A HISTORICAL REVIEW OF THE USE OF LOCAL PHYSICAL SIGNS IN BURNS[1]

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Antiquity to the Sixteenth Century A.D.—The earliest account of the treatment of burns is recorded in the Papyrus Ebers, written about 1500 B.C. (Bryan, 1930). For the most part the section on burns is a collection of recommended preparations. " A frog, warmed in oil and rubbed on " is advised " to prevent burn wounds ", and other preparations are appointed specifically for the first, second, third, fourth and fifth days. Among the indications for some of the preparations are a few references to local physical signs, such as " if the burn suppurated ", or " persisted in its downward course and began to turn white ". In the latter case one was advised to apply a remedy which sounds almost modern—a linen shirt steeped in oil. Other preparations were used to stimulate granulations, or to check them if excessive.

It appears, therefore, that in the medicine of ancient Egypt local physical signs were used in the treatment of burns to gauge their progress and to be a guide to the remedies applied; moreover, since suppuration called for special treatment, it was probably regarded as an avoidable complication. There was no consideration of the depth of burning, however, and no surgical intervention.

Hippocrates taught the great principle of avoiding suppuration by simple cleanliness: wounds were never irrigated except with clean water or wine, and an attempt was made to keep them dry (Garrison, 1922). Whether these principles were applied as strictly to burns as to other wounds is doubtful: one empirical treatment he advised was, " having melted old swine's seam, and mixed with resin and bitumen, and having spread it on a piece of cloth and warmed it at the fire, apply the bandage " (Harkins, 1942). Apart from the excision of contracted scars described by Celsus, surgery had no place in the treatment of burns in Greek and Roman medicine (Mettler, 1947).

During the next 2000 years there was no development either in the understanding or treatment of burns; in fact the whole rationale of treatment became distorted and fixed by two superstitions. The first was that suppuration was essential to healing, a retrograde doctrine for which Galen was responsible. The second was a pre-Hippocratic aphorism, mentioned in the Agamemnon of Aeschylus, which has been traced by Baas to the ancient Hindus, that " diseases not curable by iron are curable by fire " (Garrison, 1922). Whatever this dictum meant originally, it became the pretext for wholesale cauterisation, often to prevent or cure suppuration. It was a trend which reached its height in the Arabian school when Avicenna substituted the use of the cautery for the knife, and this custom was continued by some surgeons well into the Middle Ages in spite of the efforts of Saliceto (1210-1277) and Henri de Mandeville (1260-1320) to return to Hippocratic principles (Garrison, 1922).

Such was the downward trend: at the dawn of the history of medicine burns were regarded as an accidental injury that could be complicated by suppuration: by the end of the Middle Ages they were frequently the result of surgery, and suppuration was regarded as essential to healing. Nothing was learned from 500 years of therapeutic burning, save that it was best avoided.

Although gunpowder had been used at the siege of Calais in 1347, it was not for

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another 100 years that its increased use began to attract the attention of army surgeons. The first allusion to powder burns was by a Bavarian army surgeon called Heinrich von Pfolspeundt in 1460 (Garrison, 1922). But interest in burns was completely overshadowed by the controversy which raged over the nature of gunshot wounds, the new feature of Renaissance surgery. Brunschwig (1497) and Vigo (1514) had each written detailed accounts of gunshot wounds, regarding them as poisoned burns, and therefore requiring an initial treatment with boiling oil. This treatment, which was in accord with the pseudo-Hippocratic superstition already mentioned, was regarded as orthodox until it was corrected by Paré. After running short of oil one night in camp, he found that gunshot wounds healed better without it, and he concluded that these wounds were neither burned nor poisoned, but were simple lacerations accompanied by considerable contusion (Johnson, 1649).

The first detailed description of the treatment of powder burns was written by William Clowes (Clowes, 1591), who served as fleet surgeon against the Armada and was afterwards made physician to the Queen. Describing an accident in 1577, he recalled that two men were heating gunpowder in a brass pan when it exploded, and they were severely burned. In his treatment he used one remedy for the parts that were blistered, carefully avoiding breaking the blisters to prevent pain, and another ointment for the parts " where the skinne was burned off, and the parts made rawe and paynfull ". Evidently these were relatively superficial flash burns such as frequently follow explosions, for he concludes, " In the end I finished these cures without blemish or signs of any burnings ". Of the ointment that he used, he wrote, " it healeth without ulceration and paine, and bringeth againe the beauty of the skin ". For this delusion he may be excused since it is still commonly entertained today. Nevertheless, Clowes stands out in history as the first surgeon since the Middle Ages to use the physical signs of recent burns to dictate his local treatment.

The Seventeenth and Eighteenth Centuries.—In 1607 Wilhelm Fabry of Hilden produced the first classification of burns in his book *De Combustionibus* (Sonnenburg and Tschmarke, 1915). It was a classification of the intensity of surface burning, judged by external appearance, and recorded in three degrees : these were,

(*a*) Redness and blistering of the skin.
(*b*) Withering of the skin without charring.
(*c*) Eschar formation and charring.

This type of classification, based on surface appearance but with the occasional introduction of additional physical signs, stood with only minor alterations for nearly 200 years.

It was not long, however, before surface appearance became identified with the depth of burning, a mistake which is still the source of considerable confusion. This association is reflected in the classification of Richard Wiseman which is recorded in his discussion on gunpowder burns (Wiseman, 1676).

(*a*) " Superficial, it raiseth the cuticle up in blisters."
(*b*) " Deeper into the skin, . . . it causes an eschar."
(*c*) " Deeper into the flesh, . . . it makes a hard crust with a contraction.

One case described by him was that of a man carrying a helmet full of gunpowder which ignited ; another was that of a 10-year-old boy at boarding school who filled his pockets with squibs and crackers on the evening before 5th November ; somehow these accidentally went off and set his clothes alight causing severe burns of his leg—an injury typical of Guy Fawkes celebrations for 350 years!

A striking feature of his discussion of these cases is the care with which he correlated his treatment with his classification. The " parts that were burned to an eschar " received one preparation, " those that were raw " had another, and he concludes " thus each part required to be particularly considered. In these large burns there are required a variety of intentions at one and the same time ", namely, to ease the pain, to digest the slough and to " rub off the unequal callus with a caustic stick ".

The eighteenth century saw a further development of Fabry's classification in two directions : one was towards a classification by depth, and the other towards a classification based on pathology.

In 1739, Heister (1683-1758) published a general system of surgery in which he dealt with the treatment of burns, and he devised a new classification (Heister, 1743). At first sight he appears to have modified Fabry's classification and complicated it by adding different degrees of pain and blistering, with a time factor brought in as a further diagnostic aid. His four degrees were :

(*a*) " Heat, pain and small vesication in the injured part in a short time."

(*b*) " Instant great pain and vesication."

(*c*) " When the common integuments and subjacent flesh are so burned that they form a crust."

(*d*) " When everything is destroyed quite down to bone."

The chief feature, however, is the emphasis on depth ; the first two degrees are burns of the skin, the third includes subjacent flesh and the fourth is down to bone. Almost a century was to pass before Dupuytren, the next protagonist of a classification based on depth, was to state this view and incidentally receive the credit for it.

Heister's opening sentence in his section on burns is as interesting as his classification, for it prepares us for the next type of classification which was to follow in the latter half of the same century. Here he writes, " I believe no one will be offended at our treating of burns as a species of inflammation, since the appearance as well as the consequences of both are exactly the same."

Such a classification, based partly on pathology, has been attributed to " Hunter " (Sonnenburg and Tschmarke, 1915), but the writers have given no reference and no initial. The classification was as follows :

(*a*) Superficial inflammation.

(*b*) Deep inflammation.

(*c*) Skin crust formation.

(*d*) Deep charring.

It seems quite probable that this was indeed John Hunter (1728-1793), especially in view of his interest in the process of inflammation, but I have been unable to find any such classification by him. This classification was in fact little more than the original type partly translated into pathological terms.

The trend, however, was carried further shortly afterwards, both in England and France, when the classification of burns was reduced to two pathological categories completely divorced from external appearances.

Edward Kentish in his Essay on Burns, first published in 1797-1800, after quoting Heister's classification, went on to give his own as follows :

(*a*) " Injuries due to Caloric, where the action of parts are alone increased."

(*b*) " Injuries due to Caloric, where the action of parts are increased, and the organisation of some other parts destroyed " (Kentish, 1817).

The classification of Delpech of Toulouse (1777-1832) was very similar (Sonnenburg and Tschmarke, 1915):

(*a*) Inflammation.
(*b*) Destruction.

At first this bears a resemblance to the present classification of burns into "partial" and "full-thickness skin-loss", but it lacked the one essential which could have given it practical value, an association with the depth of burning. This was to be the next advance.

The Nineteenth Century.—In spite of the trend to a pathological classification, there were still those at the beginning of the new century who used and taught the old type of classification.

Richter (1742-1812) concentrated more on the superficial planes of injury than had previously been done, adding another local physical sign, oedema, and also a constitutional one, pyrexia (Sonnenburg and Tschmarke, 1915). His three degrees of burning were:

(*a*) Smooth redness of the skin.
(*b*) Redness with swelling and associated fever.
(*c*) Blister formation.

Boyer (1757-1833) distinguished three degrees which he regarded as important because each was to be treated with a particular method (Boyer, 1814). They were:

(*a*) An erythema.
(*b*) Blistering leading to superficial ulcers.
(*c*) An eschar.

It is this classification of the intensity of surface burning as judged by outward appearance which is still the generally accepted one in America today.

These previous classifications were known to Dupuytren (1777-1835) who mentions those of Fabry, Boyer, Heister and Delpech in his treatise on burns (Dupuytren, 1832). He criticised them because they were concerned chiefly with the intensity of symptoms, and did not give enough consideration to the depth of tissue destroyed. He claimed for his own classification that it distinguished those shades of destruction which the others had confused in their third and fourth degrees. His classification may be summarised as follows:

(*a*) Erythema which blanches on pressure.
(*b*) Cutaneous inflammation with the loss of epidermis and blistering.
(*c*) Destruction of a portion of the papillary body.
(*d*) Disorganisation of whole dermis down to subcutaneous tissue.
(*e*) The formation of eschars down to and including muscles.
(*f*) Carbonisation of the whole thickness of the burned part.

It was probably an anatomical classification, and not a histological one as has been suggested (National Research Council, 1943), for it was not until two years after Dupuytren's death that Henle brought out his classic work on the skin and epithelial tissues of the body; moreover, there is no suggestion in Dupuytren's description that his classification was based on anything more than macroscopical appearances. This accounts for his reference to the papillary body as being the site of epithelial regeneration.

The importance of this classification was its emphasis on depth; its shortcoming, however, was the lack of any contemporary method of differentiating the degrees which

were out of sight. As Dupuytren himself remarked, these degrees are in most cases difficult to distinguish immediately after the accident. At that time the difficulty was not of particular importance since the procedure of primary excision followed by immediate skin grafting was not yet practised.

Believing that Dupuytren's last four degrees were of academic interest only, Hebra returned to a three degree classification " as representing three degrees of intensity ", but he too assumed that these degrees were associated with the depth of destruction (Hebra, 1866). They were,

(*a*) " Erythema, blanching on pressure, with some swelling and pain."
(*b*) " Blistering, with loss of the epidermis, and the true skin which is intensely reddened presenting numerous bloody points produced by hæmorrhage."
(*c*) " Eschars, of ash-grey, yellow, brown or black colour, and more or less dry, hard, firmly adherent, and devoid of sensation. These eschars arise immediately after injury."

" It is not possible ", he adds, " from the form, colour and thickness of the eschars to determine directly after the accident to what extent the subjacent parts have been injured, as well as the tissues of the skin itself. For the appearance presented by the eschars is nearly the same when the muscles and even the bones have been destroyed, as when the skin alone has been attacked." ". . . for all practical purposes the three grades which I have described are sufficient, and we may include under burns of the third degree those forms which Dupuytren and others have spoken of as burns of the fourth, fifth and sixth degrees."

Dupuytren had used the sign of blanching on pressure, but Hebra appears to be the first to have mentioned petechial hæmorrhages. Moreover he says, " The appearances produced in the cutaneous surface by the action of heat vary according to the degree of temperature to which the integument is exposed, and the nature of the medium by which the heat is transmitted." Yet, in spite of this important statement, he failed to realise that the appearances of a burn of his second degree might be associated with partial or complete skin destruction. There seems to be no doubt that by second degree burns he meant the former, for he described them as healing within two to four weeks. Again he states, " after burns of this kind cicatrices may be altogether wanting ; if present, they are flat and covered with numerous small pits." This is the characteristic appearance of skin which has healed after a burn involving almost the full thickness of the skin.

The Twentieth Century.—The first authoritative account of burns in this century was written by Sonnenburg and Tschmarke (1915). These authors drew a distinction between burns which healed only from the edges, and those which healed from the rete Malpighii, the hair follicles, the sweat ducts and the sebaceous glands. They also noticed the stasis of blood in widely dilated vessels which is such a characteristic feature of some burns of the dermis.

Pack and Davies (1930) made no new observations on the local physical signs, and they wrongly attributed the red points on a white background in the healing burn to the dermal papillæ. This conclusion no doubt arose from the old belief that most partial-thickness burns of the skin healed from the rete pegs of the epidermis.

A more recent classification of burns, which has been increasingly adopted during the last 25 years, is one based on depth alone—National Research Council of Canada (1942). In this there are two degrees only :

(*a*) " Partial-thickness skin-loss ".
(*b*) " Full-thickness skin-loss ".

The term " partial-thickness skin-loss " implies that the deeper portions of the

hair follicles and sweat ducts are still living, and that epithelialisation will occur from these. " Full-thickness skin-loss " signifies complete destruction of all the epithelial elements in the burned skin, so that natural healing can only occur by contraction of the wound and epithelial cell migration from its edge.

In the last 30 years attention has been focussed on the early diagnosis of full-thickness skin-loss so that deep burns could be excised and grafted immediately after burning. A dozen different methods at least have been explored to diagnose the depth of burning and they are reviewed very briefly below. With one exception—the method using sensitivity to pin-prick—they all, at least in part, measure skin circulation which is no criterion of the viability of skin immediately after burning, or they judge the state of the deepest layers of the skin by surface appearances. In some methods both errors are present.

1. In the early part of the second World War the presence of dermal circulation as judged by redness, blanching on pressure, was regarded as evidence of partial-thickness skin-loss (Wakeley, 1940; National Research Council of Canada, 1942). Since then, however, careful observation has shown repeatedly that *early* dermal circulation is no index of partial-thickness skin-loss, and the absence of visible circulation is no criterion of total skin destruction (Jackson, 1953, 1969).

2. In 1942 fluorescein was used for measuring the circulation time of the blood, for determining the viability of bowel in clinical cases of strangulated hernia, and in gangrene of the extremities; (Herrlin *et al.*, 1942; Lange and Boyd, 1942). In the following year it was advanced as " a clinical test for differentiating second and third degree burns " (Dingwall, 1943). Second degree burns, it was claimed, fluoresce, while third degree burns remain dark under the Wood's lamp.

3. A third method was introduced by Patey and Scarff (1944), who used a modified Van Gieson's stain applied to the surface of the burn to show up the areas of dermal necrosis. Mapping out the areas of surface necrosis with dyes, like noting the presence or absence of circulation, indicated nothing deeper than the eye could see, whereas the critical layer in burns is the deepest plane of living epithelial elements.

4. In 1945, Gibson and Brown used Kiton Fast Green, a high molecular weight dye which had previously been used for ocular lesions, " to differentiate deep avascular burns from more superficial lesions ". However, one of their four patients had severe vomiting and they abandoned the method.

5. Two years later Cope, Langohr, Moore and Webster (1947) wrote: " No objective method of determining the depth of destruction of a burn has proven of aid to us. Among other methods we have tried the fluorescent ultra-violet lamp, as suggested by Dingwall, but since it depends upon the presence of the circulation of the blood at a visible level, it has proved no more useful in our hands than the naked eye ".

6. The weakness of the above methods was that they gave information about the surface of the burned skin only. What is needed is a method which would map out the deep viable remnants of hair follicles and sweat ducts while they are still covered with superficial slough. The alteration in pain sensitivity of burned skin had been recognised for many years (Dupuytren, 1832; Colebrook *et al.*, 1945; Cope *et al.*, 1947). In 1949 Bull and Lennard-Jones showed experimentally that there was a correlation between the appreciation of pin-prick and the depth of burning. Subsequent clinical evaluation has shown that appreciation of pin-prick as sharp on firm pressure with a hypodermic needle, several times to the square inch, is a most valuable physical sign that a burn is partial thickness skin destruction only—whatever its colour or surface appearance; such a burn will heal in three weeks without grafting and probably without serious scarring. Analgesia, on the other hand, signifies deep partial skin loss or whole skin loss (Jackson, 1953).

7. In 1957 Bennett and Dingman using radioactive ^{32}P, 36-48 hours after the burn injury, claimed that uptake varied inversely with the depth of burning. The method needed special equipment.

8. In 1958 Tempest published his work on intravenous disulphine blue for assessing the viability of burned tissue and crush injuries of the hand. Complete body staining is established in five minutes and takes one or two days to disappear (Tempest, 1970).

9-10. In 1961 Goulian, working with Evans blue which binds firmly with serum protein showed that first and second degree burns stained a deep blue, while third degree remained unstained : it simply revealed the status of the circulation at the time of injection. As this dye remained in the tissues for several weeks, he moved on to the use of Bromphenol blue which has a looser bond with protein ; uninjured tissues clear this dye in a day but if it diffuses into areas of necrosis it remains indefinitely (Goulian and Conway, 1965). At the time of writing the dye had not been cleared for clinical use.

11. In 1963 Malek, Dobrkovsky, Zastava and Kolc studied the fluorescent staining of burned skin after giving tetracycline antibiotics to their patients ; this substance produces a golden yellow fluorescence in ultra-violet light in mild burns, while severe burns remain without fluorescence. The authors claimed that the tetracycline tag not only demonstrated circulation but became fixed to tissues damaged to certain degrees.

12. In 1966, Georgiade, using a sensitive thermograph in an ambiant temperature of 72°F, traced the infra-red rays radiating from burned skin on to Polaroid film. Second and third-degree burns were colder than unburned skin and showed up as grey and black areas respectively on a white background. The differential temperatures are probably largely due to circulation and evaporation. Expensive and complicated apparatus is required for this investigation (Mladick *et al.*, 1966).

One cannot help asking why none of these methods of diagnosis has been internationally adopted by burn surgeons in their clinical practices. Several reasons are evident. Many surgeons still regard surface appearance as an adequate guide to the depth of burning ; it is, of course, of some value, but it is not an accurate or reliable enough criterion for confident primary excision. A few of the methods described above require expensive equipment and the skill to use it. Other methods stain the whole patient in a rather alarming way, even if they are safe.

Sensitivity to pin-prick is the only guide free of the twin objections of assessing the circulation only or giving information about the skin surface only. Although the pin-prick test is sometimes difficult to use in children under the age of 3 years, it is still the simplest and most reliable way of separating burns that will heal spontaneously in three weeks (those sensitive to pin-prick) from the analgesic deep partial and full-thickness burns which are likely to need grafting.

Summary

The use of physical signs to describe and classify burns has been reviewed from earliest times to the present day.

During the last 30 years a number of methods have been studied for diagnosing partial and full-thickness skin destruction. These are enumerated, and the opinion is advanced that sensitivity to pin-prick is the best and simplest guide we have as to whether the deepest epithelial elements in the skin are alive or not.

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