavity, the fat normally present in the omentum and retroperitoneal space becomes semiliquid and occasionally form yellow-white plaques due to fat necrosis.

As pointed out above, if the external genitalia has sustained stab wounds, especially before the victim died, these tissues may no longer be recognizable due to early decomposition, which has been enhanced by maggot and other insect activity. Typically, the uterus and prostate are the last organs to decompose unless they have sustained traumatic injuries. Another modifier of the appearance of incised and stab wounds to the external genitalia is animal activity. Having said this, you still need to look. Although, examining decomposed bodies can be unpleasant, missing a gun shoot or stab wound can be equally unpleasant, if not catastrophic, for the Forensic Pathologist who did the case. The body needs to be examined as thoroughly as possible.

Fig. 126. This image is of a decomposed body with multiple stab wounds of the chest. What can be very helpful in your interpretation is to examine the bones and cartilage near such injuries. This will help you to differentiate antemortem injury from postmortem decomposition. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Fig. 127. The above image shows stab wounds in the sternum of the decomposed body shown in the previous image. (Sharp Force Injuries, J. Prahlow, MD, and S. Cina, MD, Medscape, Mar 29, 2010)

Representative tissue samples of any remaining organs should be taken for micro-copic examination. You will find such tissue does not fix well and the traditional hemotoxylin and eosin (H&E) stains will usually show a homogenous pale red color with little definition. However, you may still be able to see evidence of antemortem acute hemorrhage. However, both the trichrome and Van Gieson's stains will show more definition. Fibrous tissue can be further examined by using polarized light.

There is a variant of decomposition commonly seen in bodies buried in a cool to warm, damp, humid environment called adipocere. Adipocere represents the transformation of body fat through a process of hydrolysis to free fatty acids, both saturated and unsaturated.

Saturated fat consist of triglycerides containing only saturated fatty acids. Saturated fatty acids have no double bonds between their carbon atoms of the fatty acid chain. In essence, the chain of carbon atoms forming the fatty acid chain is fully saturated with hydrogen atoms. Examples of saturated fatty acids are palmitic and stearic acid..

Unsaturated fat consist of fatty acids in which there is at least one double bond within the fatty acid chain. A fat molecule is monounsaturated if it contains one double bond, and polyunsaturated if it contains more than one double bond. When double bonds are formed, hydrogen atoms are eliminated. An example of an unsaturated fatty acid is oleic and palmitoleic acids. Oleic acid is the most abundant fatty acid in human adipose tissue.

Both endogenous lipases and bacterial enzymes, principally those produced by *Clostridium perfringens (welchii),* break up the natural fats into saturated fats, such as palmitic and steric and unsaturated fats such as oleic acid. The process by which *C. perfringens* break up the natural fats into saturated fats, such as palmitic and stearic, and unsaturated free fatty acids, such as palmitoleic and linoleid acids is called hydrolysis due to the presence of water and enzymes. The released free fatty acids, such as palmitoleic and linoleic react further with hydrogen present in the water to form hydroxystearic, hydroxypalmitic acids and other stearic compounds, a process known as saponification or adipocere formation.

This process can occur in a body buried in wet ground, mud at the bottom of a lake, a sealed casket buried in damp or water soaked soil, whether the body is embalmed or not.

Although decomposition of fatty tissue starts almost immediately after death, the time for adipocere formation can vary from 2 weeks to one or 2 months, on average, due to several factors, such as temperature, embalming and burial conditions, and material surrounding the body. Once formed and without air it can persist for centuries due to its considerable resistance to bacterial action. This resistance also allows for slower decomposition of those areas where adipose tissues are present, such as the cheeks, buttocks and thighs.

Women, infants and obese persons are more prone to adipocere formation because they contain more body fat. However, bodies exposed to insect activity or animal scavenging will prevent adipocere formation due to their enhancement of decomposition.

The use of adipocere formation to estimate the time of death is somewhat limited because the process has so many variables, most especially temperature and quantity of water. Although adipocere formation is accelerated by warm temperatures, temperature extremes impede it.

Fig. 128. Adipocere formation of the head and face.

Fig. 129. Adipocere formation of the trunk and portions of the lower and left upper extremity.

The reason I devoted some discussion to adipocere is to emphasize its presents does not preclude finding stab wounds, even though not visible on the surface of the body. As an example, I was asked to examine the remains of an adult male who had allegedly died in a house fire approximately 15 years age. Evidence had developed since his death that his wife, who had been married previously, was implicated in the untimely deaths of those spouses.

When the deceases coffin was removed from the burial site, it was found the soil was saturated with water. On opening the coffin, besides the body, it was filled with water. The deceased body showed extensive adipocere formation.

The autopsy was performed using a stream of water and various autopsy tools to genitally remove the putty like grayish-white to tan wax-like material. The process was tedious, but necessary so that we would not induce any artifacts to the under-lying skeleton. On exposure of the anterior rib cage we identified multiple stab wounds to various ribs. Close inspection of the penetrated periosteum revealed a reddish-brown color indicative of antemortem hemorrhage. The decomposition of what remained of the heart and lungs was so advanced we could not identify stab wounds. The deceased spouse was subsequently found guilty of his murder.

Chronological Histological Features for Dating of Incised and Stab Wounds

This section is devoted to a discussion of the microscopic features associated with time frames beginning with the infliction of the incised or stab wound to complete healing or death of the victim. Although, some Forensic Pathologist are reticence to give a time interval between the infliction of the injury and death, the pathophysiologic sequence of the biological reaction to such injuries has been known for decades. Today, the molecular events that participate in the healing process have been well elucidated. Although, it is true you cannot give a precise time interval since the infliction of the injury, you can most definitely give the investigating police agency, prosecutor and defense council a period when the injury was inflicted within a reasonable degree of probability. The following is a discussion of the histological and molecular features associated with each time interval.

1. **Immediate to 4 hours:** The immediate local reaction to an injury is dilatation of capillaries followed by increased permeability of capillaries. Initially vasodilatation leads to an increase in blood flow, which is why the injured area develops a red color as well as a sensation of being hot. The underlying physiologic reason for vasodilatation is the release of histamine, bradykinin, prostaglandins-I_2, E_2, D_2, F_2, prostacyclin, and nitric oxide, with their effect on vascular smooth muscle. Histamine is released from mast cells, basophils and platelets. Bradykinin is a vasoactive nonapeptide, which is released by the kinin system, the activation of which is triggered by the contact activation of the Hageman factor. The Hageman factor is made active by the release of neutrophils and other leukocytes responding to the traumatic injury, platelets which have become activated and contact with collagen. The cyclooxygenase pathway produces prostaglandins and prostacyclin. Nitric oxide is produced by a myriad of cells.

   Vascular dilatation with its increase in blood flow is immediately followed by increased vascular permeability, which caused an outpouring of protein-rich fluid into the extra-vascular tissues of the injured area, which in turn causes the injured area to swell. The mediators responsible for increased vascular permeability are histamine, serotonin, bradykinin, fibrinopeptides, C3a and C5a (anaphylatoxins), leukotriene C_4, D_4, E_4, PAF (platelet activating factor), and oxygen metabolites. C3a and C5a are products of complement activation, which consist of activating and effector sequences consisting of 20 protein components common in plasma. Serotonin is released from platelets and basophils. Leukotrienes are products of the lipoxygenase pathway, and were originally identified in leukocytes. Fibrinopeptides are peptides released from the amino end of fibrinogen by the action of thrombins to form fibrin during the clotting of blood.

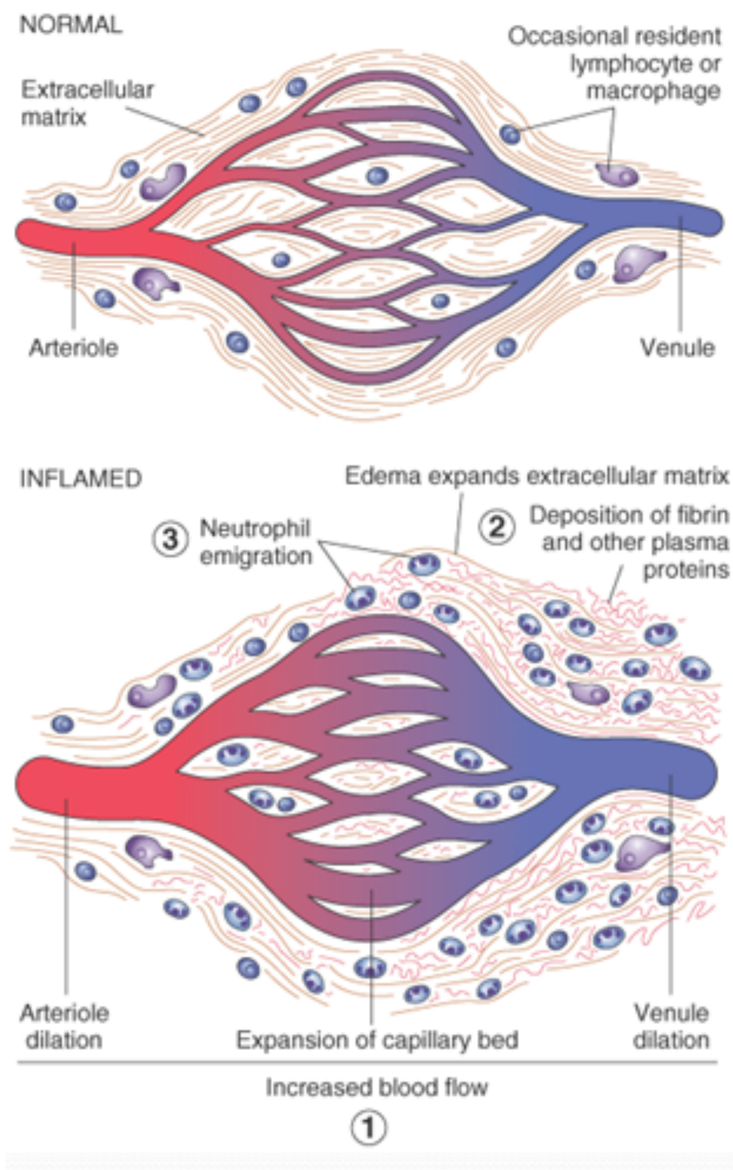


Fig. 130. The above illustration depicts dilatation of the arterioles with expansion of the capillary bed and dilatation of the venules resulting initially in increase in blood flow.

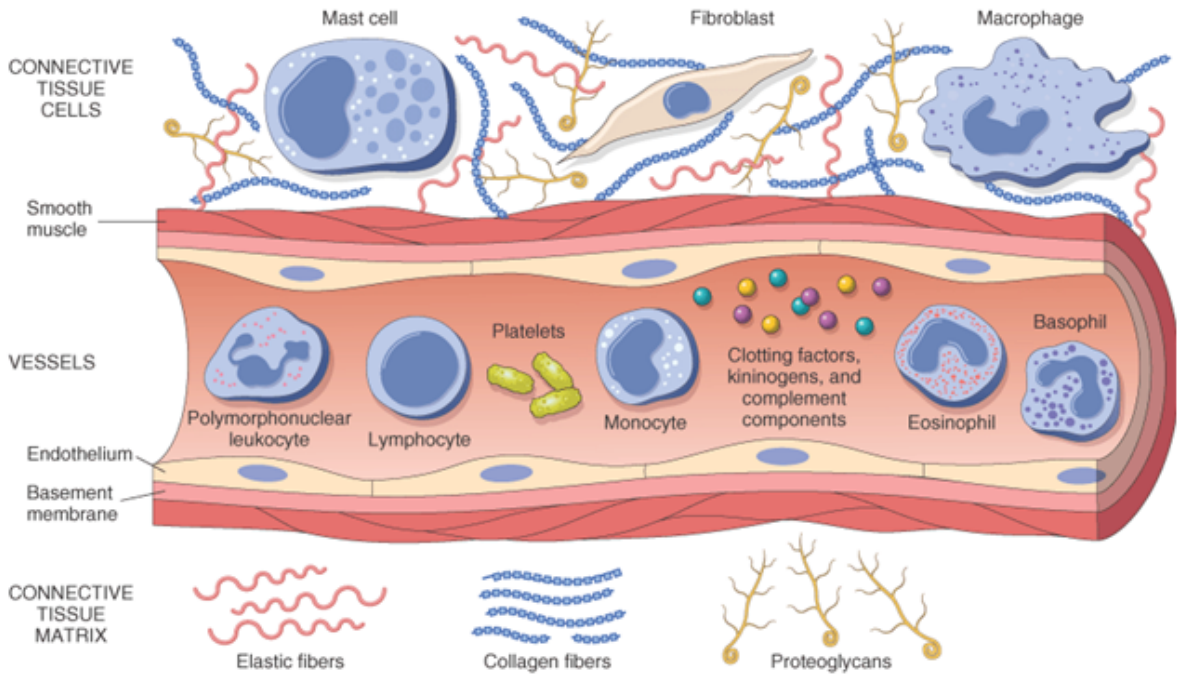


Fig. 131. This is an illustration of the components of a blood vessel and the factors involved in vascular dilatation and increase in vascular permeability.

The loss of this protein-rich fluid from the blood vessels in the injured area causes the rate of blood flow to decrease creating stasis within these vessels. Grossly and microscopically stasis is visualized as vascular congestion, which further enhances the red color (erythema) of the injured area. As this stasis develops, leukocytes (white blood cells), principally neutrophils (polymorphonuclear leukocytes) within the blood leave their normal position within the central column of the blood flowing through the vessels, fall out and slowly gravitate toward the endothelial surface. At some point as the neutrophils tumble slowly across the endothelial surface they develop adhesion molecules, which cause the neutrophils to adhere to the endothelial surface, which when viewed through the microscope is recognized as margination. There is another term you may see used referred to as ‘pavementing,’ which is when the endothelium of the vessels within the injured area appears to be lined by neutrophils. The process of margination begins within a few minutes of injury with pavementing becoming apparent within 30 minutes of the injury.

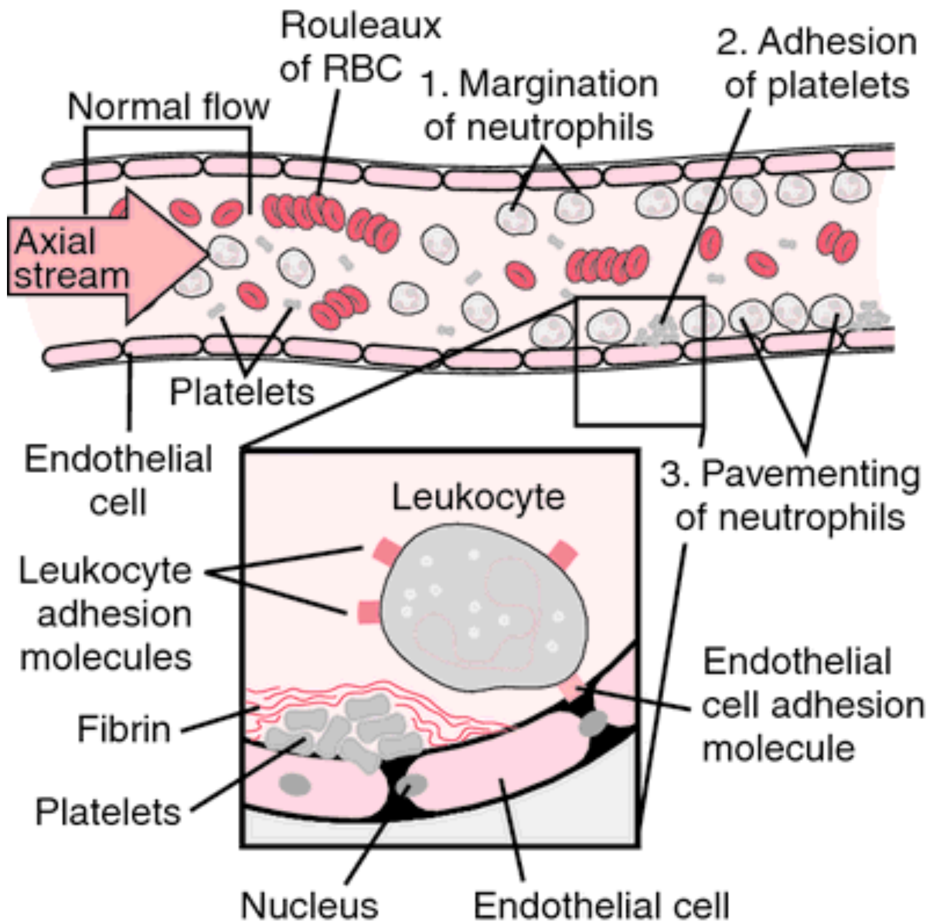


Fig. 132. This is an illustration depicting margination and pavementing of neutrophils.

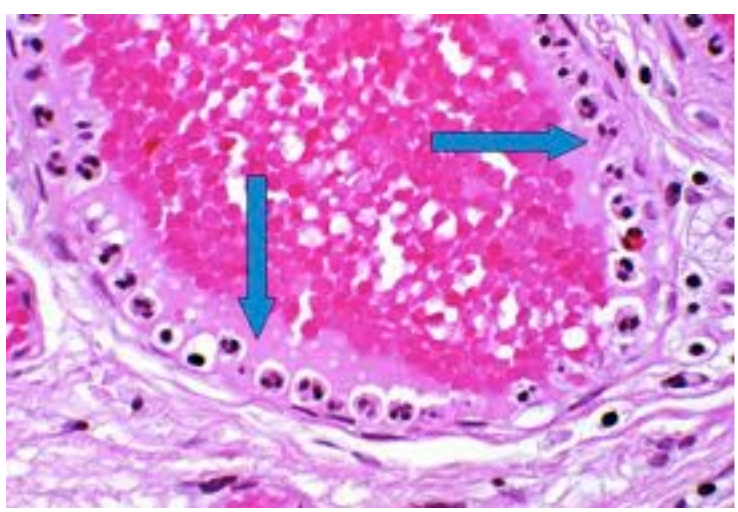


Fig. 133. The above is a photomicrograph of a venule showing margination and pavementing of neutrophils.

Along with the reaction of blood vessels to tissue injury, there are another group of vessels, which also participate in the process and they are called lymphatics. The lymphatic system, which includes lymph nodes, normally filters and polices the extravascular fluid. The lymphatics normally drain the small amount of extravascular fluid that seeps from the capillaries. Initially, due to the outpouring of the protein-rich fluid from the vessels in the injured area, the flow within the lymphatics is increased. However, along with the outpouring of protein-rich fluid from the blood due to an increase in vascular permeability, there is also the exudation of fibrinogen, which is one of the plasma proteins. This causes the formation of fibrin, which in turn leads to plugging of the afferent lymphatics further enhancing interstitial edema, which is perceived as swelling. Fibrin appears within a few minutes. Experiments have shown that the severity of the swelling of the injured site tends to be proportional to the extent of the lymphatic obstruction.

Margination and pavementing are followed within minutes by the emigration of the neutrophils and other leukocytes. This is the process by which leukocytes journey from their location along the endothelial surface of the blood vessels, migrating across the endothelial surface and then through the vessel wall.

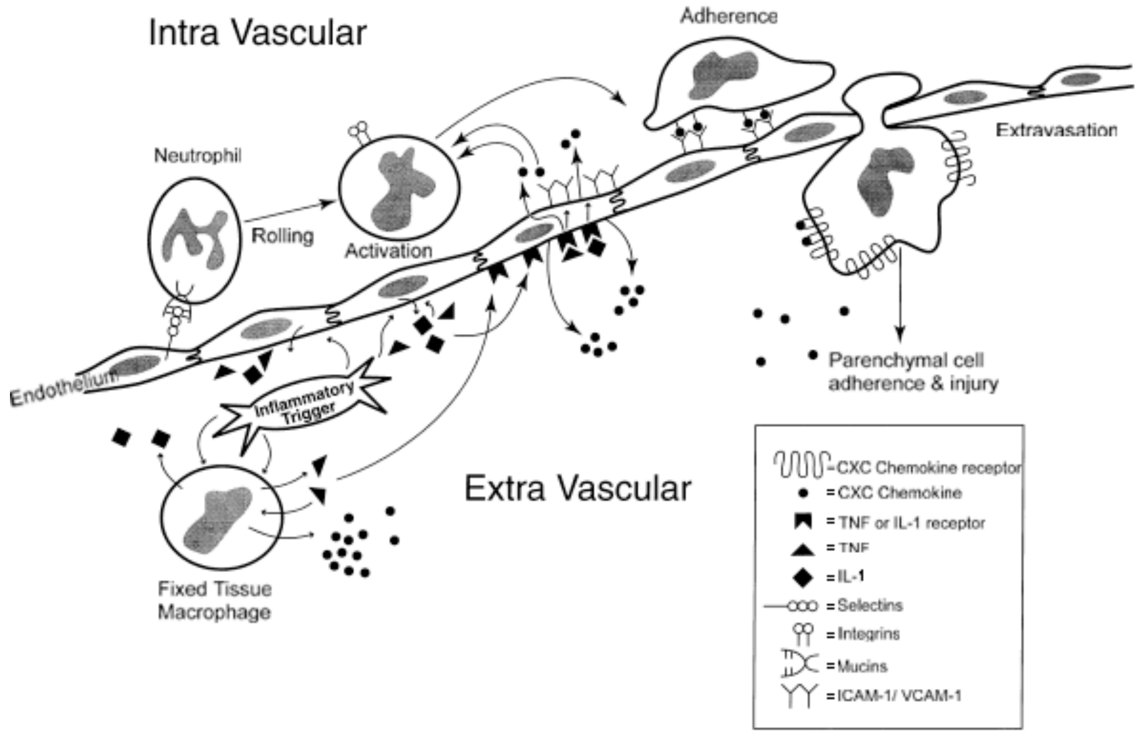


Fig. 134. This is an illustration of the margination, pavementing and emigration of the leukocytes through the vessel wall into the perivascular tissue.

Following the migration through the vessel wall the leukocytes migrate through the perivascular tissue, reaching the injured site.

Different molecular structures play a predominant role in each of the above steps: selectins are responsible for the rolling of the neutrophils along the endothelial surface of the blood vessels; chemokines activate the rolling neutrophils to have an increase avidity for integrins, which are surface proteins of the neutrophils. Also, cytokines induce expression of integrins on the surface of the endothelial cells. The combination of cytokine-induced expression of integrin ligands on the endothelium and activation of the integrins on the neutrophils results in firm integrin-mediated binding of the neutrophils to the surface of the endothelial cells, thus promoting margination and pavementing.

The migration of the neutrophils through the vessel wall is due to a molecule called CO31, which is also called PECAM-1 (platelet endothelial cell adhesion molecule). Following transmigration of the vessel wall, the neutrophils penetrate the basement membrane of the vessel, probably by secreting collagenases, which focally disrupt the basement membrane allowing the neutrophils to enter the extravascular tissue. This entire process primarily takes place in postcapillary venules due to the fact they have an adequate number of inter-endothelial gaps and an adequate number of receptors for chemical mediators, especially histamine.

After emigrating through the vessel wall, the neutrophils continue to emigrate in the perivascular tissue to the site of injury. The process by which emigration takes place is called chemotaxis. Chemotaxis is the directional migration in response to a chemical gradient produced by chemotaxins and chemokines, which are collectively referred to as chemoattractants. Chemoattractants are substances that make neutrophils and other leukocytes travel to them. Both exogenous and endogenous substances can act as chemoattractants. The most common exogenous agents include: cytokines, especially those of the chemokine family (e.g., IL-8); components of the complement system, especially C5a and C5a des-Arg; and arachidonic acid (AA) metabolites, mainly leukotriene B_4 (LTB_4).

Neutrophils, although peaking in numbers between 3 to 5 hours, they soon begin to disintegrate and for the most part are fragmented within 21 hours and by 30 hours the basophilic nuclear fragments have undergone autolysis or have been engulfed by the phagocytic monocytes, which are another type of leukocyte that migrates, as the neutrophils, to the site of injury.

In order to enhance understanding I believe it would be appropriate to explain the terms, leukocytes and neutrophils, as well as some other cells.

Leukocytes (also spelled leucocyte), otherwise referred to as white blood cells, are cells of the immune system involved in defending the body against both infectious disease and foreign material, such as those which induce traumatic injuries. There are five different types of leukocytes, all of which are derived from a single mother cell called a hematopoietic stem cell, which live in the bone marrow. Leukocytes are found throughout the body, including the blood and lymphatics.

Typically, white blood cells (WBC) are placed into two broad categories: Granulocytes and agranulocytes. Granulocytes are those cells which contain fine granules in their cytoplasm when viewed through a microscope. These granules represent membrane bound enzymes, the primary function of which is to digest particles engulfed by the leukocytes. There are three types of granulocytes: neutrophils, basophils, and eosinophils.

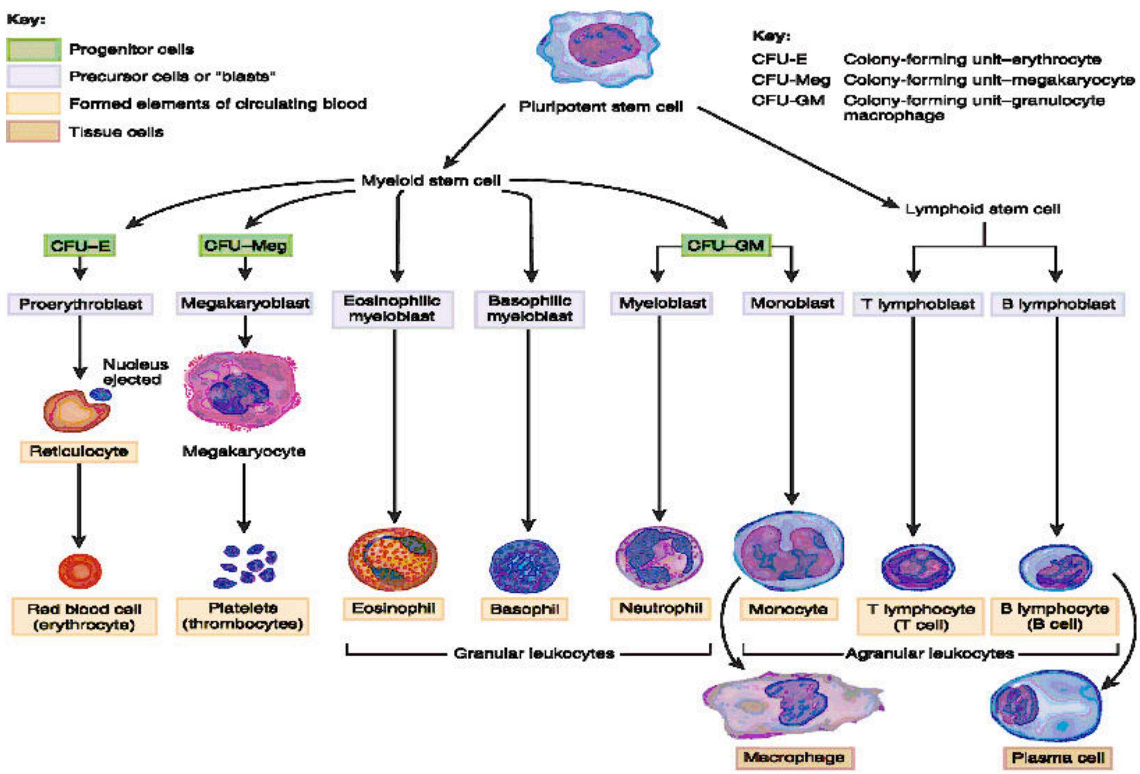


Fig. 135. Origin of cells within the blood: Erythrocytes (red blood cells), Megakaryocytes (origin of platelets), Granulocytes (neutrophils, basophils and eosinophils), Monocytes (origin of macrophages), Lymphocytes (B cell, T cell and Natural Killer cell [NK cell]).

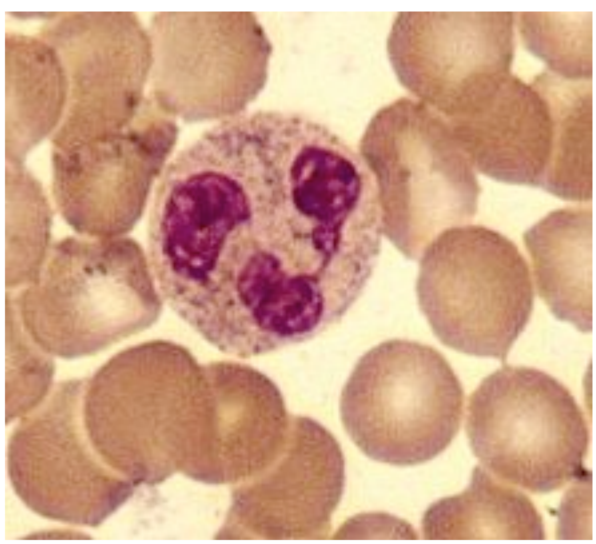


Fig. 136. The above is a photomicrograph of a neutrophil.

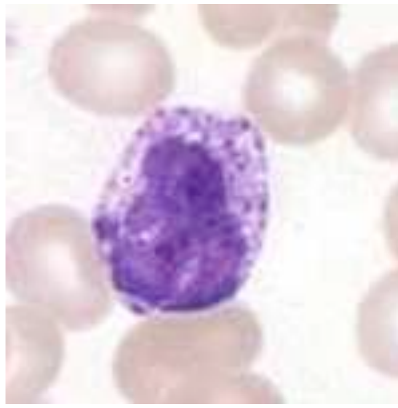


Fig. 137. Basophil

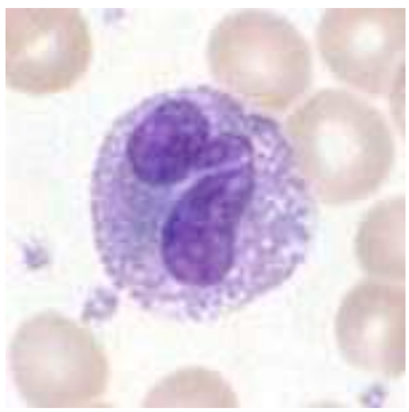


Fig. 138. Eosinophil

Agranulocytes (mononuclear leukocytes) are leukocytes characterized by the apparent absence of granules in their cytoplasm. Although, the name implies these cells have no granules, they do contain finite granules, which are not stained by the usual methods used in making microscopic slides so that tissue can be viewed by the light microscope. The nonspecific granules are called azurophilic granules. They are called azurophilic because although they do not stain with hematoxylin and eosin (H & E), which are the usual stains for preparing microscopic slides and stain the granules in granulocytes, they stain with azure dyes, such as azure blue aniline dye or a similar metachromatic thiazine dye. These cells primarily include lymphocytes and monocytes, however, macrophages and dendritic cells are also included in this category.

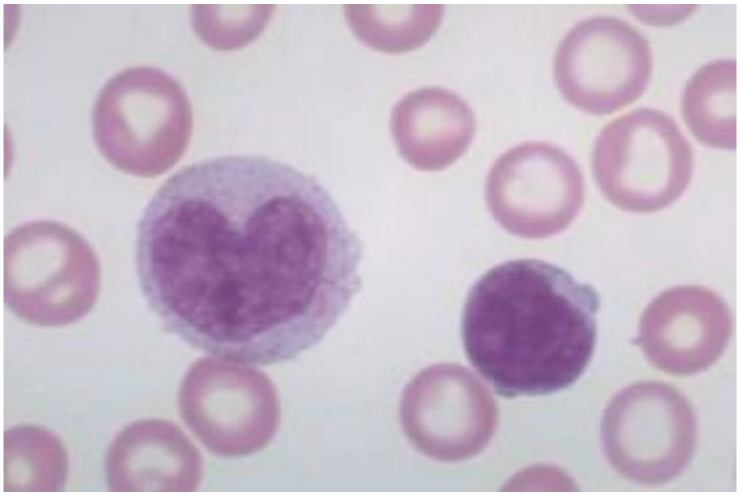


Fig. 139. The cell on the left is a monocyte, the one on the right is a lymphocyte.

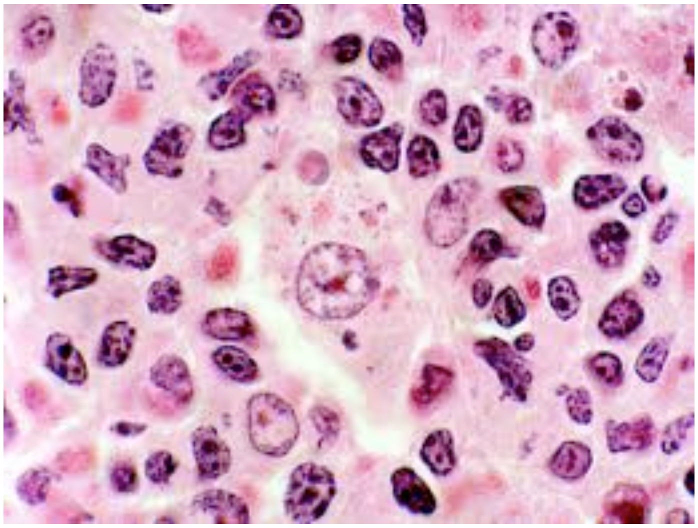


Fig. 140. This is a photomicrograph of a macrophage, which is in the center.

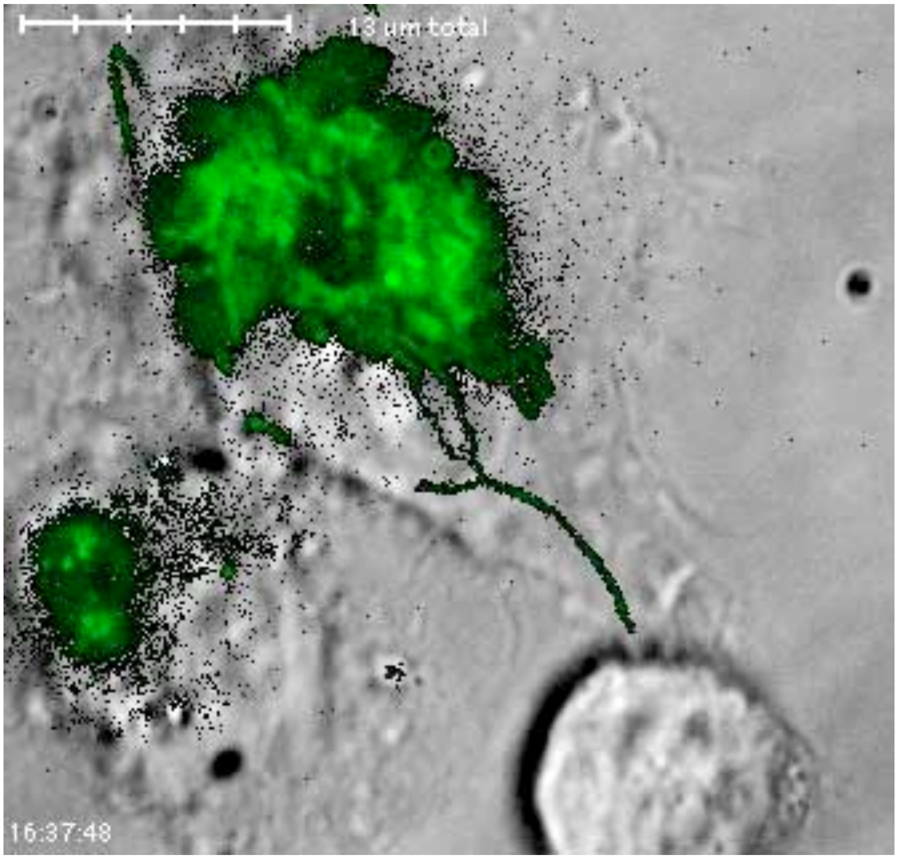


Fig. 141. The two green cells are dendritic cells. The larger is seen communicating through a long green tubule with a T lymphocyte. The dendritic cell is transferring antigen peptides that it has engulfed through the green tubule to the T lymphocyte so that it can manufacture antibodies.

Macrophages are included by some due to the fact they are WBC, which are derived from the differentiation of monocytes in tissue (see Fig. 135). Macrophages function in both nonspecific defense (innate immunity), as well as initiate specific defense mechanism (adaptive immunity). Their role is phagocytosis (engulf and then digest) cellular debris and pathogens. In essence, they are specialized phagocytic cells that attack foreign substances, infectious microbes (bacteria, etc.) and cancer cells. Macrophages (see Fig. 140) have other functional responsibilities besides killing microbes and engulfing dead cells. They produce a number of growth factors that cause the proliferation of endothelial cells and fibroblasts with their attendant increase production of collagen, as well as enzymes that remolded connective tissue. It is these processes which lead to the repair of traumatized tissue. It appears that how macrophages respond, or are activated, is based on the type of stimulus they are subjected to. For example, when macrophages are exposed to bacterial products and T-cell cytokines, such as IFN-λ (interferon lambda), they respond with microbicidal activity. However, when macrophages are exposed to cytokine IL-4, they respond by a proliferation of repair macrophages (M2) and inhibit the “classical activation” of M1 macrophages with their strong microbicidal activity. When exposed to cytokine IL-13, their response is similar to exposure to IL-4, however, IL-13 is more important as the central mediator of the physiologic changes induced by allergic inflammation and it also has anti-inflammatory properties. Thus, different stimuli activate leukocytes to secrete mediators of inflammation, as well as inhibitors of the inflammatory response.

Macrophages have a life span that is determined by whether they have been activated (i.e., they are responding to an inflammatory response), in which case they have a life span of days; in their inactive state their life span is months to perhaps years.

The reason some include dendritic cells under the category of agranulocytes, along with lymphocytes, moncytes and macrophages is because some dendritic cells are believed to be derived from monocytes, which depending on the signal the monocyte receives, differentiate into either macrophages, as discussed above, or dendritic cells. Fundamentally, there are five types of leukocytes: neutrophils, basophils, eosinophils, lymphocytes and monocytes. In this article we will primarily address neutrophils, monocytes, lymphocytes and macrophages (addressed above).

Neutrophils are commonly referred to as polymorphonuclear (PMN) leukocytes, although, technically PMN refers to all granulocytes. They are called polymorphonuclear because they have a multilobed nucleus, which gives the appearance of multiple nuclei when visualized through the microscope (see Fig. 136). Within the cytoplasm are fine granules which stain a pale lilac color with H & E. Interestingly enough, they also contain azurophilic granules when stained with an azure dye. Neutrophils defend against bacterial and fungal infection and participate in the early inflammatory response in traumatically induced injuries; they are very active in the phagocytosis of bacteria. The life span of a neutrophil is about 8 days.

Monocytes participate in phagocytosis as the neutrophils, but they live much longer than neutrophils. This longevity allows them to perform an additional function. During the phagocytosis process in which they digest bacteria, breaking them up into small parts, they in turn present some of these fragments to another group of cells called T cells. To give you an idea how this presentation may take place please see fig. 141, in which a dendritic cell, some of which are derived from monocytes, is presenting antigenic peptides to a T cell. The T cells then in turn manufacture antibodies against these bacteria, killing them. Should these bacteria ever gain entrance to that person again, some of the T cells will remember them and quickly manufacture antibodies to kill them. To accomplish phagocytosis, the monocytes emigrate, as the neutrophils, through the vessel wall gaining entrance to the perivascular tissue where they differentiate into tissue macrophages. The life span of monocytes is hours to days.

Another cell which has an important function in the acute inflammatory response is the mast cell. Mast cells react to physical trauma, breakdown products of complement, microbial products, and neuropeptides. These cells produce histamines, leukotrienes, enzymes, and many cytokines, such as tumor necrosis factor (TNF), IL-1 and chemokines, all of which contribute to the acute inflammatory reaction. Mast cells can be found in several types of tissue, characteristically surrounding blood vessels and nerves, and are especially prominent near the boundaries between the outside world and the internal milieu, such as the skin, mucosa of the lungs and digestive track, as well as the mouth, conjunctiva and nose.

Mast cells are very closely related to basophils in the blood. However, evidence suggest that mast cells and basophils arise from different precursor cells in the bone marrow. Having said this, both mast cells and basophils are believed to take origin from bone marrow precursor cells expressing the CD34 molecule. Basophils leave the bone marrow already mature, whereas the mast cells circulate in the blood in an immature form, maturing when they emigrate to extravascular tissue. It is believed the tissue site the immature mast cell settles in determines its particular function. There are two types of mast cells, those living in connective tissue and those in the mucosal tissues. The function of these latter mast cells is dependent on T cells.

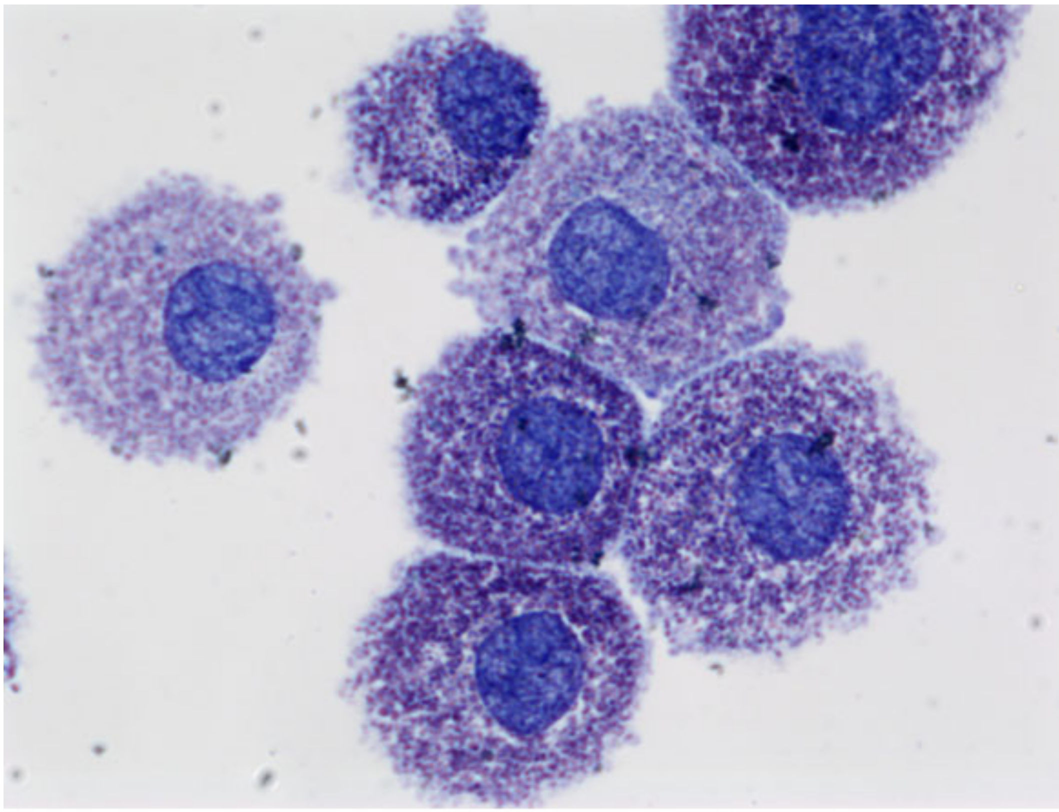


Fig. 142. These are human mast cells cultured from peripheral blood in stem cell factor (SCF) and IL-6 mediated activation, stained with Toluidine Blue.

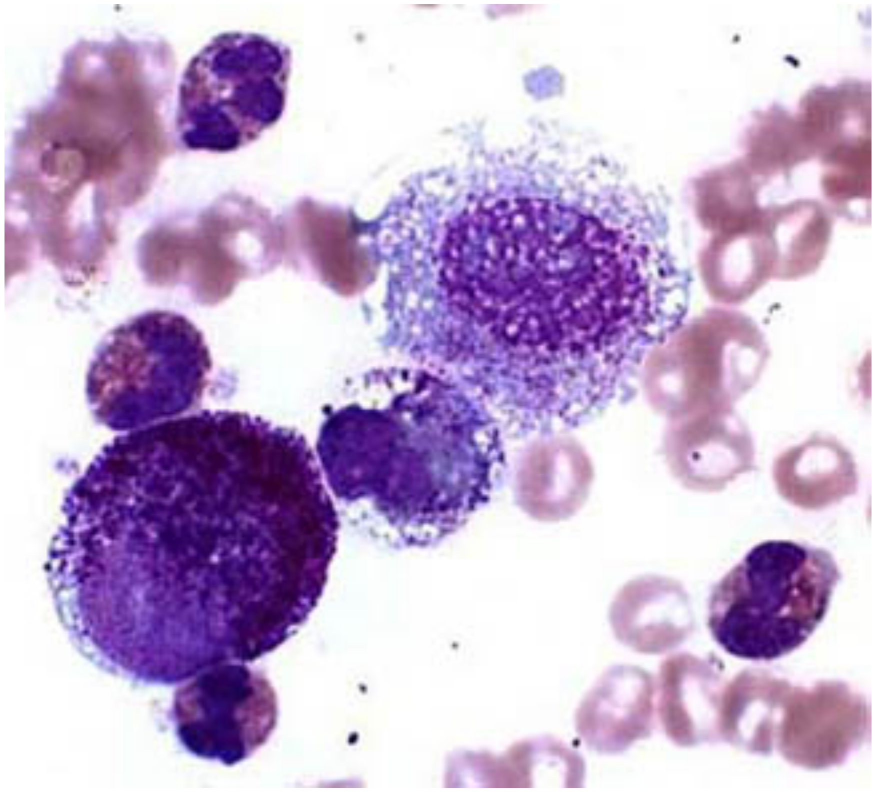


Fig. 143. These are mast cells from a cutaneous mast cell tumor of a dog, Wright-Leishman stain. The mast cells have numerous purple granules that partially obscure the nucleus.

Lymphocytes are not seen in the acute inflammatory response of immediate to 4 hours. They will be discussed in the following time interval of 4 to 12 hours.

Before I move on to the inflammatory response in the 4 to 12 hour time interval, I would like to very briefly comment on eosinophils and basophil since they have been shown in some of the illustrations and come under the heading of granulocytes.

Eosinophils are the primary reactive inflammatory cell in allergic reactions. An increase of eosinophils, eosinophilia, in the blood or tissues is seen in asthma, hay fever, hives and parasitic infections. Generally their nucleus is bilobed (see Fig. 138), and their cytoplasm contains granules which stain a pink-orange color with H & E stain.

Basophils are primarily responsible for allergic and antigen response, releasing histamine, which causes vasodilatation. They also contain heparin, which prevents the blood from clotting to quickly. Their nucleus is bi or tri-lobed, but can be very difficult to see due to the abundant coarse granules within the cytoplasm. These granules are large and blue (see Fig. 137).

2. **4 to 12 hour time interval:** The predominant inflammatory cell in this time interval is the neutrophil. As previously discussed, they begin to disintegrate after 3 to 5 hours, and are mostly fragmented by 21 hours. Migrating monocytes usually do not appear until between 12 and 24 hours after injury. The quantity of monocytes is determined by the amount of tissue destruction. Tissue macrophages can show activation within 6 hours of the traumatic injury. Some have noted swelling of the vascular endothelial cells and tissue macrophages within 1 hour of injury.

   Another cell you will see during this period is the lymphocyte, albeit in even more limited numbers than the monocytes. Lymphocytes occur in greater numbers during the repair process. Lymphocytes, along with monocyte derived macrophages, are common participants in the inflammatory response in wound repair.

   Lymphocytes have a deeply staining nucleus, which is eccentric in its position within the cytoplasm, the latter of which is small in quantity (see Fig. 139). There are three types of lymphocytes: B cells, T cells and Natural Killer cells (NKC).

   B cells make antibodies that bind to pathogens to enable their destruction. B cells not only make antibodies that bind to pathogens, but after an attack, some B cells will retain the ability to produce an antibody to serve as a 'memory system,' so that should that particular pathogen attempt another attack, it will be met very quickly with an antibody response.

   T cells consist of three subtypes:

   a. CD4 + (helper) T cells coordinate their immune response and are important in the defense against intracellular bacteria.
   b. CD8 + cytotoxic T cell are able to kill virus infected and tumor cells.
   c. ϒδ T cells possess an alternate T cell receptor as opposed to CD4 + and CD8 + αβ T cells and share characteristics of helper T cells, cytotoxic T cells and natural killer cells.

   Natural killer cells are able to kill cells of the body, which are deploying a signal to kill them, as they have been infected by a virus or have become cancerous.

   Molecules such as ϒ-interferon and several cytokines can be produced by T cells.

Also, a form of heparin-binding epidermal growth-like factor (HB-EGF), and a basic fibroblast growth factor (FGF). Thus, the secretion of two potent growth factors adds another dimension to the role of T lymphocytes in that they are not only serve as components of the immune inflammatory response, but also as an antecedent of fibroblast response associated with inflammation.

HB-EGF is an extremely potent stimulator for cells, which contain EGF receptors, causing proliferation of these cells, especially smooth muscle cells, vascular endothelial cells and fibroblastic cells. There is also evidence that lymphocytes, like M2 macrophages, can help mitigate, or switch off, acute inflammation.

The gross appearance of the injured tissue appearing red and swollen is very much in evidence. As indicated above, the endothelial cells of the vessels are swollen as is true of the tissue macrophages. You may also see evidence microscopically of the beginning of epithelial repair at the edges of the wound at the level of the basal epithelium.

3. **12 to 24 hour time interval:** Although neutrophils are the predominant cell, you will see an ever increasing number of monocytes as macrophages and lymphocytes. The neutrophils form a marginal zone around the area of tissue destruction. Their number however, begin to decline and the mononuclear cells increase in number. A basophilic tinge begins to develop in the tissue microscopically with most of the neutrophils having been fragmented by 21 hours. Tissue macrophages are swollen and fibroblast begin to show mitotic figures around the 15 hour mark. The epithelium grows down the edges of the incised and or stab wound, as well as extending across the defect from its edges.

   The termination of the acute inflammatory response to traumatized tissue, in part occurs, because the mediators of inflammation are produced in rapid bursts. This will continue to occur as long as the stimulus persists, having short half-lives, and are quickly degraded after their release.

   The mediators we understand are involved in the acute inflammatory response, their principal sources and function are as follows: those mediators, which lead to vasodilation are histamine, bradykinin, prostaglandins-I_2, E_2, D_2 F_2 and nitric oxide. Histamine is produced by mast cells, basophils and platelets; bradykinin is produced by mast cells, basophils, eosinophils, neutrophils, macrophages, dendritic cells, endothelial cells and the liver; prostaglandins are produced by mast cells and leukocytes; and nitric oxide is produced by many cells.

Those mediators, which cause increase vascular permeability are histamine, serotonin, bradykinin, fibrinopeptides, C3a and C5a (anaphylatoxins), leukotrienes C_4, D_4, E_4, PAF (platelet activating factor), and oxygen metabolites. Serotonin is produced by platelets; complement products (C3a, C4a, C5a and D4) are produced in the liver; leukotrienes are produced by mast cells and leukocytes.

Those mediators which are responsible for chemotaxis are LTB_4 (leukotriene), C5a, bacterial products, neutrophil cationic proteins, cytokines-chemokines (IL-1, TNF, IL-8), and PAF. Remember, chemotaxis is directed locomotion in response to a chemical gradient driven by a chemoattractant, which are substances that make leukocytes travel to them. Cytokines, such as TNF and IL-1 are manufactured by macrophages, endothelial cells and mast cells.

Mediators which lead to fever are IL-1, IL-6, TNF and prostaglandins.

Mediators responsible for pain are PGF_2 (prostaglandin F_2 alpha, which is an eicosanoid that stimulates the growth of skeletal muscle) and bradykinin. Remember, prostaglandins are produced by mast cells and leukocytes.

Those mediators responsible for tissue damage are oxygen free radicals, lysosomal enzymes and nitric oxide.

As previously indicated, neutrophils have a very short half life in tissue and die by apoptosis within a few hours of migrating into the extravascular tissues. As intimated above, as the acute inflammatory process evolves, a number of stop signals are triggered, which ultimately bring the acute inflammatory process to and end. Part of this termination includes a change in the arachidonic acid metabolite produced from the pro-inflammatory leukotrienes to the anti-inflammatory cytokines which include transforming growth factor-β (TGF-β) and IL-10, from macrophages and other cells; the production of anti-inflammatory lipid mediators resolvins and protectins, derived from polyunsaturated fatty acids; and participation of the peripheral nervous system (PNS) through neural impulses causing cholinergic discharge, which inhibit the production of tumor necrosis factor (TNF).

4. **24 to 72 hour time interval:** Leukocyte infiltration reaches its peak between 24 to 48 hours. As previously discussed the basophilic nuclear fragments of the polymorphonuclear leukocytes have either undergone autolysis or have been engulfed by phagocytic activity of macrophages by 30 hours. When the mononuclear cell infiltration reaches its peak is determined by the degree of tissue destruction; the greater the tissue destruction the longer it will take for their numbers to peak. What is important to remember is the duration, quantity, and cellular character of the inflammatory response varies according to location of the injury, the amount of tissue destroyed and the presence or absence of infection or foreign bodies.

   The predominate cell becomes the macrophage between 48 to 96 hours. These cells are essential to tissue repair and the clearing of extracellular debris, fibrin and other foreign material, as well as promoting angiogenesis and extracellular matrix deposition.

   It is during this period that the second phase of the inflammatory reaction, repair takes place. This is manifested primarily by the proliferation of fibroblasts and the formation of new blood vessels. If the edges of the wound are closely approximated, as by suturing, there is minimal intervening dead tissue or extravasated blood, the defect is bridged, first by fibrin and blood clot and later by proliferating fibroblasts, but abundant granulation tissue does not form. This enhances rapidity of repair and decreases scar formation. Pronounced granulation tissue forms when either the primary or secondary effect of the injury results in a persistent interruption in the continutiy of living tissue thus, giving rise in delay of repair and abundant scar formation. The migration of fibroblasts to the traumatized site is the result of chemokines, TNF, PDGF (platelet derived growth factor), TGF-β (transforming growth factor beta) and FGF (fibroblast growth factor). The subsequent proliferation of these migrated fibroblasts is due to multiple growth factors, such as PDGF, EGF (epidermal growth factor), TGF-β, FGF, and cytokines IL-1 and TNF. The macrophages are the main source for these factors, although other inflammatory cells and platelets may produce them. Of these growth factors, TGF-β is the most important fibrogenic agent. It produces most of the cells in whatever quantity of granulation tissue that forms and causes fibroblast migration and proliferation, increased synthesis of collagen and fibronectin and decreased degradation of extracellular matrix by metalloproteinases.

5. **3 to 6 day time interval:** It is during this period that collagen is formed, being first present at the margins of the incised or stab wound. Collagen is formed by the fibroblasts, first as elongated fibrils, which at first are vertically oriented and do not bridge the incised wound. As they become more abundant they then begin to form a bridge across the wound defect. At first the type of collagen formed is type III, which is gradually replaced by type I collagen.
   The epidermis continues to grow from the spurs of epithelial cells, which appeared between 24 to 48 hours at the edges of the wound. If the wound edges are closely approximated, they will bridge the wound defect during the 3 to 6 day period fusing in the midline beneath the scab. Complete epithelialization of those wound defects, in which the wound edges are closely approximated will take much longer.
   Macrophages stimulate the fibroblasts to produce FGF-7 (keratinocyte growth factor) and IL-6, which enhance keratinocyte (epithelial cells) migration and proliferation. Other mediators for stimulating re-epithelialization are HGF (hepatocyte growth factor), HB-EGF (heparin binding epidermal growth factor) and signaling through the chemokine receptor CXCR3. These mediators not only participate in the recruitment of inflammatory cells but also in wound healing through enhancing re-epithelialization.
6. **10 to 15 day time interval:** The process of wound healing continues with the loose, edematous appearing vascularized newly formed connective tissue becoming more compact and begins to contract. The initial step of wound contraction involves the formation, at the edges of the wound, of a network of myofibroblasts that express smooth muscle a-actin and vimentin. These cells have characteristics of smooth muscle cells, contract in the wound tissue, and may produce extracellular matrix components. The number of inflammatory cells decrease. Fibroblasts continue to lay down collagen. Elastic fibers and reticulin are formed. The epidermis continues to thicken, but no papillae are formed.
7. **Two weeks to several months:** There is continued consolidation of wound healing. The replacement of granulation tissue with a scar comes about through a change in the extracellular matrix (ECM). Collagen and elastin fibers continue to increase forming an avascular scar through a process of connective tissue remodeling; this

process requires a balance between ECM synthesis and degradation. Some of the growth factors that stimulated the synthesis of collagen and other tissue connecting various tissue molecules also modulate the synthesis and activation of metallo-proteinases, which as pointed out above, are enzymes that degrade the ECM components. Metalloproteinases are a family of enzymes that includes more than 20 members that have in common a 180-residue zinc-protease domain. The epithelial surface continues to thicken with eventual formation of dermal papillae. Adnexa do not appear unless islands of viable skin survived in the wounded area. Unless there has been a secondary infection of the wound site, all the inflammatory cells have disappeared.

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Fig. 78. External anatomy of the neck