Cigarette burns in forensic medicine

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Dedicated to Prof. P. Saukko on the occasion of his 60th birthday.

Abstract

Skin lesions suspected to have been caused by a burning cigarette require thorough diagnostic evaluation as to the mode of infliction. Accidental cigarette burns must be differentiated from injuries due to self-infliction or maltreatment. The typical categories are presented on the basis of the literature and exemplary cases from the authors’ own study material. An intentional infliction must be taken into consideration when a body region is involved which does not normally come into contact with a cigarette by chance. Full thickness burns from glowing cigarettes require an exposure time of more than 1 s. One should also keep in mind the possibility of confusion with local skin infections or thermal effects by traditional medical practices (e.g. moxibustion). In unclear cases, repeated inspection of the lesion is recommended in order to facilitate its classification as to causation and age. The courses of healing in first- to third-degree cigarette burns are demonstrated by means of continuous photographic documentation. The discussion deals with different kinds of accidental and intentional cigarette burns, e.g. in drug addicts, psychiatric patients, victims of child abuse, maltreatment and torture, but also in persons feigning a criminal offence.

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1. Introduction

In forensic practice, cigarette burns are seen in many contexts and with different relevance. It is particularly important to identify those cases in which the lesions were either inflicted as a special form of maltreatment or with the intention to simulate a criminal assault. When the persons involved are not able or not willing to give a plausible explanation as to the origin and time of the injury, the diagnosis has to be established on the basis of the morphological criteria.

Pounder [1] gives a brief overview of the fundamental aspects of cigarette burns: “Burns from cigarettes are of the expected size, round and punched out. To produce cigarette burns requires firm contact for some seconds and cannot occur simply as the result of an accidental dropping of a cigarette, or brushing against one. A cigarette burn implies deliberate infliction, more obviously so when multiple burns are present. They may be seen in victims of child abuse, torture in custody, inter-prisoner violence, self-harm in individuals with low self-esteem and personality disorders. Whether fresh injuries or old scars, cigarette burns seen at autopsy always raise serious concerns which demand further investigation.” It goes without saying that this applies to clinical forensic medicine as well.

2. Fundamentals

2.1. Physical and pathophysiological requirements of burns

For a better understanding of cigarette burns it seems reasonable to outline the basics of thermal damage to the skin first.

The degree of a local heat damage depends on the contact temperature, the duration of exposure [2] and the affected skin region [3]. In contact burns, further parameters of burn severity are whether they are caused by a metallic or non-metallic hot object and moist or dry heat, which is apparent from the coefficient of thermal conductivity. Dry heat requires an
essentially longer exposure time than moist heat to cause a burn of comparable intensity at the same temperature [4].

Experimental animal studies conducted by Price et al. [5] already demonstrated that skin and subcutaneous tissue are extraordinarily effective heat insulators. Even the hot jet flame in a gasoline-oxygen explosion (temperature about 3000 °C) brings about only a moderate increase in skin temperature due to the very short exposure time of approximately 0.5 s (47.5 °C at a depth of 1 mm and 42 °C at a depth of 1.5 mm). In such flash burns, the surface of the corneal layer may be charred without any major temperature increase in the basal layer of the epidermis. An effect of 100 °C for 0.1 s does not yet cause an increase in temperature at the dermis/fat interface [6]. The critical temperature for clinically relevant tissue damage ranges between 50 and 55 °C [4,7]. The epidermis of an adult on the palms and soles is about 1 mm thick compared with an average thickness of 50 μm and a maximum thickness of 200 μm in the other body regions [8]. The thickness of the dermis varies between 400 μm and more than 2000 μm [9].

Depending on the body region and the ambient temperature, the skin temperature ranges between 16 and 38 °C. In the superficial layers of the epidermis, heat is mainly transferred by conduction, whereas in the deeper tissue layers convective transport with the blood stream predominates. The heat capacity of the epidermis is greater than that of the dermis and the subcutaneous fat. The thermal conductivity is lower in the epidermis than in the corium and subcutaneous tissue. As a consequence, heat saturation in the epidermal layer precedes the slightly delayed heat transfer to the dermis [10].

2.2. Reflex time

The warm receptors of the skin have a maximal rate of discharge around 40 °C [11]. With temperatures above 45 °C, the sensation of heat in the skin is mediated jointly by both pain and paradoxical cold impulses [12]. Heat pain causes two kinds of sensation: a fast pricking pain and a slow burning pain. The difference in quality between these will be known to anyone who has inadvertently stepped into an excessively hot bath. The initial response is to withdraw the affected foot quickly, but an intense pain slowly develops which is also slow to subside. The A-delta nerve fibres of the cold receptors and the fast pricking pain nerves have a conduction velocity of 5–30 ms⁻¹, the slow burning pain is relayed by C-fibres with a conduction velocity of 0.5–2.0 ms⁻¹. The fast pricking pain triggers the reflex withdrawal of the affected body region from the source of injury. In the efferent alpha-motoneurons of the protective reflexes the conduction velocity amounts to 70–120 ms⁻¹ [11]. Provided that mobility is not impaired, the intense pain stimulus caused by heat thus results in powerful withdrawal of the exposed body part in a fraction of a second.

2.3. Burn severity

Cigarette burns show the same characteristics as larger burns on a smaller scale. The nomenclature used in the following is therefore based on the common classification of burns into three degrees [3,4,13]:

1. First degree: Superficial burn similar to a sunburn. The skin is erythematous due to vasodilation, painful for 2–3–4 days and may show local oedema. It heals in 5–10 days without scarring. Sometimes hyperpigmentation is seen, which fades within months.
2. Second degree: Partial thickness burn (of the epidermis and the outer layer of the dermis). Very painful erythema with blister formation. If the blister bursts, the wound may become infected. The injury heals slowly within 2–3 weeks with pigmentation, but no scarring.
3. Third degree: Full thickness burn (of the epidermis and the dermis). Lesions show either blister formation or a dry, pale or brownish leathery appearance without blisters due to heat coagulation of the tissue. The fresh injury is anaesthetic. Painful, itching sensations occur only as the wound heals. The initial formation of a brown eschar is followed by progressive scarring. Healing of the lesion takes 6–8 weeks or sometimes even months, if the wound becomes infected [1].

3. Clinical course of healing

When evaluating lesions in living persons, repeated inspection may be advisable if the circumstances are unclear. For a better understanding of the healing process in cigarette burns the findings in the three cases described below have been observed continuously over a long period of time.

3.1. Case 1

A 72-year-old, right-handed, alcohol- and nicotine-dependant male with episodes of paranoia had inflicted a total of 31 cigarette burns on the extensor sides of his own forearms falsely claiming to have suffered them during an assault. The first forensic examination was performed 16 h after the incident and the healing process could be documented over 4 months (Fig. 1).

Fig. 1: Left forearm with 17 s- to third-degree burns 10–13 mm in diameter.
16 h, Fig. 1(a): Fluid-filled burn blisters with 2 mm wide hyperaemic rim; where a blister burst, its base is moist, shining and honey-coloured.
36 h, Fig. 1(b): Intact blisters unchanged, exposed dermis parched yellowish-brown, no inflammatory reaction.
1 week, Fig. 1(c): Loss of the blister surface, shallow wound craters with brownish scab and intense inflammatory reaction at the periphery. The injured person had treated the burns with salt water and spirits for disinfection.
2 weeks, Fig. 1(d): Incipient granulation tissue with radial tension wrinkles. Brownish dermis. Whitish residues of medical treatment with an
ointment. Inflammatory marginal zone. Meanwhile fever and chills had occurred.

3 weeks, Fig. 1(e): Progressive granulation from the wound periphery inward, marked radial structure of the newly formed epidermis, yellowish dried secretion in the wound centres, strong inflammatory peripheral redness.

4 weeks: Lesions almost completely covered by reddish granulation tissue growing from the periphery towards the centre with a residual ulcer.

6 weeks: Completely epithelialized burns with silvery surface surrounded by a brownish rim. Inflammatory reaction has subsided.

8 weeks, Fig. 1(f): Brownish foci with a silvery sheen on the surface. This finding remained constant until the end of the observation period (week 16).

3.2. Case 2

A 50-year-old woman intentionally inflicted three cigarette burns on her left arm in order to attract attention. The healing process was documented from 1 h to 4 months after the incident. The injuries were not treated with any therapeutic substances (Fig. 2).

Fig. 2: Flexor side of the left forearm with three lesions after contact with a burning cigarette (brushing against it or slight contact for several seconds). Retrospectively, the changes could be classi-
fied as first-, second- and third-degree burns.

1 h, Fig. 2(a): Where the cigarette brushed against the skin, a reddish, comma-like stripe a few millimetres in length is discernible. The two other lesions demonstrate a whitish, dry centre with a reddish margin. No blister formation yet. The centre of the third-degree burn is anaesthetic.

19 h, Fig. 2(b): The brushing lesion shows minor concomitant reddening. The second-degree burn shows significant and the third-degree burn minor formation of blisters, each with a narrow red rim.

3 days, Fig. 2(c): The blister formation is equally intense in the second- and third-degree burn.

4 days, Fig. 2(d): The blister cover of the second-degree burn begins to parch. From the third-degree burn the blister surface was removed; a crater-like, honey-coloured, dry base is discernible with the red rim being more pronounced than with the second-degree burn.

5–7 days, Fig. 2(e): Progressive drying of the blister cover and formation of brownish-yellow eschar on the blister base.

13–15 days, Fig. 2(f): The blister cover is completely adhering to the lesion’s base. It has a radial structure and shows punctiform eschar formation at the centre. In the third-degree burn, a dark-brown, hard, firmly adhering eschar has formed. Both skin lesions are surrounded by a narrow scurfy rim. The first-degree burn has healed apart from a minor brownish residue.

22 days, Fig. 2(g): The crust of the third-degree burn has come off. At the centre of the second-degree burn, punctiform eschar is still discernible encircled by a light brown rim.

4 weeks, Fig. 2(h): Both burn lesions show central punctiform residual scabs.

5 weeks, Fig. 2(i): On the second-degree burn, where the blister surface had not been removed, there is still a crust in the centre, whereas on the third-degree burn it has already come off.

6 weeks, Fig. 2(j): The first-degree burn from the brushing contact is no longer discernible. The second- and the third-degree burns are covered by a thin, radially structured layer of skin with a silvery sheen surrounded by a brownish rim.

4 months, Fig. 2(k): The second-degree burn has healed into a round patch with brownish pigmentation and inconspicuous skin structure. Of the third-degree burn a round,
brownish-white scar with a diameter of 7 mm remained, which turned completely white after a few months.

3.3. Case 3

An 18-year-old adolescent suffered a second-degree burn on the left side of the neck when accidentally brushing against a burning cigarette in a crowded discotheque. The injury healed without scarring (Fig. 3).

Fig. 3: Left side of the neck with burn lesion.
2 days, Fig. 3(a): Roughly triangular, irregular injury, 7 mm × 11 mm in size. The residual blister cover is still discernible (on the right). The base shows honey-coloured dried secretion; the wound surroundings are slightly reddened due to inflammation.
3 days, Fig. 3(b): The lesion shows minor parching at the edges surrounded by a red rim.
4 days, Fig. 3(c): The size of the skin lesion has decreased to 4 mm × 9 mm.
16 days, Fig. 3(d): Largely healed injury with recently removed residual eschar.

4. Discussion

4.1. Categories of infliction

In deceased or living individuals assigned for forensic examination the question has to be answered whether injuries were self-inflicted or caused by another person and if the infliction was accidental or intentional. Specifically for cigarette burns, the following categories can be distinguished:

4.1.1. Accidentally caused by another person

Case 3, in which a lighted cigarette was accidentally touched in a crowd, is an example for this injury mode. This type of infliction is more often seen in children when they stay near a smoking adult and are inadvertently touched with the burning tip of a cigarette. If this happens, the injury will be located in a body region, which was not covered by clothing (e.g. face, neck, hands). Burns of this type are superficial, irregular in shape as from a brushing contact with redness, swelling and possibly blister formation. As the exposure to the hot object is very short and the affected limb is quickly withdrawn because of the immediate pain reflex, no third-degree burn occurs [13,14].

4.1.2. Accidental self-infliction

Smokers may accidentally cause up to third-degree cigarette burns on themselves when they are in a reduced state of consciousness or pain sensation due to intoxication. For example drug addicts, who are usually also tobacco consumers, often show burns on their fingers (Fig. 4) [15,16] or on other parts of their body and the respective clothing, if they rest their hand holding the glowing cigarette in contact with the skin. Grose [17] reported on a patient who suffered a cigarette burn after intravenous sedation and tumescent anaesthesia for liposuction, when he fell asleep while smoking and the cigarette dropped onto the still anaesthetized thigh causing a third-degree burn.

4.1.3. Caused by another person with the intention of maltreatment or torture

Of special importance are offences against the freedom from bodily harm in which cigarette burns are inflicted with the intention of maltreatment, e.g. in child abuse [2,13,18], rape (e.g. [19]), torture [2,20,21] and inter-prisoner violence [1].
Such burns are mostly located in body regions typical of abuse, e.g., on the back and the palms of the hands \cite{18,20,22}, the soles \cite{23}, the genitals \cite{22,24}, the neck, shoulders, back and buttocks \cite{13,18,25}, but also the forehead \cite{26} or the chest \cite{22}. Burns located in body regions usually clothed, protected or inaccessible are especially suggestive of abuse \cite{27}.

Typical deliberately inflicted cigarette burns are sharply defined, as is known from the contact with other hot objects \cite{13,26,28–30}. A multitude of cigarette burns \cite{13} and an arrangement in a geometric pattern, e.g., a line or rosette \cite{24,26}, are particularly suspect.

4.1.5. Intentional self-infliction for the purpose of simulating a criminal offence

Intentionally self-inflicted cigarette burns are sometimes difficult to diagnose, if they were induced to simulate a criminal offence; they may resemble abusive injuries (Case 1) \cite{35,36}. The psychosocial personality features and the current living situation as well as inconsistencies between the reported story and the actual findings may help to clarify what really happened.

4.1.6. Infliction by another person based on mutual consent

Finally, one also has to bear in mind that cigarette burns may be inflicted by another person by mutual agreement, for example in so-called tests of courage and in gang initiation rites \cite{37}.

4.2. Temperature and duration of exposure

While dragging on a cigarette, the burning tip can reach a temperature of 600–900 °C. In the stationary burning zone insulated by the ash, the temperature is about 400 °C and rapidly drops below 100 °C further away from the tip \cite{38}. Consequently, when touching the glowing cigarette contact temperatures of 400 °C or less have to be expected. If the tip is covered by an insulating ash coat upon contact, the temperature is accordingly lower. This explains why in a short brushing contact, in which the amount of heat transferred is relatively small and the heat is rapidly dissipated, no third-degree burn with subsequent scarring will occur.

The duration of exposure necessary to produce a third-degree cigarette burn is significantly longer than the reflex time for removing the limb after accidentally brushing against the glowing tip. It can therefore be assumed that a cigarette burn with subsequent scar formation in a person who was not unconscious or otherwise impaired at the time of sustaining the injury indicates deliberate infliction with an exposure time of more than 1 s \cite{39}.

4.3. Morphology of cigarette burns

Contact with the glowing tip of a cigarette may occur by brushing against it (Case 2 and Case 3), holding it tightly against the skin (Case 1 and Case 2) or stubbing it out (Fig. 5). A brushing contact causes an inhomogenous, oval or wedge-shaped and poorly defined lesion \cite{18,24}. Firm contact produces a third-degree burn lesion 5–10 mm across \cite{22} resulting in a small circular or oval, depigmented scar with a pigmented rim \cite{40}. A burn injury or a scar with an irregular rim is found when the cigarette was stubbed out on the skin (Fig. 5) and/or when inflammatory reactions and wound manipulations changed the lesion’s initial shape (Case 1).

Characteristic pathognomonic details are observed in the healing process, if the burn was caused by a contact lasting more than 1 s and if it was allowed to heal without intervention (Case 2). These are:
- A round or oval lesion about 5–10 mm across with a moist or dryly coagulated base sometimes covered by a blister (Fig. 2).
- In a third-degree burn, blister formation occurs later than in the second-degree burn (Fig. 2(b)).
- After the blister has burst, a firm brown eschar forms (cf. Fig. 2(f)), which is displaced by granulation tissue growing from the periphery towards the centre explaining a prolonged presence of punctiform eschar in the centre (cf. Fig. 2(g)).
- After healing, a silvery scar resembling tissue paper with radial wrinkling remains (Fig. 2(j)).
- The scar is initially surrounded by a brownish rim (Fig. 2(j, k)).
- The healing process is lengthy and takes several weeks.

4.4. Differential diagnosis

It goes without saying that in cases in which a cigarette burn is suspected it is important to exclude other possible causes in order to avoid a wrong diagnosis which may lead to an unjustified accusation for abuse [27].

Singular lesions in blister-forming pyoderma, especially in children (impetigo contagiosa sive bullosa, bullous impetigo), show typical flaccid vesicles on a reddened skin filled with initially clear, later purulent fluid. The subcorneal impetigo vesicles rupture easily evolving into honey-coloured crusts. Healing occurs without scar formation and may be associated with hyperpigmentation. As this is a contagious skin infection, it may be useful to ask for the possible infection source among the child’s contacts [13,25,41]. Impetigo lesions heal promptly after administration of antibiotics and can thus be distinguished from cigarette burns.

Other singular lesions of focal pyoderma (furunculosis, small abscesses [40], acne vulgaris, prurigo chronica, ecthyma and insect bites) may occasionally resemble cigarette burns (Fig. 6) (e.g. [20]) just as sharply punched-out erosions accompanying “ammoniacal” diaper rash [13] and inflamed injection marks healing with scar formation in drug consumers using non-sterile needles.

Chicken pox heal without scars or, after secondary bacterial infection, with small, hypopigmented or hyperpigmented, depressed or hypertrophic foci, which are mostly located on the trunk and in the face [42]. Chicken pox should always be included in differential diagnostic considerations [27]; the same applies to lesions due to urticaria or acute dermatitis [14].

Scars from cigarette burns may resemble the scars produced by small pox vaccination. Vaccination scars are typically located on the outside of the upper arm, the forearm, thigh or buttock [20]. The normal vaccination reaction begins on day 3–4 with the formation of a slowly increasing papule. After about 5–6 days, a grey vesicle develops in the centre, which changes to a pea-sized, flat, yellow pustule with a central depression. Simultaneously, the initially narrow red areola becomes wide and elevated. The peak is reached between day 8 and 11. The pustule dries up from the depression forming a brown scab, which falls off 3–4 weeks after vaccination leaving a vague, whitish scar. Between day 6 and 11 fever usually occurs with moderate impairment of the general well being and swelling of the axillary lymph nodes [43].

Apart from skin infections, round electric marks may also resemble cigarette burns [20,44]. In unclear cases, it is therefore particularly important to include the general circumstances of the person’s life into one’s considerations.

Moreover, cigarette burns must be differentiated from burns produced in connection with folk remedies or alternative healing practices such as moxibustion in traditional Chinese medicine (Fig. 7) [20,45]. It should also be taken into account that in Japan moxibustion was used as punishment for children in the past [46] and that branding of children with a hot metal object was common in India as a remedy [47]. In most of these cases, multiple singular lesions are arranged in a conspicuously regular geometric pattern on the back. Peltier et al. [13] rightly pointed out that even if the cause of injury is determined to be a folk remedy, investigators should exercise caution and carefully evaluate all circumstances surrounding the incident.

In post-mortem examinations, roundish abrasions may be misinterpreted as cigarette burns by an inexperienced physician, if the lesions assumed a brownish leathery appearance due to local drying of the unprotected dermis [15]. This is especially true for skin areas overlying bony prominences such as the spinous processes of the vertebral column.

4.5. Medicolegal evaluation and forensic implications

Persons accused of having physically abused dependents often give a false account of the injury’s origin or they deny that it has been inflicted deliberately by claiming that the contact with the cigarette was accidental or was brought about by hot ash dropping from the tip. If the victims are unable or too frightened to give a plausible report of the incident (e.g. children, mentally handicapped persons, individuals in need of care, foreigners with language problems), the origin and time of the incident have to be determined on the basis of the morphological findings [26].

An accidental dropping of a cigarette on to a child or a child brushing against a lighted cigarette will cause only a very slight superficial burn because of the short duration of exposure and the...
minor intensity of the contact [13,39]. Consequently, an only glancing contact with a lighted cigarette is not sufficient to produce a third-degree burn, as the glowing tip is insulated by a coat of ash [38] and its temperature decreases on firm contact with the skin due to smothering and cooling. Moreover, the penetration of heat is drastically reduced in the deeper skin layers [4,5]. Last but not least, the pain reflex in a victim capable to act would induce a powerful immediate withdrawal of the affected body region before a full thickness burn occurs [13,14].

For comparison, measurements obtained from running over charcoal embers, which have a temperature of 120–450 °C, showed that even short-term peak temperatures of 200 °C at the stratum corneum of the plantar surface do not cause burns if exposure lasted between 0.25 and 0.8 s. Only if the heat effect continued for more than a second, did a burning pain and in some cases burn blisters occur, provided that the arch of the foot, which is not covered by a thick layer of calloused skin, came into contact with the coal or if there were hot metal parts in it. At a lower skin temperature (cold feet) a longer exposure time was possible [48].

The intensity and depth of the skin burn correlates with the duration of exposure. Causing a cigarette burn with consecutive scar formation is an act, which requires the glowing end of the cigarette being held in firm contact with the skin for 2–3 s [39,49] or several seconds [50]. Scars from cigarette burns can thus be of important evidence, if victims of torture consistently describe their infliction [50]. If maltreatment of dependents, especially of children, is suspected, then full thickness cigarette burns prove an intentional infliction and indicate physical abuse [49]. They should give rise to further investigations looking for other traces of (previous or present) bodily harm [13,51]. On the other hand, one has to be aware of the possibility that cigarette burns may also have been self-inflicted for different reasons. With regard to the sequelae of the injury, it has to be taken into account that first- and second-degree burns with reddening and blister formation are primarily and persistently painful, whereas in third-degree burns the nerve endings in the corium are destroyed, which makes the hurt area insensitive to touch and pain at first. In diagnosing and dating the age of a cigarette burn, one has to be aware that the distinction between a second-degree burn possibly caused accidentally and a third-degree burn (with subsequent scar formation) can only be made on the basis of the healing process. This means that the first examination performed soon after the incident should be followed by one or more further inspections until the injury has healed. Observation over a period of 2–3 weeks will also permit a differentiation between burn injuries and local infections [13].

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