

If there is a discrepancy between the injury and the history, one should trust the injury and not the history!

2.1 Introduction

The skin is one of the largest organs of the human body (Goldsmith 1990). The total body surface of the skin varies from 0.2 m² in a full-term newborn to around 2 m² in an adult (Patient.co.uk 2007). The skin weighs about 15% of the total body weight. It is also the most accessible organ of the human being and plays an important role in the communication between human beings. Skin irregularities and abnormalities can be seen by everybody. Because of its easy accessibility, it is the most frequently damaged organ in accidents as well as in child abuse or physical assaults.

The skin has three major functions: protection against external influences, regulation (thermoregulation, osmoregulation, excretion, and secretion), and sensory perception (touch, temperature, kinesthetic sense, pain). In forensic terms, the most important function of the skin is protection. The skin forms a barrier between the environment and the organism and protects the organism against injuries caused by mechanical (static and dynamic loading; Sect. 2.5) and nonmechanical or physical (thermal, chemical, electrical, and radiation trauma; Sect. 2.6) agents.

The skin consists of three layers, namely, the epidermis, the dermis, and the hypodermis. These layers form together a smooth and supple

protective shield, which protects the body against injuries.

The epidermis is the compact, firm, and elastic outer layer of the skin. The epidermis protects the body against external influences. Because of its elasticity, the epidermis is not easily damaged in blunt-force trauma or crushing (Langlois and Gresham 1991).

The second layer is the dermis which is composed of three types of tissue that are present throughout the dermis: collagen, elastic tissue, and reticular fibers (Brannon 2007). Because of this composition, the dermis is capable of stretching under force and returning to its original form without damage (Kaczor et al. 2006). The dermis is the second skin layer to absorb the energy which is transferred during blunt-force trauma. The dermis is very well vascularized and has an extensive superficial capillary network. In adults, up to 4.5% of total blood volume is found in the dermis (Coleman 2001).

The hypodermis consists of connective tissue and fat. It is richly vascularized, just like the dermis. Because of the elasticity of the hypodermis, this layer will easily deform and will function as a shock absorber for the underlying structures, such as bones. The fat tissue in the hypodermis functions not only as a shock absorber but also as a thermal insulator. The fat protects the body against cold and defines the body's contours.

One square centimeter of the dermis and hypodermis may contain up to 70 cm of blood vessels (Fridman 2001). During blunt-force trauma, these

vessels are the most vulnerable structures with the majority of bleeding occurring from the capillaries and venules in the subcutaneous tissue (Langlois and Gresham 1991). The injury threshold of these vessels is lower than that of the epidermis or other parts of the dermis or hypodermis. Blood will leak into the perivascular tissues when damage occurs (Kaczor et al. 2006). The extravasated blood will spread along any line of cleavage in the tissue producing a visible discolored area – a bruise (Langlois and Gresham 1991). The blunt-force trauma will in most cases not lead to loss of the integrity of the epidermis or the superficial layers of the dermis, as happens in a laceration.

According to Kaczor et al. (2006), the skin varies in relative tissue composition and thickness throughout the body to meet the functional requirements of the different body parts. The thickness of the epidermis and dermis together varies in thickness from less than 0.5 mm on the eyelids to 4 mm or more on the palms and soles (Fridman 2001). The epidermis itself is the thinnest on the eyelids (0.05 mm) and the thickest on the palms and soles (1.5 mm). The thickness of the dermis also varies depending on location, for example, 0.3 mm on the eyelid and 3.0 mm on the back. The size of the hypodermis varies throughout the body and from person to person (Brannon 2007).

As a consequence of these structural differences of the skin between body regions, some parts of the body will bruise or be injured in another way more easily, while other parts of the body require more loading. One will see increasing extravasation of blood in areas with increasing laxity and loose subcutaneous elements in the tissues, for example, bruising around the eyes is more obvious than bruising of the hand palm (Langlois and Gresham 1991).

A superficial bruise may be visible as a discoloration immediately, while deep bruises may take hours to days before becoming visible (Wilson 1977; Langlois and Gresham 1991). Deeper bruising sometimes will not become visible, except when the skin is incised, for example, during a forensic autopsy (Langlois and Gresham 1991).

2.2 Evaluating Skin Injuries: “The Kipling Principle”

I Keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who. (Kipling 1902)

In 1990, Johnson stated: “Physicians must approach an injury as a symptom requiring a diagnosis of cause. This is best accomplished by careful examination and documentation of each injury.” In other words, evaluating an injury in a child should be done in a standardized way, and findings should be described in a standardized and well-defined terminology. Only then the findings can be understood correctly and used properly by others if a child needs protection.

In 1902, Rudyard Kipling (1865–1936) published the “Just So Stories” (Fig. 2.1). He ended one of the stories in this book, “the Elephant’s Child,” with a poem in which he described the questions a child has to answer to find solutions for daily problems. These questions are also the questions to be asked and answered by doctors in a standardized forensic evaluation of suspicious physical findings in a child: “What and Why and When and How and Where and Who.”

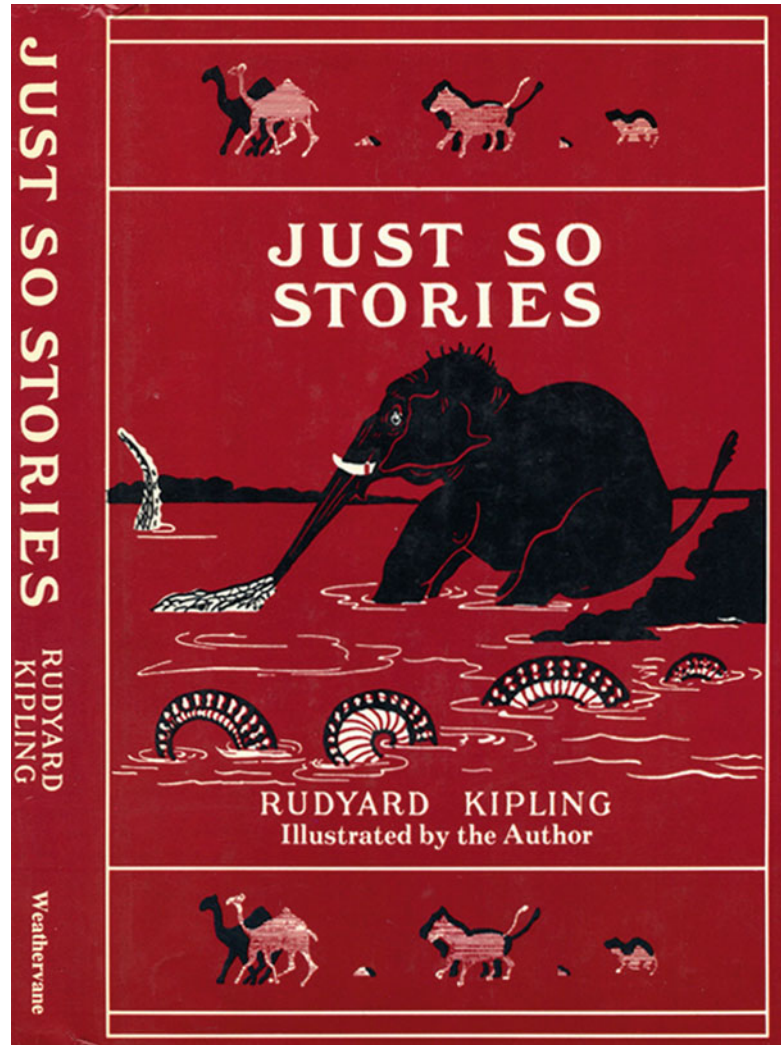
2.3 What: Defining Injury and Types of Skin Injuries

2.3.1 Defining Injury

The first question to be answered in a forensic medical evaluation of a suspicious physical finding is what do I see? In other words, whether the finding is an injury or something else, for example, a normal variant or a disorder. Sometimes, the answer to this question can only be formulated after a comprehensive evaluation and differential diagnosis.

An injury (bodily injury, physical injury) is defined as any wounding or physical damage that results from the (sudden) subjection of the body or parts of the body to amounts of energy that exceed the threshold of physiological tolerance or, in other words, that are beyond the body’s

Fig. 2.1 Rudyard Kipling: Just So Stories (the elephant's child)



ability to absorb (Health Canada 2003; WHO 2006),

- Without or with externally visible damage to the skin or the mucous membranes and/or.
- Without or with externally visible signs of damage to the skeleton or internal organs.

Physical injury can also be the result of lack of one of the vital elements (e.g., oxygen, trace elements, vitamins, water, or warmth) (Health Canada 2003; WHO 2006). Although not mentioned by Health Canada or the WHO, an excess of one of the vital elements can also result in physical injuries of all body parts (including the skin) or even death as can be seen, for example, in salt poisoning, hypervitaminosis, water poisoning (hyperhy-

dration), or overheating (hyperthermia, heat stroke) (el Awad 1994; Meyer-Heim et al. 2002; Zhu et al. 1998; Arieff and Kronlund 1999; Martos Sánchez et al. 2000; Quereshi et al. 2010).

During a forensic medical evaluation (including a forensic autopsy), all physical findings are important, irrespective of how trivial they may seem to be from a clinical and medical point of view. Even the combination of injuries on certain parts of the body and the absence of injuries on other parts of the body is forensically relevant because this may help to determine what happened. Therefore, a correct and complete description and registration of all medical findings (with the standardized description of anatomical

Table 2.1 Types of skin injuries in mechanical trauma: closed injuries

Bruise (Chap. 3)	<p>Bleeding, due to the rupture of blood vessels, generally located superficially in the skin and subcutaneous tissues with usually externally visible surface discoloration</p> <p>Caused by blunt-force trauma (collision/compression or stretching)</p> <p>Will not blanch under diascopy (Figs. 2.2 and 2.3)</p> <p>Synonyms (sometimes used for specific types of bruising and bleeding): contusion, hematoma, purpura, and ecchymosis</p>
Petechia (Chap. 3)	<p>Small red, purple, or brown spot caused by minor bleeding (0.1–2 mm – pinpoint to pinhead) in the skin, the mucous membranes, and/or the serosal surfaces, due to leakage of blood from the postcapillary venules (Fig. 2.4)</p> <p>Caused by a sudden rise of the venous pressure in the postcapillary venules</p> <p>Will not blanch under diascopy</p> <p>Synonym: pinpoint bleeding</p>
Erythema (Chap. 7)	<p>Redness of the skin, due to cutaneous vasodilatation</p> <p>Caused by a local reaction to physical agents (e.g., friction, rubbing, or pressure) or application of irritating chemical substances</p> <p>Will blanch under diascopy (Figs. 2.5 and 2.6)</p>

locations and injuries – mechanical trauma, see Tables 2.1 and 2.2 and Sect. 2.5; nonmechanical trauma, see Table 2.5 and Sect. 2.6), including the description and registration of absence of findings, is imperative.

2.3.2 Injury Classifications

Injuries can be classified in many other ways than purely on the type of injury (Tables 2.1 and 2.2). An overview of examples of injury classifications is given in Table 2.3 by using the “Kipling principle.”

2.4 How and Why: Cause and Manner of Skin Injuries

The cause (or mechanism) of injury refers to the way the skin, the mucosa, or any other tissue (muscles, organs, and bones) is damaged; in other words, how skin injury occurred (what caused the injury). The manner (or mode) of injury describes the circumstances under which the injury was sustained or the injury event happened; in other words, why (under which circumstances) the injury occurred.

In general, injuries to the skin are caused by the transfer of energy to the skin, in which the transferred energy exceeds the capacity of the

skin (and/or the underlying tissues) to absorb the energy. Transfer of energy, leading to injuries, results from mechanical trauma (static and dynamic loading; Sect. 2.5) or nonmechanical trauma (contact or near contact with physical agents; Sect. 2.6).

While determining the cause of an injury, one should also differentiate between the underlying cause and the direct cause. According to the CDC (2007), the underlying cause is what starts the chain of events that leads to an injury. The direct cause is what produces the actual physical harm. In children and adults, the underlying and direct causes can be the same or different (CDC 2007).

If a child sustained bruising on the forehead after he or she stumbled while walking and hit his or her head on a coffee table, the fall, caused by the stumbling, is the underlying cause (the action that started the chain of events leading to the injury = stumbling and falling), leading to the contact with the table, which is the direct cause of the bruising (the action that caused the actual physical harm = impact trauma).

Determining the cause of injury does not say anything about the manner (mode) of injury. The cause of injury may indicate the circumstances in which the injury was sustained (manner of injury), but rarely ever will prove the exact manner. Determining that the child fell and hit the table (causing a bruise to the forehead) does not determine under which circumstances the tumbling

Table 2.2 Types of skin injuries in mechanical trauma: open injuries

Abrasion (Chap. 7)	<p>Superficial injury to the skin, characterized by the traumatic removal, detachment, or destruction of the epidermis (Figs. 2.7 and 2.8)</p> <p>Caused by blunt-force trauma (collision/compression or stretching or friction/transverse motion during collision/compression/stretching – shearing force)</p> <p>Synonyms: scrape, graze, erosion, excoriation</p>
Laceration (Chap. 7)	<p>Full-thickness injury of the skin and subcutaneous tissues, characterized by tearing of tissue in a frayed and irregular pattern and often associated with abrasions, contusions, and crushing of the wound margins (Fig. 2.9)</p> <p>Caused by blunt-force trauma (collision/compression or stretching – shearing force)</p> <p>Synonyms: tear, tear wound</p>
Avulsion (Chap. 7)	<p>Laceration in which skin and subcutaneous tissues are not just separated but torn away from the underlying tissues</p> <p>Caused by blunt-force trauma (collision, compression, or stretching – shearing force)</p>
Cut	Injury in which the integrity of the skin is compromised by blunt-force (laceration, avulsion) or sharp-force trauma (incision, stab wound)
Incision	<p>Slicing injury with sharp edges (clean cut), which is longer than deep, varying from minimal as a paper cut to significant as a surgical incision, if caused by sharp-force trauma with a clean, sharp-edged object (e.g., a knife, a razor, or a glass splinter) (Figs. 2.10 – 2.13)</p> <p>Slicing injury with laceration-like edges, which is longer than deep, if caused by sharp-force trauma with a sharp serrated object (e.g., a bread knife)</p> <p>Synonym: incised wound</p>
Stab wound	<p>Deep, narrow injury, which is deeper than its length visible in the skin, caused by a sharp-pointed object puncturing the skin (e.g., nail, needle, knife, or broken glass). Usually sharp edged, except often in case of a sharp serrated object (Figs. 2.14 – 2.19)</p> <p>Synonyms: puncture wound, penetrating injury</p>
Gunshot wound	<p>Injury caused by an object entering and often leaving the body at a high speed, typically a bullet or similar projectile</p> <p>Often two wounds are found, one at the site of entry and one at the site of exit (through-and-through injury) (Fig. 2.20). Wound characteristics depend on size of projectile, speed, and distance between gun and target</p> <p>Synonyms: missile wound, velocity wound</p>

Table 2.3 Classifications of injuries

	Classification based on	Example
What	Probability	No injury – inconclusive – possible – probable – reasonable medical certainty – injury proven
	Severity	Mild – moderate – severe – fatal
	Type	<p>Closed and open (Tables 2.1 and 2.2)</p> <p>Blunt force versus sharp force (penetrating)</p> <p>Mechanical and nonmechanical</p>
How	Cause/mechanism (biomechanics)	Mechanical (static and dynamic loading) and nonmechanical (physical agents) (Tables 2.4 and 2.5)
Why	Manner/mode (circumstances)	<p>Accidental versus non-accidental</p> <p>Non-inflicted versus inflicted</p> <p>Non-intentional/unintentional versus intentional/deliberate</p> <p>Non-abusive versus abusive/negligent</p>
Where	Anatomical location	<p>Head/neck – trunk – extremities</p> <p>External (skin, mucosa) – internal (muscles, brain, abdomen)</p>
	Tissue	<p>Soft tissues (skin, mucosa, muscles, joints) – hard tissues (skeleton)</p> <p>– special tissues (brain, thoracic and abdominal organs, eyes)</p>
When	Dating	Old – recent
Who		<p>Person – object</p> <p>Self-harm – harm by others</p>

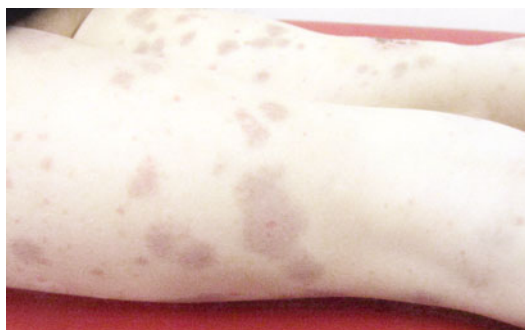


Fig. 2.2 Bruising



Fig. 2.5 Erythema



Fig. 2.3 Diascopy in bruising: no blanching



Fig. 2.6 Diascopy in erythema: blanching



Fig. 2.4 Extensive petechiae in the face of a strangled child (= Fig. 3.95)



Fig. 2.7 Abrasion



Fig. 2.8 Abrasion



Fig. 2.9 Laceration of the scalp with tissue bridges of vessels and/or nerves within the tear (= Fig. 7.53)



Fig. 2.10 A small paper cut wound (Laurence Facun 2008 from Wikimedia Commons 2011: Oww Papercut 14365.jpg)



Fig. 2.11 Incision in a bruise: visible blood (= Fig. 3.86)



Fig. 2.12 Incision in a Mongolian spot: no visible blood (= Fig. 3.88)



Fig. 2.13 Fresh incised wounds, next to scars in self-cutting (Hedwig Klawuttke 2009 from Wikimedia Commons 2011: Borderline.jpg)

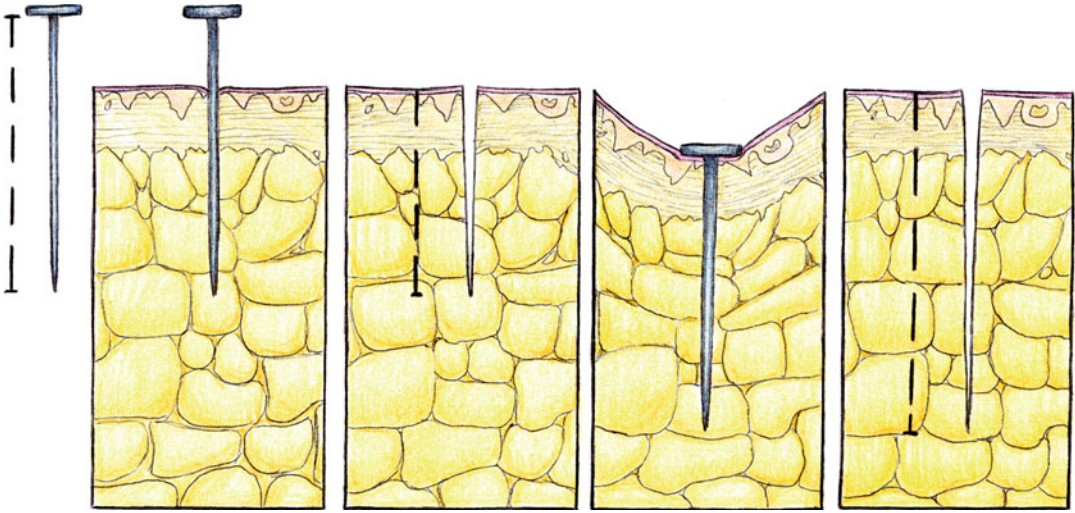


Fig. 2.14 Sharp penetrating trauma (puncture wound): deeper than its length visible in the skin and often deeper than the length of the penetrating object



Fig. 2.15 Sharp penetrating trauma: stab wound with a sharp object, probably with a single-edged knife because of the fishtailing on one side of the wound (= Fig. 7.65)



Fig. 2.16 Stab wound, probably with a double-edged knife because of the sharp angles on both sides of the wound



Fig. 2.17 Stab wounds: paired injuries

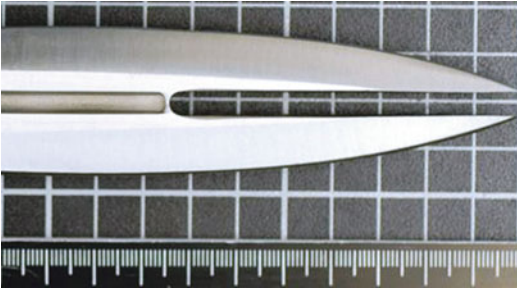


Fig. 2.18 Knife: paired blades



Fig. 2.20 Gunshot wound to the left thigh showing entry and exit wounds in 3-year-old girl (Bobjgalindo 2010 from Wikimedia Commons 2011: Gunshot wound to leg.jpg)



Fig. 2.19 A puncture wound from playing darts (James Heilman 2010 from Wikimedia Commons 2011: Knee puncture.JPG)

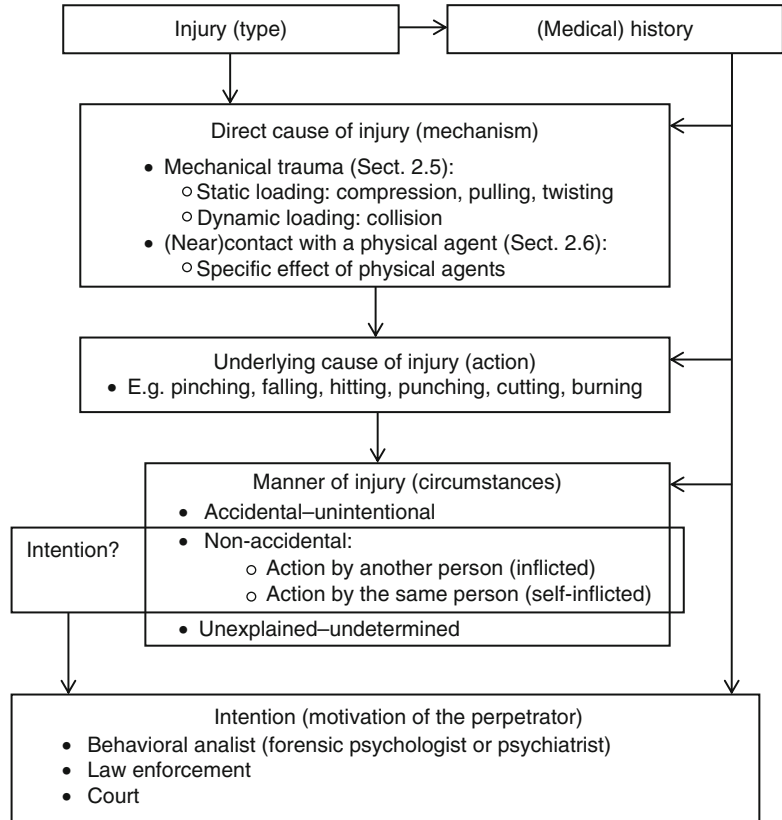
took place. The stumbling may have been caused, for example, by the unstable walking of the child (developmental level), just being wild during play, being pushed by another child during play or during a fight, or intentionally or unintentionally being pushed by an adult. The resulting injury may look the same, because it is caused by an impact trauma (cause of injury), despite the different circumstances (manner of injury).

As stated before, the manner of injury describes the circumstances under which the injury was sustained or the injury event happened (NCECI 2007). The manner of injury can be divided in three types of circumstances. Terms used in the medical literature to describe the manner of (pediatric) physical trauma are:

- Accidental (often used synonyms: non-inflicted, non-intentional or unintentional, non-abusive)
- Non-accidental (often used synonyms: non-accidental, inflicted, intentional, deliberate, abusive/negligent)
- Unexplained (undetermined)

Using the term “accidental” is factually misleading. It implies that the events leading to the injury were inevitable and could not be avoided. In case of minors, especially younger children, most accidents (perhaps even almost all) are, at least in retrospect, preventable and sometimes even predictable (WHO 2006). Non-inflicted is a misleading term just like accidental: the use of this term implies that the injury was not inflicted and that nobody was involved in causing the injury, although, for example, in a motor vehicle accident, the driver is involved in causing the injury. “Non-intentional or unintentional” are more neutral terms: the injury event happened but there was no intention for it to happen, despite the fact that the incident could have been

Scheme 2.1 Evaluation of suspicious injuries: the relation between injury and medical history, cause of injury, manner of injury, and the motivation of the perpetrator



prevented if the necessary precautions had been taken. Nevertheless, in this book, the terms “accidental” and “unintentional or unintended” will be used for injuries which are the result of an unintended non-abusive incident, despite all shortcomings of these terms.

Using the term “intentional” as synonymous for “non-accidental,” “inflicted,” or “abusive” in the medical evaluation of injuries is also misleading. It would mean that the motivation of the perpetrator (intentional: willingly, consciously, deliberately) to inflict an injury can be determined by using characteristics of the injury. This is almost never possible purely on the findings during the physical examination, except probably for pinch marks (Chap. 3), bite marks (Chap. 8), or multiple stab wounds. In a physical assault, the action that led to an injury is almost always the result of a conscious decision and therefore intended, but it is almost never the intention of the perpetrator to inflict (serious) injuries. “Inflicted” is a more

appropriate term, because it states that the injury was the result of an action by a human being (and perhaps an animal in bite marks), without saying anything about the intention (to inflict = to give or impose something unpleasant and unwanted, for example, to inflict serious injuries – Kernerman English Multilingual Dictionary, 2010).

The evaluation of injuries is a (forensic) medical task, in which injury characteristics and the patient’s or parent’s (medical) history can be used to a certain extent to differentiate between inflicted, accidental, and unexplained injuries (Scheme 2.1). In each step, a carefully taken and comprehensive (medical) history may add information, which may enable differentiation.

The evaluation of the motivation (the intention) of the perpetrator is not a (forensic) medical task but is the task of the behavioral analyst (forensic psychologist or psychiatrist) or law enforcement. In this book, the terms “non-accidental” or “inflicted” will be used for the

circumstances in which injuries resulted from an abusive incident (an injury event resulting from violent behavior of an adult toward a child).

The clinical assessment of the circumstances is based on a careful evaluation of the context, including:

- Data about the age and developmental level of the child
- Explanations given by the child (if possible), the parent(s), and others (people involved in the case, regardless of their background: professionally involved or not)
- Other (historical) physical signs and symptoms (e.g., stress-related physical signs or older bruises and/or other soft tissue injuries, fractures, head injury, and abdominal injury)
- Additional findings during physical examination/forensic medical examination
- Findings during laboratory examination: blood tests (e.g., blood clotting)
- Findings during imaging: skeletal survey, CT/MRI brain, abdomen, total body
- Assessment by social work/child protection service. Inquiry by the police
- Data from the clinical and forensic pediatric literature about the differential diagnosis of physical findings and the possibility and probability of injuries in certain circumstances
- In case of suspicions of fatal abuse, findings during a forensic autopsy

Even if all these data are used, it is not always possible to conclude whether the injury resulted from an abusive act or negligent behavior. For example, a young child (age 3) becomes a victim of a house fire (and dies). Cause of (injuries and) death: carbon monoxide intoxication and/or burn injuries. The house fire was not supposed to happen; the injuries (and death) were the result of the fire:

- The fire resulted from, for example, a malfunctioning electrical device and the parents tried everything to save the child: the manner of the injuries, resulting in death will be categorized as accidental and unintended.
- The child was left alone in house without any supervision, and the injuries, resulting in death, could have been prevented if the child had been taken care of in a proper way: the manner of death will be negligent and non-accidental.

- The fire was started deliberately. The manner of death will be manslaughter, if the death of the child was not intended to happen, or homicide, if the death of the child was intended to happen.

However, sometimes, medical findings will remain unexplained (by history) even after comprehensive investigations, including a clinical examination or forensic autopsy.

2.5 Mechanical Trauma

Mechanical trauma (Figs. 2.21 and 2.22) can lead to injuries caused by either static or dynamic loading. Skin injuries occur when the loading during the contact exceeds the capacity of the skin (and/or the underlying tissues) to absorb the transferred energy. Burton (2007) exemplifies

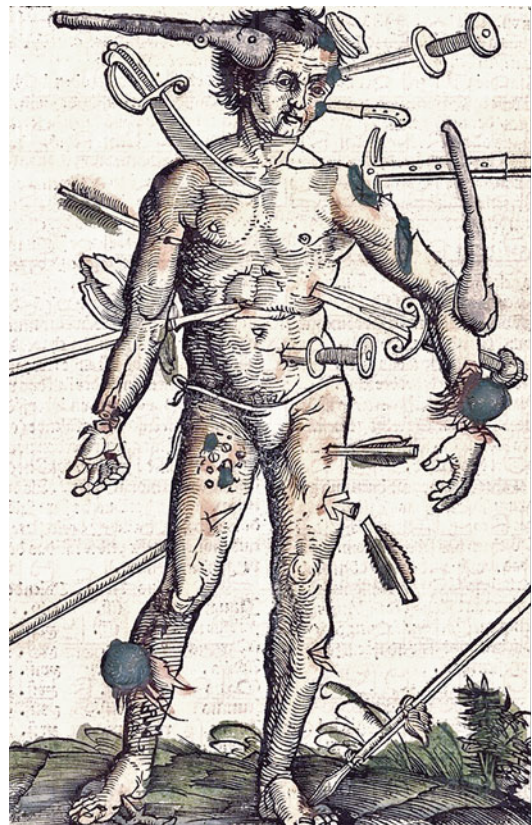


Fig. 2.21 Blunt- and sharp-force trauma: der verwundete Mann (the wound man) (Hans Gersdorff, *Feldtbuch der Wundartzney* 1517)

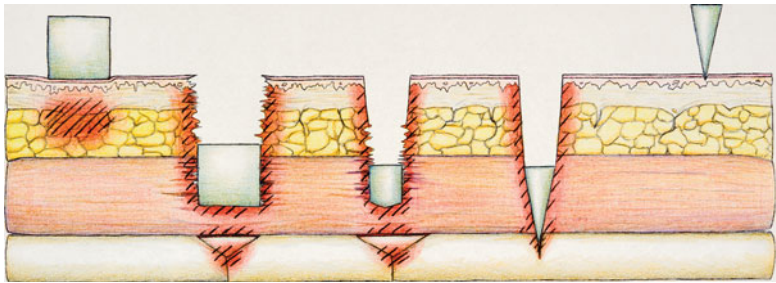


Fig. 2.22 Blunt- and sharp-force trauma (from left to right): (1) Superficial blunt force – bruising. (2) Blunt penetrating trauma – damage to subcutaneous tissue (e.g., bones). (3) Blunt penetrating trauma – damage to subcutaneous tissue

(e.g., bones). (4) Sharp penetrating trauma – damage to subcutaneous tissue (e.g., bones). (5) Superficial sharp-force trauma – superficial incision or abrasion with or without damage to the underlying dermis and subdermis

Table 2.4 Injuries resulting from mechanical trauma (static or dynamic loading)

Blunt-force trauma	Erythema (Sect. 7.2) Bruising (Sect. 3.2) Abrasion (Sect. 7.3) Laceration (Sect. 7.4) Avulsion (Sect. 7.4) Blunt penetrating trauma (Sect. 7.4.5)
Sharp-force trauma	Incision/incised wound Puncture wound/stab wound/penetrating injury Gunshot wound/missile wound/velocity wound

the difference between static and dynamic loading: “Consider the effect of a stationary bullet resting on your chest, compared to the effect of a moving bullet striking your chest. The stationary bullet exerts a static load on your chest. A moving bullet exerts a dynamic load” (Burton 2007).

An overview of injuries resulting from mechanical trauma is given in Table 2.4.

2.5.1 Static Loading and Injuries

In mechanics, a static load is defined as a non-varying load, for example, a nonvarying force exerted on a surface by the weight of a mass at rest. In everyday language, the mass of an object equals the weight of the object. In mechanics, however, mass and weight are defined differently (NYU 2003; Wikipedia 2011):

- Mass is a measurement of the amount of matter in an object by using a balance comparing a known amount of matter to an unknown amount of matter (unit of mass: kilograms or pounds).
- Weight is the measurement of the force experienced by an object due to gravity or the force exerted on a surface by the object. Weight is measured on a scale (unit of force: Newton). Weight is calculated as followed: Force (weight)=mass×(gravitational) acceleration ($F=ma$ or $W=mg$). In other words, an object with a mass of 1.0 kg will weigh 9.8 N.
- The mass of an object does not change when an object’s location changes. Weight, on the other hand, does change with location, if the gravity changes.

In static loading, an object does not change direction, level of exerted force (except when the gravity changes), and position during the time of exposure of the surface. In other words, there is neither a change in loading nor a gradual buildup of loading, and the transferred energy stays the same during the contact. For that reason, a static load in mechanics is also known as a dead load.

In the biomechanics of skin injuries, static load and static loading are used slightly different than in mechanics in general. The type, severity, dimensions, and appearance of skin injuries (and injuries of the underlying tissues), caused by static loading, are not only determined by mass, weight, gravity, or force but also by:

- The surface of the compressing object (flat, curved, patterned, blunt, sharp, more or less flexible) and of the compressed skin (flat,

curved, underlying tissues – connective tissue, fat, bone)

- The size of the contact surface between the compressing object and of the compressed skin
- The source that determines the mass of the object (gravity, human behavior, accidental wedging)
- The force exerted on the skin (the level of loading). Gradual or repetitive buildup of loading or changes in loading of the skin during the time of exposure may happen, because the force that is exerted is not only determined by gravity but also by the amount of changes in pressure actively exerted on the skin, for example, if a person is grabbed by another person, or if a person is overrun by a very slow driving car, or by movements of the person who is subjected to the load and actively resist the loading or passively changes position. This will lead to changes in the energy that is transferred from the compressing object to skin during the time of exposure (contact time) and will influence the final effect of the static load on the skin.

In physical assaults, static loading mostly will be caused by blunt-force trauma due to compression, but loading of the skin may also be caused by pulling or twisting the skin. Static loading may happen in sharp-force trauma, when a sharp-pointed object (e.g., a needle) is first held and then pressed against the skin (often leading to a penetrating trauma).

If static loading in blunt-force trauma leads to injuries of the skin and underlying tissues, including the vessels (subcutaneous veins or capillaries), the injuries are the result of direct damage by the distorting force (compressing, pulling, twisting) at the site of the distortion. The integrity of the skin (and/or the underlying tissues) may or may not be compromised during static loading.

Static loading varies from low- to high-pressure loading. The amount of pressure loading is mainly determined by the ratio between the exerted force and the surface exposed to the loading (the distribution of force per square centimeter). The difference between low- and high-pressure static loading can be exemplified as the difference

between a stationary object of a certain weight passively resting on an extended surface of the skin (e.g., the back) (distribution of the exerted force over a larger area) and a stationary object with the same weight and a small surface being pressed against a small surface of the skin (concentration of the exerted force on a smaller area).

The risk of injuries to the skin and the underlying tissues, for example, bones or visceral organs, will be much higher in high-pressure loading than in low-pressure loading.

In case of low-pressure static loading, for example, in normal daily activities like holding the child, the loading caused by the holding of the child will not result in bruising or other skin injuries. However, this accounts only if there are no complicating factors added to the low-pressure loading, which decrease the capacity of the skin and the underlying tissues to absorb the transferred energy, for example, a coagulation disorder, other medical conditions, like vascular disorders or disorders of the connective tissue, or the use of medication, for example, corticosteroids and anticoagulants. Also prolonged exposure to low-pressure loading as sometimes can be seen in tight clothing may lead to superficial skin injuries, like bruises (if only compression takes places) and superficial abrasions (if there is some degree of friction between the tight clothing and the skin).

In case of high-pressure static loading, as can be seen in accidents (e.g., resulting from prolonged wedging in motor vehicle accidents) or in child abuse (e.g., in pinching, grabbing, or tying) (Sect. 3.2.5), it may result in more extensive bruising or other injuries of the skin or underlying tissues.

2.5.2 Dynamic Loading and Injuries

2.5.2.1 Defining Dynamic Loading

Dynamic (or rapid) loading can be divided in dynamic impulse and dynamic impact loading. Dynamic impulse loading is the result of rapid (often repetitive) movements without (external) impact (inertia effect), as can be seen in, for example, abusive head trauma due to shaking or

some abdominal injuries. Dynamic impulse loading has never been described as the cause of skin injuries in child abuse. If dynamic loading leads to skin injuries, these are always caused by dynamic impact loading: the application of an external force with a certain mass and velocity during a relatively short period of contact between the object and the skin/body.

An injury caused by dynamic loading is also referred to as a kinetic injury. A kinetic injury in impact loading is an injury caused by the exchange of energy during motion, leading to a transfer of energy during collision as long as the contact continues between the human body and the colliding object, for example, an object or (parts of) another human body (mechanical trauma). Kinetic energy is the energy contained in a moving object or body.

2.5.2.2 The Occurrence of Injuries in Dynamic Impact Loading

During a collision, the energy of a moving body/object (bodies/objects) is transferred. Whether an injury does occur in dynamic impact loading is mainly determined by the amount of kinetic energy, which is transferred during the collision plus the total contact area during the collision. The amount of the transferred kinetic energy (KE) can be calculated and is determined by the mass and velocity of the moving body/object: $KE = (\text{mass} \times \text{velocity}^2) / 2$. The formula shows that velocity is a more important determinant of the amount of kinetic energy than mass. If the velocity doubles, the kinetic energy quadruples. If the mass doubles, the kinetic energy doubles.

Depending on the difference in velocity between the colliding body and object, the effects of dynamic impact loading can be divided in low- and high-velocity impact loading or low- and high-velocity impact trauma. Although the defining of an injury, caused by blunt-force trauma, as a low- or high-velocity injury does suggest a clear dividing line between high- and low-velocity impact trauma, this is not true. There is a continuum in the effects of the impact velocity, in which injuries show more or less typical characteristics that fit to a high-velocity or a low-velocity impact trauma. The difference

between low- and high-velocity loading is best illustrated by comparing the effects of a bullet thrown at a person and hitting the person (low-velocity dynamic impact loading – not penetrating or even bouncing back) to the effects of a bullet fired at a person and hitting the person (high-velocity dynamic impact loading – penetrating). The risk of injuries to the skin and the underlying tissues, for example, bones or visceral organs, will be much lower when the bullet is thrown at the person than when the bullet is fired at the person, because during the collision with the fired bullet, much more kinetic energy is transferred than during the collision with the thrown bullet.

In case of low-velocity impact loading, for example, in normal daily activities, during play or sports or in short-distance falls, injuries may occur but will be less serious or extensive (because of the lower amount of transfer of kinetic energy) than in high-velocity impact loading. The loading in low-velocity impact does not exceed the capacity of the skin to absorb the energy as much as it does in high-velocity impact. However, this accounts only if there are no complicating factors added to the low-velocity loading that decrease the capacity of the skin and underlying tissues to absorb the transferred energy. These factors are the same as in static loading: medical conditions or the use of medication. More complicated injuries may also occur in short-distance falls, in which the child falls on an object (Wheeler and Shope 1997).

High-velocity impact loading may happen in accidents (e.g., resulting from pedestrian versus motor vehicle accidents or long-distance falls) or in child abuse (e.g., in hitting or kicking) (Sect. 3.2.5). The high-velocity loading of the skin during the collision may result in more extensive bruising or other more serious skin injuries than in low-velocity impact loading.

2.5.2.3 The Type of Injuries in Dynamic Impact Loading

What type of injury does occur depends not only on mass and velocity during collision but also on the specific characteristics of the collision, the impacting and the impacted object/body:

- Type of mechanical trauma
- Type of collision
- Angle of collision
- The amount of the absorbed and returned (=transferred) kinetic energy
- The type of object used as “weapon” and the impact site on the body
- The structures underneath the skin

2.5.2.4 Type of Mechanical Trauma

Dynamic impact loading of the skin is mainly caused by two types of mechanical trauma, namely, blunt-force trauma and sharp-force trauma. During blunt-force trauma, the energy, which is transferred during the collision between a blunt object and the body, is distributed over a relatively large body area. For that reason, the integrity of the surface of the skin will not be broken in most cases of blunt-force trauma, even if underlying structures, like vessels, are damaged. This damage will result in bruising.

In sharp-force trauma, the kinetic energy of the colliding object, for example, a more or less sharp object like a knife (sharp penetrating trauma) or a bullet (gunshot wounds), is concentrated on a small body area. This will lead to piercing of the skin and underlying structures, which can result in complete perforation of a body part, for example, an extremity, or the whole body.

Blast injuries are also the result of dynamic loading caused by extreme differences in pressure (the transfer of kinetic energy, resulting from the impact caused by a shock wave). This type of trauma is rare in childhood, except, for example, in case of war or terrorism. It has never been described in suspected child abuse and will therefore not be discussed in this book.

2.5.2.5 The Type of Collision

In dynamic impact loading, there are three possible types of collision:

- An object impacting a static body
- The body impacting a static object
- The body and the object both moving during the impact

During the collision, the energy of a moving body/object (bodies/objects) is transferred (see before). If the colliding objects are both moving

in the same direction, the transferred energy equals the KE of the fastest moving objects minus the KE of the slowest moving object (front to back collision). If both objects continue to move in the same direction after the collision, less energy will be transferred than in a situation in which the colliding object stops moving after the collision and the object that was hit “shoots away.”

If the objects are moving in an opposite direction, the kinetic energy of both moving objects will be combined (front to front collision, in which both objects/bodies may stop moving after the collision), leading to deformation of one object or both objects (= injury).

In general, collision while moving in the same direction will result in less serious injuries than collision while moving in opposite directions at the same speeds. In other words, the amount of transferred depends on the relative speed of objects compared to each other.

When a child is beaten and the child’s momentum is away from the blow (moving in the same direction before or during the collision), the difference in velocity between the colliding object and the child is less than when the child remains stationary or is leaning into the blow (moving object against static body or moving in opposite directions). If the child’s momentum is away, the duration of the contact (the moment of transfer of energy) between the object and the body is generally more protracted. This will lead to less severe injuries than when the child remains stationary or is leaning into the blow, in which more kinetic energy is transferred. However, if the child is falling away from the blow, this may lead to double impact, namely, first the impact of the object and second the impact against another object such as a table or a wall, in which case the overall severity of the injury increases.

2.5.2.6 The Angle of Collision

The angle between the object and the body during collision in blunt-force trauma will also influence the resulting type of injury. The angle of contact may vary from almost parallel to the skin surface (0°) to perpendicular (90°) in a collision between a moving and a static object.

The angle of contact during moving of the colliding objects/bodies may vary from almost zero to almost 180°: in other words, from an impact while moving in the same direction to a frontal collision while moving in the opposite direction and all impact angles in between. The angle may increase the type and degree of distortion of the skin (and underlying structures) and, because of the distortion, the chance of compromising the integrity of the skin, resulting in injuries varying from erythema and bruises in perpendicular loading without much distortion to abrasions, lacerations, and avulsions in tangential and distorting loading.

2.5.2.7 The Amount of Transferred Kinetic Energy

The degree of force used during the incident will determine the amount of energy that will be transferred upon contact with the skin. If the object used in, for example, beating, deforms or breaks upon impact, less energy will be exchanged between the object and the body and finally transferred on the body because part of the energy will be absorbed by the deformation or breaking of the object. Consequently, this will lead to a less severe and/or less extensive injury than when the object had remained intact.

2.5.2.8 The Type of Object Used as “Weapon” and the Impact Site on the Body

The severity of an injury decreases as the area of the contact surface increases. When a child is beaten with a flat object, for example, a shoe or slipper, the energy will spread over the entire surface of the impact area and as such will lead to less severe injuries than when a child is beaten with equal force but with a small object, for example, a cane.

If a child is beaten with a flat, rigid object, the damage caused by beating on a curved, relatively rigid body surface such as the head will be more serious than when the beating takes place on a flat, reasonably flexible surface such as the back. Because on the back the contact area between the object and the body is larger, the energy is spread

over a wider surface. When the beating is on the head, the energy will spread in such a manner that it will lead to deformation of the skull and to fractures at the point of maximal deformation. This may be the site of impact, but depending on the deformation, it can also be found in other sites on the skull.

If the object is rounded, the chance of rupturing the skin is less than if the object has a more or less angular form.

2.5.2.9 The Structures Underneath the Skin

Usually there will be no damage to internal organs or bony structures in abusive blunt-force trauma to the skin. The damage will be inflicted predominantly to the venules and capillaries in the dermis and hypodermis, while the epidermis and the underlying organs stay undamaged. However, skin lesions such as bruises and abrasions may be the first indications of damage to the underlying structures, such as intra-abdominal organs or bones (Johnson 1990).

Bruising of the abdominal wall may indicate trauma to intra-abdominal organs. However, in physically abused children with intra-abdominal injuries, bruising is absent in a considerable percentage of the children. Barnes et al. (2005) reported the absence of abdominal wall bruising in about 25%, while others report absence of bruises in as much as 80% or more of the children with abdominal trauma (Ledbetter et al. 1988; Bowkett and Kolbe 1998; Gaines et al. 2004). Bruising of the abdominal wall is also not necessarily instantly visible at the location of the impact. Traumatically extravasated blood can migrate through the surrounding connective tissues and only become visible after a number of days at a different location than the impact area, for example, bruising caused by blunt-force trauma to the upper abdomen may be visible after a number of days as a hematoma in the groin (Herr and Fallat 2006).

There is also a widespread misconception that the force required to cause traumatic fractures (either intentional or non-intentional) will generally also cause bruising. Others believe

that, according to the opposing premise, the absence of bruises would indicate that only minimal force was required to cause the bone to fracture and that the fracture should not be explained as a result of trauma but as the consequence of metabolic disease or osteogenesis imperfecta (Paterson 1987; Taitz 1991a, b). Mathew et al. (1998) and Starling et al. (2007) showed that bruising is seen in only a minority of fractures (<10–30%, excluding skull fractures) regardless of their etiology. According to Mathew et al. (1998), one cannot differentiate between abusive and non-abusive fractures based on the presence or absence of bruising. Cutaneous bruising is seen in less than 10% of the children with fractures immediately after the fracture occurred. When bruising arises, it becomes visible within 1 week in 30% of the cases (Mathew et al. 1998).

2.5.3 Telltale Injuries in Static or Dynamic Loading

Skin injuries, resulting from static or dynamic loading, may show a recognizable grouping or a specific shape. In that way, these injuries may suggest what happened (or what did not happen) and what caused the injury (or what did not cause the injury). These injuries are called telltale injuries, pattern injuries, shaped injuries, or mirror injuries. Telltale injuries may occur in accidental or non-accidental circumstances (Fig. 2.23). Recognition of a pattern injury without a clear history, however, may indicate that the injury was inflicted. Another example of a “telltale” in an injury in a young child is a pattern or shape and location of an injury that cannot be explained through play or normal interactions with other children or adults and therefore indicates that it was inflicted.

Through careful examination of a patterned injury, it is often possible to identify which object caused the injury, especially within the first 24 h. Sometimes, it will take longer to recognize the implement in question, for example, in bitemarks. For that reason, it is advised to photograph this



Fig. 2.23 Pattern injury in static (and dynamic impact) loading: extensive bruising on the trunk of an abused child (suggestive for gripping, punching, and prodding) (= Fig. 3.69)

kind of injury at regular time intervals, for example, every 6 h (see Chaps. 8 and 9).

2.5.3.1 Telltale Injuries in Static Loading

As stated before, in static loading, the skin and subcutaneous tissues, including the vessels (subcutaneous veins or capillaries), are damaged directly by the distorting (compressing, pulling, twisting) force at the site of the compression. This may lead, especially in high-pressure loading, to a recognizable pattern, caused by grouping of bruises (e.g., in fingertip bruising or in a grip mark) (Fig. 2.23) or recognizable compressive bruising, for example, in more complex “imprints” such as a car tire (accidental: pedestrian overrun by motor vehicle) or a shoe sole (accidental during a stampede; non-accidental when a perpetrator is standing on the victim).

2.5.3.2 Telltale Injuries in Dynamic Impact Loading

Skin injuries in dynamic loading result from impact with velocities, varying from low to high. High-velocity blunt-force trauma may lead to injuries with a pattern or imprint, especially if the impact is in a location with soft tissues and no bone underlying the skin (e.g., cheeks and thighs) and if the applied force is spread over a small area, for example, by using a small implement such as a stick or a cord. The object causing the

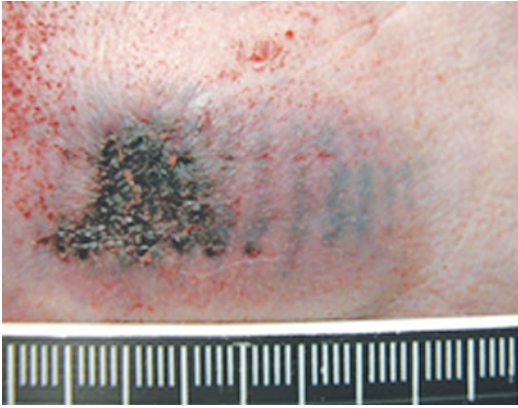


Fig. 2.24 Pattern injury in dynamic impact loading: repeating pattern in the injury – ca. 4 per 1 cm

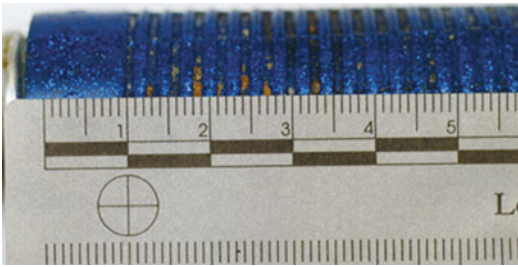


Fig. 2.25 The object, which probably caused the pattern in Fig. 2.24: repeating pattern in the object – ca. 4 per 1 cm – possible match



Fig. 2.26 An example of an object which resembles the object in Fig. 2.25: repeating pattern in the object – ca. 2.5 per 1 cm – no match

injury, mostly bruising, is mirrored by the pattern: a silhouette or outline of the implement on the skin (Figs. 2.24, 2.25, 2.26, and 2.27). The kinetic energy transferred on impact is absorbed mostly by the skin at the periphery of the object. The impact caused by the blow with the object will distort and crush the skin and underlying tissues

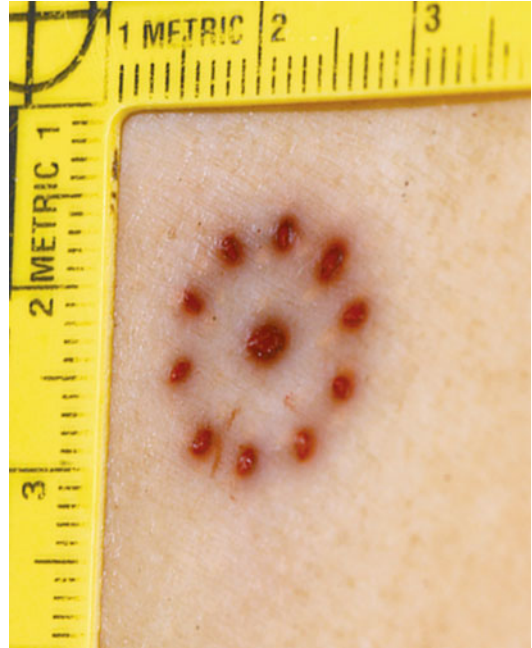


Fig. 2.27 Pattern injury, caused by a bone injection gun

and rupture subcutaneous vessels (venules and capillaries) in contact with the edges of the object. According to Williams (2003), whip injuries (caused by a rope, belt, or electrical cord) show a recognizable pattern injury with a uniform depth which follows the body curvatures, reflecting the object used. These injuries may be deeper at their distal end or at the body curvatures, because of the higher distortion and crushing of the skin and underlying tissues at these sites, sometimes leading to an abrasion or even laceration at these sites. These injuries may result in hypopigmented scarring. In an infant or a young child, an injury with the characteristics of a high-velocity impact trauma usually will be inflicted, although accidental circumstances cannot be excluded automatically.

It will be more difficult to recognize the pattern (or the object) if the high-velocity impact loading is spread over a broader area, for example, in slapping with an object, like a slipper, with flexible, broad, and flat surface.

Injuries caused by low-velocity impact loading usually do not show recognizable patterns or shapes. These injuries usually result from

accidents during daily activities, like collisions during play or short-distance falls. If present, these skin injuries are usually located at places where the skin is more at risk of diffuse “crushing” between the impacting object and underlying bone (e.g., knees, shins, or elbows). The resulting injuries may resemble the more diffuse injuries caused by static loading.

2.6 (Near) Contact with Physical Agents and Injuries

The transfer of energy during a direct contact or near contact of the skin with a physical agent (thermal, chemical, electrical, electromagnetical, and ionizing trauma) may lead to a nonmechanical trauma. Most important injuries caused by a non-mechanical trauma are burns (Table 2.5). Burns are not only caused by exposure of skin to heat but also by the effect of chemical or physical agents (acidic and alkaline chemicals, electricity, microwaves, and radiation), which may have a similar effect on the skin and the subcutaneous tissues as heat, or may create heat at the moment of contact with the skin (Panke and McLeod 1985; Richardson 1994; Pounder 2000). Besides external burns, internal burns may arise due to electrocution or swallowing and inhalation of chemicals.

2.6.1 Thermal Trauma

In a thermal skin trauma, the damage to cells is caused by the direct transfer of thermal energy

to the skin and/or the subcutaneous tissues, as a result of the exposure of tissue to high and low temperatures. The extent of the damage is determined both by the temperature and the duration of exposure. Thermal trauma may result from:

- Direct contact (transfer of energy by conduction) with a solid heat source (dry burns – Fig. 2.28), hot liquids, vapors, or gases (scalds or wet burns – Figs. 2.29 – 2.34), and open fires (cigarette burns, fire and flame burns – Figs. 2.35 – 2.40)
- Exposure of the skin and the subcutaneous tissues to the radiant heat of an object, for example, the close proximity to a radiant fire or electrical heater (Fig. 2.41)

Thermal trauma can also be caused by low or freezing temperatures (cold-related injuries) (Figs. 2.42 and 2.43).



Fig. 2.28 Dry contact burn: steam iron (= Fig. 8.10)

Table 2.5 Injuries caused by nonmechanical trauma

Thermal injuries	Heat: burns and scalds Cold: chilblains and frostbite (Sect. 6.5)
Chemical injuries	Burns Allergic reactions (topical and generalized) Generalized poisoning manifestations
Electrical injuries	Burns High- and low-voltage injuries
Radiation injuries	Burns



Fig. 2.29 Inflicted hot water burn



Fig. 2.30 Bullous impetigo in the differential diagnosis of hot water burns in the diaper area

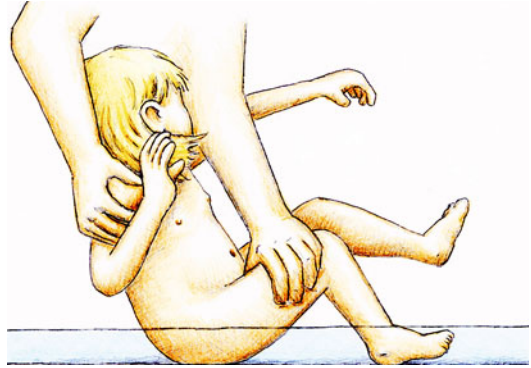


Fig. 2.31 Forced immersion in hot water (low level)

Friction burns do not occur because of heat transfer through direct contact or radiation but occur because of the development of high temperatures caused by the friction generated between the skin and a surface (generally with a normal temperature) over which the body moves (Fig. 2.44).

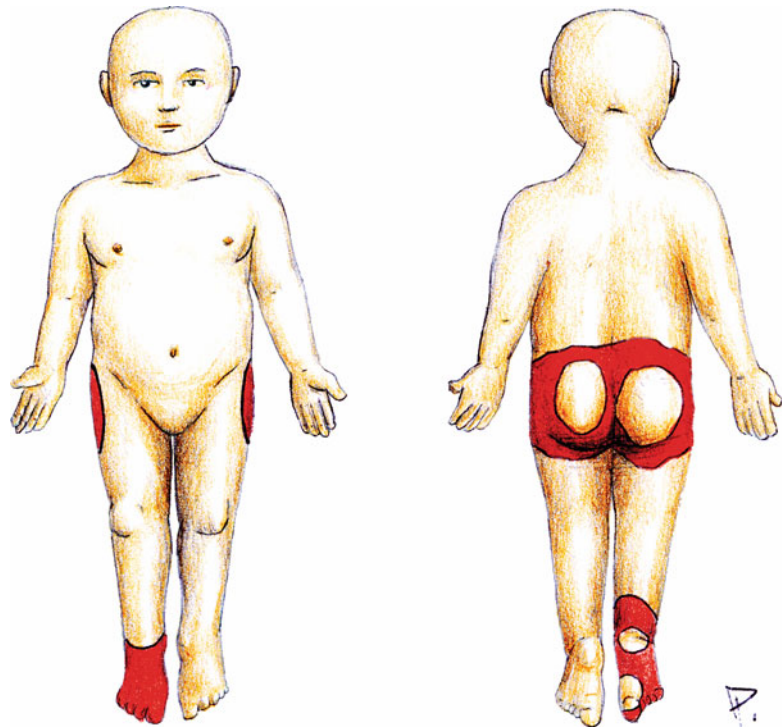


Fig. 2.32 Burn pattern due to immersion, as seen in Fig. 2.31: hole in the donut phenomenon on the buttocks

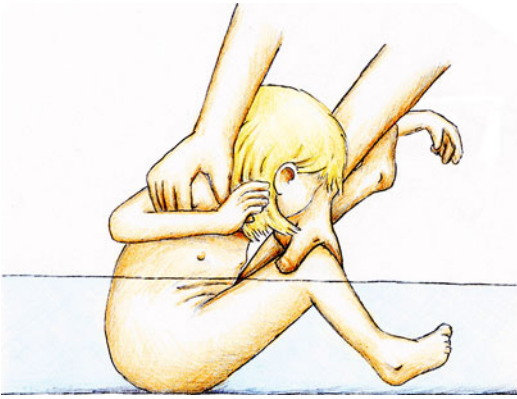


Fig. 2.33 Forced immersion in hot water (higher level)

2.6.2 Chemical Trauma

In chemical injuries, the damage to tissues is determined by many more variables than in thermal injuries, for example, the acidity and amount of the agent, the level to which the agent penetrates the skin, and the contact site and manner of contact. The harmful effect of the agent continues until the agent is neutralized by another chemical agent or is inactivated as a result of tissue reaction (Pounder 2000) (Figs. 2.45 – 2.50).

Fig. 2.34 Burn pattern due to immersion, as seen in Fig. 2.33: hole in the donut phenomenon on the buttocks and zebra distribution on the abdomen

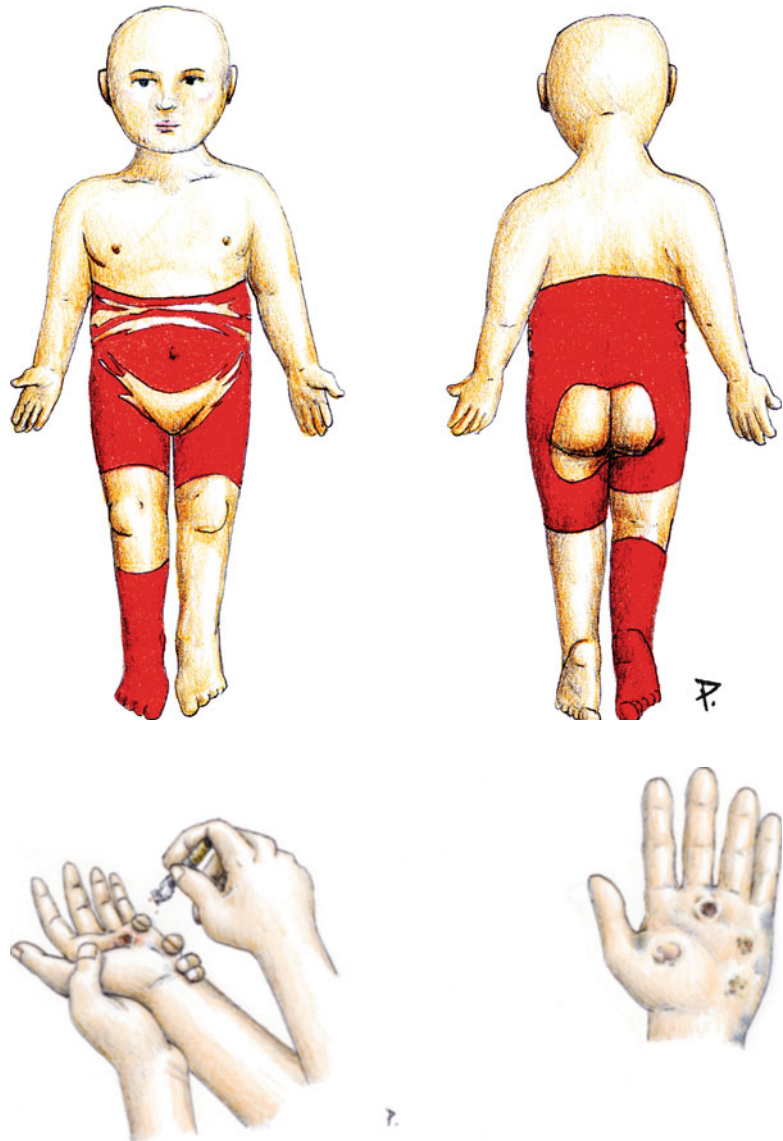


Fig. 2.35 Thermal trauma: cigarette burns



Fig. 2.36 Thermal trauma: cigarette burns



Fig. 2.38 Thermal trauma: cigarette burns, due to self-mutilation (= Fig. 1.1)



Fig. 2.39 Impetigo in the differential diagnosis of cigarette burns



Fig. 2.37 Same child as in Fig. 2.36: superficial cigarette burns

2.6.3 Electrical Trauma

Electrical injuries are caused by a combination of heat (leading to burns) and a direct effect of electricity (electrical forces) on polarized molecules in the skin, the subcutaneous tissues, and the organs. The extent of the damage generally depends on the amount of heat that is generated during the incident. According to Koumbourlis (2002) and Hettiarachy and Dziewulski (2004), voltage is a more important



Fig. 2.40 Depigmentation as a result of an inflicted burn



Fig. 2.41 Erythema ab igne on trunk (= Fig. 6.23)



Fig. 2.42 Chilblains (Sapp 2007 from Wikimedia Commons 2011: Wintertenen.jpg)



Fig. 2.43 Frostbite (Eli Duke 2010 from Wikimedia Commons 2011: Injuries at Antarctica – ouch!.jpg)

determinant in tissue damage than current. The pathway that the electrical current follows through the victim's body and the duration of the contact with the source of the current also play a role.

2.6.4 Other Nonmechanical Traumata

Radiation injuries are usually caused by the transfer of ionizing energy, for example, during the exposure to the ultraviolet (UV) spectrum in sunlight, resulting in sunburn. Sunlight, however, also may damage the skin by radiant heat (infrared). Radiation injuries may also occur from radiant energy from X-rays or radiation therapy for cancer treatment. Most victims with radiation injuries were seen in 1945 and the following years after the atomic bombs were dropped in Japan (Figs. 2.51 and 2.52).

Fig. 2.44 Friction blisters
(AndryFrench 2009: Friction
Blisters On Human Foot.jpg)



Fig. 2.45 Chemical burns caused by mustard gas
(US photographer 1918 from Wikimedia Commons
2011: MustardGasChemicalBurns.jpg)



Fig. 2.46 Chemical burns caused by mustard gas (1916–
1918 from Wikimedia Commons 2011: Mustard gas
burns.jpg)

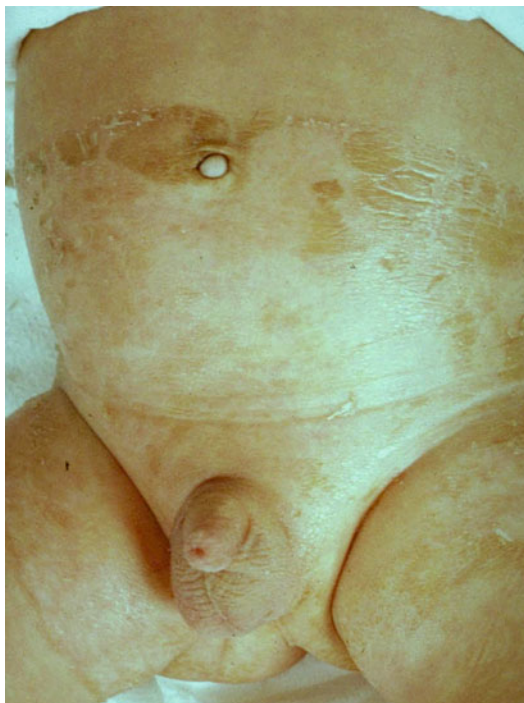


Fig. 2.47 Chemical trauma: bleaching agent



Fig. 2.49 Same patient as in Fig. 2.48: chemical trauma, due to self-mutilation – unknown substance



Fig. 2.48 Chemical trauma, due to self-mutilation – unknown substance



Fig. 2.50 Chemical burn, caused by exposure to a less than 10% sodium hydroxide solution (lye), 44 h after exposure (Blazius 2009 from Wikimedia Commons 2011: Sodium hydroxide solution burn.png)



Fig. 2.51 Radiation burns: victim of atomic bomb, Hiroshima, 1945



Fig. 2.52 Radiation injury: victim of atomic bomb, Hiroshima, 1945

2.7 Why and How: Physical Injuries in Child Abuse

2.7.1 Abusive Injuries

As stated in Chap. 1, the presence of injuries is not essential in establishing whether a child is a victim of physical abuse/physically aggressive behavior by parents or others. Trocmé et al. (2003) evaluated the data of 3,780 cases in which child maltreatment was substantiated and found that some type of physical injury was documented in 18%, mostly superficial injuries such as bruises, cuts, and abrasions. Trocmé concluded that the rates of physical injuries were lower than they expected. Nevertheless, other authors stated that at any given moment injuries can probably be found in up to 90% of victims of physical assault (Stephenson 1995; Nobuyasu 2001).

Maguire et al. (2005) did a comprehensive review of the medical literature on bruising in childhood related to suspicions of child abuse and found prevalence figures for child abuse-related bruising in 28% of abused school age children up to 98% in infants with suspected abuse. Maguire concluded that “bruising is common in children who are abused.” Most of the inflicted injuries will be superficial, externally visible, and include (Hobbs et al. 1999; Coulter 2000; Trocmé et al. 2003):

- Bruises, scratches, abrasions, and lacerations, caused by blunt-force trauma (Chaps. 3 and 7). Bruises are the most frequently observed injuries in child abuse.
- Baldness due to abusive hair pulling (Fig. 2.53) and subgaleal hematoma.
- Incisions and stab wounds, shot wounds, caused by sharp penetrating trauma.
- Burns and scalds from various causes and injury due to cold.

Other more severe inflicted injuries involve skeleton, central nervous system, and internal organs. These can be demonstrated by the use of supplementary investigations including:

- Imaging techniques (e.g., fractures, intracranial hemorrhages/injuries to the central nervous system, eye, intra-abdominal injuries)



Fig. 2.53 Trichotillomania as differential diagnosis of (abusive hair pulling)

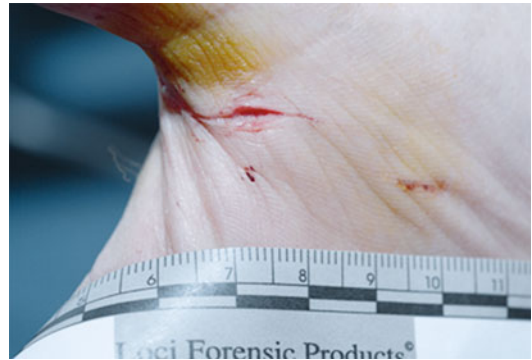


Fig. 2.54 Incised wound: self-defense injury on the palm between the thumb and index finger

- Laboratory investigation (e.g., intra-abdominal injuries)
- Fundoscopy (e.g., retinal hemorrhages, retinoschisis)
- Forensic light sources (e.g., old and new superficial and deeper subcutaneous injuries)

The severity of inflicted injuries varies from superficial injuries which cause pain and psychological harm to life threatening or fatal outcome. Trocmé et al. (2003) found that in only 4% of 3,780 substantiated cases of child abuse and neglect, the injuries were severe enough to require medical attention. McCurdy (1993) found that in 3.2% of children, the injuries were so serious that medical treatment or admission to hospital was required.

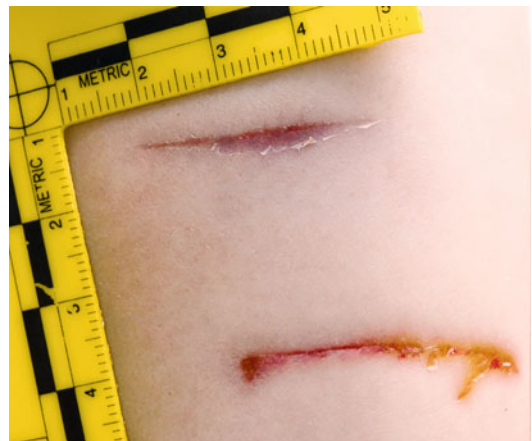


Fig. 2.55 Abrasion and superficial incised wound: self-defense injuries on the forearm

2.7.2 Self-Defense Injuries

Injuries and wounds resulting from self-defense against violence constitute a subcategory of non-accidental injuries (Figs. 2.54 and 2.55). This type of injuries is comparable in nature with those mentioned earlier but is sustained in a different manner. They are the result of an attempt by the child/person to defend himself/herself (often instinctively) in which he/she assumed a protective posture so as to sustain

minimal damage during the assault or to reduce the risk for severe injury. Consequently, the injury may initially not show any recognizable form or pattern. In such cases, it may be useful to have the child show the posture he/she had possibly assumed during the assault. Generally, this concerns a protective posture, for example, a raised arm in front of the face or assuming a fetal position. The form or pattern will be clear when the child assumes this position once again. In principle, the injuries that

may be sustained through self-defense can be all types of injury: bruises, abrasions, lacerations, incisions, stab and shot wounds, burns, and fractures.

2.7.3 Injuries Caused by Instrumental Violence

Instrumental violence is another subcategory of violent behavior against children. The violence is used as an “instrument” of behavior control and is goal directed. It occurs in the absence of emotional arousal and without provocation by the victim (Hodges 2007). It is premeditated and motive driven. The perpetrator has complete control over his/her actions and knows exactly why he or she is using violence. In child abuse, it is seen in situations in which power and pain are used to force the child to cooperate, for example, in child sexual abuse or in physically abusive education of children, comparable to the physically abusive training of military personnel. The violent behavior may cause injuries but is not motivated by the desire to cause physical harm per se. Injuries caused by instrumental violence are the same as injuries caused by other forms of physical abuse. The difference between instrumental violence and physical abuse is found in the motivation of the perpetrator: abuse of power in instrumental violence versus a variety of feelings, including powerlessness in physical abuse.

2.8 Assessment

2.8.1 “The Kipling Principle” in the Assessment of Child Abuse

Like ballistic tests and fingerprints, medical evidence is only as good as the physician who assembles it. Findings taken by hurried, inexperienced or indifferent doctors in busy clinics or hospital emergency rooms often turn out to be worthless... (Crewdson 1988)

A careful and detailed history, a comprehensive physical examination, and, if indicated, addi-

tional laboratory and radiological investigations are essential to differentiate between inflicted and accidental injuries. Experience has taught that in numerous cases, explanations for injuries in children are too readily accepted without any questioning by medical personnel. Sometimes, this is due to the acute nature and the severity of the injury that requires immediate treatment.

Sometimes, the medical assessment is the first step in the process by which physical abuse is recognized. It is usually essential to have the child examined medically at some stage. The examination should be conducted in a quiet, private, and child-friendly room, which is appropriately equipped. The room must be well lit (preferably daylight or artificial light resembling daylight). The examination itself requires a calm, unhurried approach. This is why it should not be planned, if possible, during a normal outpatient clinic or in a busy hospital emergency department. It is essential that there is sufficient time for detailed and thorough recording of findings (Hobbs et al. 1999).

Attention should be paid to interactions between the child and parents, and of both with health-care personnel during history taking and examination. Attention should also be paid to the way the parents interact with one another.

Establishing whether an injury can be explained based on the provided history is a specific task for forensically trained physicians. Physicians and other professionals are primarily trained to diagnose and treat injuries/abnormalities; however, they are not trained to explain how a certain injury may occur, how it could not have occurred, or how the injury could be explained in a different way. One should not expect professionals who have not been trained in forensic medicine/forensic pediatrics to be competent at this.

2.8.2 History

Taking a history is primarily aimed at obtaining clarity in the context of physical complaints/abnormalities and the findings during the physical examination. This means that in the first phase of contact with the child and the parents

(introduction, history, and physical examination), the physician, or other medical personnel, does not have to confront the parents with any inconsistencies in the history and hence with the suspected abuse. In case of ambiguity, questioning must continue in the interest of the child, the parents, and the treatment. Every plausible explanation must be considered to reconcile conflicting information.

At the start of the contact, the parents are usually given the benefit of any doubt, unless the situation is life threatening and involvement of the child protection service or the police may be indicated. Physicians and other medical personnel should treat the parents with respect, regardless of whether or not they are responsible for harming the child. However, acting in the best interest of the child is the paramount principle, and one cannot always act in the parent's best interest. If serious doubt remains, then the needs of the child should take precedence.

2.8.2.1 Special History

In fact, the history in suspected child abuse should be as comprehensive and detailed as the history for any other serious and complex pediatric condition (Thomas et al. 1991; AAP 2002; Hettler and Greenes 2003; Sibert 2004; Pierce et al. 2005; Kellogg 2007). There may be several starting points at the moment a child, either alone or together with his/her parents/care providers, presents to a physician. The reasons for which medical care is sought may have:

1. A direct relationship to (suspected) child abuse or lead to suspected child abuse, such as a child with subdural bleeding, retinal bleeding, encephalopathy, posterior rib fractures, and in whom an immediate suspicion of "inflicted traumatic brain injury" is justified.
2. No obvious relationship to child abuse. Concerns about child abuse arise while obtaining the history or examining the child. This could involve, for example, a child with an extensive hematoma, in whom a clotting disorder had been ruled out by laboratory investigation. It may also concern an unrelated finding, for example, a child with a dermatological disorder in whom scars of burns are found.

2.8.2.2 History of the Presenting Problem

As stipulated in the previous section, the reasons for seeking medical care should firstly be clarified. A careful and detailed description of the following aspects is essential if complaints or abnormalities that justify suspected child abuse are encountered:

- What abnormality (any finding at physical examination such as inherited or acquired abnormalities, accidental or non-accidental injury, or dermatological findings) is involved?
- What explanations are offered by the parents, guardians, or the child?
- When did the abnormality arise?
- Who was present when it happened?
- How did the child react?
- How did the parent(s) and other individuals present during the incident react?

It is important to repeat or to discuss the history with others for further clarification of the findings. The consequence of repeating may be that the history may either change completely or partially in some detail during discussion(s) with the parents (e.g., because their whole explanation, or details therein, was improbable or contradicted the explanations given by others), the child, and/or witnesses.

2.8.2.3 History Given by the Child

Children who have been abused are often unable to provide a reliable explanation for their injuries for various reasons. They may be too young, fearful for their lives or the consequences of telling the truth. They may be unable to accept that a trusted parent has harmed them in this way and may deny the abuse. Moreover, abused children frequently remain silent when they recover out of loyalty to or fear of the parents or perpetrator.

It is important to pay attention to the past history of the child and other members of the family. There may have been earlier injuries or "accidents," sometimes numerous, or admissions to hospital of the child or sibling. There may also be indications that violence had been directed toward other members of the family including a partner and other children.

A child that is raised in a violent home is at greater risk of experiencing severe forms of corporal punishment and intense verbal aggression from his or her parents than a child from a nonviolent home (Straus et al. 1980; Jouriles and LeCompte 1991; McCloskey et al. 1995). Studies show that children who are witnesses of intimate partner violence or live in homes where there is violence between adults are always emotionally abused and in addition are two to three times more likely to be physically abused than other children (McCloskey et al. 1995; Straus and Smith 2009). According to Appel and Holden (1998), the median co-occurrence rate between intimate partner violence and child physical abuse is about 40% (based on a large review). Other studies show a co-occurrence of intimate partner violence and child physical abuse or neglect in 30–60% of the cases (Edleson 1999; Herrenkohl et al. 2008; Casanueva et al. 2009). More than 90% of the mothers who were physically maltreated by their partners admitted that they used physical violence against their children, compared to 50% of the non-maltreated mothers (Moore and Pepler 1998).

Even if the child is not the direct target of the physical violence, the child will suffer as a witness of the aggression between his or her parents, which can be considered to be a severe form of psychological/emotional abuse or neglect (Henning et al. 1996; Osofsky 1998; Berry 2000; Levendosky and Graham-Bermann 2001). Witnessing domestic violence may have negative effects on the relationships between siblings and may even lead to violence between siblings after prolonged exposure to domestic violence (Moore et al. 1990). Furthermore, there may have been previous contacts with the child protection agency or the police due to domestic violence. Alcohol and/or drug abuse may also be a contributing factor to violence.

If the child immediately and spontaneously mentions how the injury occurred, there may be two explanations. Firstly, the child is telling the truth. Secondly, the child in rare situations may be coached and is telling a false history immediately and “spontaneously.”

When taking the history, contradictory explanations may be given. There may also be a conspicuous discrepancy between the explanations of the child and the parents, between the parents

themselves, and between the parents and a witness. Sometimes, no explanation is given because no witnesses were present. Explanations may constantly change. This may occur during further questioning regarding the explanation or when the history is taken on successive days. It may also be conspicuous when the child and the parents provide different explanations to different people.

The age and the developmental level of the child must be taken into account when evaluating the validity of the history. It may be that the explanation contradicts the developmental level of the child. The nature and/or the location of the injury may contradict the explanation given by the parents. It may well be that the explanation by the parents only partially explains the injuries. Finally, an explanation may be given whereby the child in question or one of the siblings is held responsible for the injuries.

2.8.2.4 History Given by the Parents

The contradiction between the severity of the injury and the degree of reaction by the parents may raise suspicions regarding maltreatment. A relatively minor injury may provoke an exaggerated reaction, or the reverse may occur, i.e., a totally inadequate (distant, indifferent) reaction is seen following serious injury. This may reflect on the parents’ poor resistance to stress. An abusive parent may react aggressively to questioning. The parent may threaten or actually withdraw the child from medical care as soon as child abuse is mentioned. Non-abusive parents are more likely to act in the best interests of the child.

The reaction of the parents with regard to suspected child abuse will vary from conscious denial to complete ignorance. Conscious denial of knowing what happened is probably the most prevalent reaction. Feelings of guilt and shame may also been seen because the parent knows that his/her behavior has resulted in harm to the child. In rare cases, the parent may be ignorant or unaware that his/her behavior caused harm to the child.

A physician must be aware when talking to the parents regarding the cause of an injury that generally parents will quickly realize that the physician doubts their explanation and suspects child abuse. This applies not only to abusive but also to non-abusive parents. It may lead to the adoption

of a defensive attitude by the parents at the start of or during the interview.

2.8.2.5 History Given by Others

Other persons (professionals or laypersons) involved in the case may give statements of what happened to the child or how the injury to the child occurred. If so, one should keep in mind that there are several possibilities about the reliability of the statement. The witness is telling the truth, or they may also have been coached by others involved in the case. However, with witnesses, there is also a third consideration, because the witness will react from his/her own norms and values. On the one hand, the witness may put his/her observations into perspective, whereas on the other hand, the observations may be exaggerated, because the witness wants to help the child or the parents. Finally, the witness may also act in his/her own interest by providing their own explanation for the injury.

2.8.2.6 Seeking Medical Care

One of the most conspicuous facts in the medical history of some cases is a delay or complete failure to seek medical care by the parents. Delay may vary from hours to days after the injury occurred. There are several explanations for this phenomenon, such as shame, incorrect evaluation of the situation, hope of spontaneous recovery, and hope that the injury is no longer recognizable as resulting from abuse.

Parents may consult other health-care providers in novel situations or as second or third opinion, when they think their pediatrician is suspecting child abuse (escape behavior), thus avoiding their usual general practitioner or pediatrician, without having to provide an acceptable explanation other than, for example, the urgency of the consultation. Care is often sought at an unusual hour, for example, in the evening, weekend, or outside normal working hours. This means that information on the child's medical care may be held by various physicians (e.g., general practitioners, pediatricians, surgeons, and others) and different departments (e.g., the departments of pediatrics and surgery, and the emergency rooms). Sometimes care for the child is sought by someone other than the parent(s), for example, the grandparents or a teacher.

2.8.2.7 Supplementary General History

The supplementary history is important in the evaluation of possible or probable medical causes of the actual complaints and physical findings. Moreover, it provides further insights into the manner in which the parents fulfill their parental tasks, the attitude of the parents toward the child and other children in the family, and the functioning of the family as a whole (Kellogg 2007):

- Pregnancy and birth – wanted/unwanted, planned/unplanned, prenatal care, peri- and postnatal complications, postpartum depression or other psychiatric disorder of mother or father, supervised or unsupervised delivery
- Growth and developmental disturbances influencing the personality and the temperament of the child
- Actual use of medication and drugs, prescribed and non-prescribed present and past
- Previous health-care contacts, both outpatient contacts and hospital admissions, trauma (accidental and non-accidental), congenital abnormalities, acute and chronic ailments, including allergies and metabolic disturbances
- Review of old notes and records
- Family history
- Clotting problems, bone abnormalities, and metabolic or genetic disorders
- Alcohol, drug, and medicine use in other family members
- Particulars of other siblings
- Earlier child abuse in other family members (children and adults)
- Parenting: care and control
- Mental health problems in parents including suicide and self-harm
- Social history

2.8.3 Physical Examination and Documentation of Findings

Considering the possible short- and long-term effects of child abuse, each case of suspected child abuse will demand a careful and thorough physical examination. Special attention should be paid to the age and the developmental level of the child, which may assist in differentiating between accidental and inflicted injuries. An example of the

importance of establishing the developmental level of the child is that bruises are rarely seen in children of less than 9 months or immobile children: “those who don’t cruise rarely bruise” (Chaps. 3 and 4) (Sugar et al. 1999).

Every inch of the body (from head to toe, including the anogenital area – Table 2.6) must be inspected, including locations where physical-abuse-related injuries would not be expected. Hobbs and Wynne (1990) showed that physical abuse may coexist with other abuse. Physically abused children are often also sexually abused and/or neglected (Hobbs and Wynne 1990). Their findings are confirmed by MacMillan et al. (1997)

and Finkelhor et al. (2005). Body parts without injuries and/or skin abnormalities must be recorded.

Sometimes, the child has older or historical injuries for which the parents are unable or unwilling to provide an adequate explanation. Such injuries may be identified from history or found at physical examination or at supplementary investigations, for example, imaging techniques.

Furthermore, during the examination, attention should not only be paid to the physical examination and description and recording of the physical findings (Table 2.7) but also to the behavior of the child and his/her parents.

Table 2.6 Complete physical examination

General impression	Functioning and physical condition of the child Level of care, signs of neglect Symmetry in movements, loss of function of body parts Sensitivity and any pain reactions during the examination
Vital functions and temperature	
Growth parameters and nutritional state	Height, weight, head circumference Mid-upper arm circumference
Development	Developmental history and assessment, including language and social skills
Emotional state and demeanor	How does the child present? How would the child’s emotional state be described?
Careful and structured inspection of all parts of the body – head to toe	
Skin	Erythema Bruises, petechiae, bitemarks (in case of bitemarks – DNA – see Chap. 8) Abrasions Lacerations Burns and scalds, cold-related injuries Incisions/stab wound, shot wound Pattern injuries Scars Tattoos Symptoms of skin disease (e.g., redness, scratch marks)
Head/neck	Scalp: e.g., swelling, bruising; traction alopecia Fontanel: level, fullness Face: e.g., bruising, petechiae, pattern injuries; symmetrical movements (smiling, crying) Nose: drainage of liquor or blood from the nostrils Neck: bruising, abrasions (nail imprints), ligature marks, or other signs of strangulation
Eyes	Periorbital bruising or petechiae Conjunctival (petechial) hemorrhage Retinal hemorrhage
Ears	Bruising of the pinna, retro-auricular bruising/mastoid bruising (Battle’s sign) Fluid or blood drainage Ear canals and drums (laceration, hemotympanum)

(continued)

Table 2.6 (continued)

Oropharynx	Injuries inside the mouth: inner surface of the lips and cheeks, the gums, tear of lip, or tongue frenulum
Thorax	Deformities of the thorax Rachitic rosary (rickets may be related to neglectful care) Flail chest (caused by blunt trauma; paradoxical or reverse motion of a chest-wall segment while breathing spontaneously)
Abdomen	Distension on inspection Bruising of the abdominal wall Tenderness during palpation Bowel activity
Female genitalia and anus	Hymenal damage or scarring Bruises, abrasions, fissures, burns/scalds, scars Female genital mutilation
Male genitalia and anus	Bruises, abrasions, fissures, burns/scalds, scars
Back	Deformities Tenderness and bruises
Buttocks	Bruises, burns/scalds, scars Pattern injuries (e.g., tramline or vertical gluteal cleft injuries)
Extremities	Bruises on the inner sides of arms and legs Fractures (callus), luxations, deformities Symmetry in movements/loss of function
Neurological examination	

When child abuse is suspected, physical examination is usually supplemented with extensive laboratory investigations and imaging techniques. However, this is not always necessary, and children should not have to go through unnecessary medical investigations, when the cause of the injuries is obvious. For example, in case of extensive pattern bruises, one might consider a comprehensive coagulation screening for completeness sake or to avoid discussions about coagulation disorders, but this is in almost all cases unnecessary because the pattern tells the story of physical abuse (see also Chaps. 3 and 5).

Certain aspects are seen more frequently in inflicted than in accidental injuries and should arouse suspicion during the examination:

- Multiple injuries of different ages and in various stages of healing
- Injuries in different areas of the body (front – back, left – right)
- Injuries with a clearly recognizable pattern (pattern injuries), for example, handprint, iron burn, implement shape
- Self-defense injuries (Sect. 2.7.2)

- Injuries in protected sites (e.g., neck, pubis, perianal area) which are normally or only rarely injured in an accident

In Table 2.7 an overview of the aspects that must be recorded in the description (and the evaluation) of the injuries/skin abnormalities is given. Every injury and all other findings, including skin abnormalities, should be recorded and described correctly (Table 2.7).

2.8.4 Supplementary Investigations

The reader is referred to the relevant chapters for details of the various supplementary investigations in various types of injuries. Here, only supplementary radiodiagnostics are dealt with. A complete skeletal survey according to the guidelines of either the “American College of Radiology” or the “Royal College of Radiologists and the Royal College of Paediatrics and Child Health” must be compiled for every child <2 years old in whom child physical abuse is suspected, and in case of other serious external or internal

Table 2.7 Description of physical findings

1.	Nature	Traumatic: Mechanical (static or dynamic loading) (Sect. 2.5) (Near) contact with physical agents (Sect. 2.6) Artificial (e.g., scars or tattoos) Dermatological disease
2.	Shape	Flat lesions: Pattern injuries Recognizable pattern for a dermatological disorder Non-flat lesions: Particularly important in sexually transmitted diseases
3.	Number	
4.	Size	Always in centimeters – never in symbols Measurement: vertical, horizontal/vertical x horizontal
5.	Site	Anatomically correct Left/right From fixed anatomical orientation points, preferably in relation to the skeleton Distribution of the injuries over the body Use body plans
6.	Border	Well demarcated Less well demarcated Varyingly demarcated
7.	Color	Generally only indicative because the description of the color of an abnormality is subjective Always use a standard color scale for photographs

Table 2.8 The standard child protection skeletal survey for suspected non-accidental injury

Skull	AP, lateral, and Towne's views (the latter if clinically indicated) Skull radiographs should be taken with the skeletal survey even if a CT scan has been or will be performed
Chest	AP including the clavicles Oblique views of both sides of the chest to show the ribs ("left and right oblique")
Abdomen	AP including the pelvis and the hips
Spine	Lateral (this may require separate views of the cervical, thoracic, and thoracolumbar regions) If the whole spine is not clearly visible on the AP view of the chest and abdominal radiographs, then additional views will be required AP views of the cervical spine are rarely diagnostic at this age and should only be made at the discretion of the radiologist
Limbs	AP of both upper arms AP of both forearms AP of both femurs AP of both lower legs PA of hands AP of feet

RCR and RCPCH (2008)

AP anteroposterior, PA posteroanterior

injuries in children >2 years old (American College of Radiology 2006; Royal College of Radiologists, Royal College of Paediatrics and Child Health 2008). The complete guidelines are

available for downloading without cost. The guidelines of the "Royal College of Radiologists and the Royal College of Paediatrics and Child Health" are given in Table 2.8.

Fig. 2.56 Who did it:
dynamic impact loading!



2.9 Who Did It?

The question of who was responsible for the occurrence of the injury can rarely be answered based solely on the injuries found in a child. It is not the task of the examining forensic doctor to prove who did it. Finding and proving who did it is the task of behavioral analysts, the police, and the court (Fig. 2.56).

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Cutaneous Manifestations of Child Abuse and Their
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Blunt Force Trauma

Bilo, R.A.C.; Oranje, A.P.; Shwayder, T.; Hobbs, C.J.

2013, XV, 264 p., Hardcover

ISBN: 978-3-642-29286-6