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IN-DEPTH REVIEW

Occupational skin cancers

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Abstract Skin cancer due to occupation is more common than is generally recognized, although it is difficult to obtain an accurate estimate of its prevalence. Over the past two centuries, occupational skin cancers have particularly been due to industrial exposure of men (it seems more so than women) to chemical carcinogens such as polycyclic hydrocarbons (e.g. from coal tar products) or to arsenic. Industrial processes have improved in most Western countries to limit this type of exposure, but those with outdoor occupations are still exposed to solar ultraviolet irradiation without this being widely recognized as an industrial hazard. Ionizing radiation such as X-rays can also cause skin cancer. Occupational skin cancers often resemble skin tumours found in non-occupational subjects, e.g. basal cell carcinoma, squamous cell carcinoma and malignant melanoma, but some pre-malignant lesions can be more specific and point to an occupational origin, e.g. tar keratoses or arsenical keratoses. An uncommon but well-recognized cause of occupational skin cancer is that which results from scar formation following an industrial burn. In the future it will be necessary to focus on preventative measures, e.g. for outdoor workers, the need to cover up in the sun and use sun protective creams and a campaign for earlier recognition of skin cancers, which are usually curable if treated in their early stages.

Key words Arsenic; burn scar; carcinogen; coal tar; ionizing radiation; occupation; outdoor worker; polycyclic hydrocarbons; skin cancer; ultraviolet radiation.

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Introduction

Cancers are an important category of skin disease due to occupation. In the UK over a 6 year period, 1608 cases of skin cancer thought to be occupationally related were reported to the occupational surveillance scheme [1]. In the historical sense, occupational skin cancer has a rich tradition as outlined below. In the current age, the relation of skin cancer to occupation is often confounded by concurrent sun-exposure from leisure pursuits. This has become much more common with the increase in leisure time and the social fashion for a suntan seen in the late twentieth century. In this article, I will examine the history of industrial skin cancers, the types of occupational cancer seen, the nature of the occupational carcinogens and future possibilities. The treatment of the conditions will not be dealt with, as most patients with occupational skin cancer will be referred to a dermatologist or plastic surgeon.

Historical perspectives

The historical aspects of skin cancers linked to occupation make interesting reading. The London surgeon Sir Percival Pott first made the link between occupation and skin cancer in 1775, when he observed the occurrence in chimney sweeps of squamous cell carcinoma of the scrotum. These lesions were often preceded by hyperkeratotic lesions known as 'soot warts'; for an historical review, see [2]. Benzo[*a*]pyrene from the burning of coal is suspected to be the causative carcinogen in the soot. The industrial revolution brought increased exposure to the products of distilling tar and pitch, and von Volkman described skin cancers in exposed workers in Berlin in 1873 [2]. Whilst the problem

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worsened in the twentieth century, Kennaway identified the carcinogen as 1,2,5,6-dibenzanthracene. Shale oil, used as a lubricant and to produce naphtha, was identified as a carcinogen causing squamous cell carcinoma of the scrotum. Southan described a notable outbreak in 'mule spinners' of the Lancashire cotton industry in 1922.

The carcinogenic effect of ionizing radiation became recognized in the early years of the 20th century when skin cancers were frequently found on the hands of doctors, dentists or technicians who were exposed to X-rays or point sources of radiation during the administration of radiotherapy [2]. The onset of the skin cancer was usually preceded by radiodermatitis. The importance of arsenic as a carcinogen in subjects exposed to the element in its mining or smelting, or in products such as sheep dip, was recognized in the first half of the 20th century [2]. Other carcinogenic effects such as the induction of skin cancer following a burn, have only recently been recognized as true phenomena.

Types of occupational skin cancer

Pre-malignant conditions

Many patients exposed to a carcinogen develop pre-malignant changes that may or may not develop into a true malignancy. Some of these pre-malignant conditions are virtually specific to the inducing carcinogen, such as the keratoses seen in arsenic exposure. Others may be seen in a variety of situations including the non-occupational; for instance, actinic keratoses may be both occupational and non-occupational. Sometimes non-malignant skin disease can be seen alongside a cancer or a pre-malignant lesion, e.g. the occurrence of oil folliculitis with pre-malignant hyperkeratotic 'warts'.

Actinic (solar) keratoses

An actinic keratosis is a localized area of abnormal keratinocytes that show loss of maturation and hyperkeratosis. Clinically, actinic keratoses are brownish or reddish scaly areas, sometimes with a papular component or with inflammation, a few millimetres in diameter [3]. They are located on sun-exposed sites, typically the dorsal aspects of the hands, the forearms, the face and the scalp (Figure 1), but also on other parts that may have been sun-exposed, such as the trunk in some workmen. They may be associated with other stigmata of sun-damaged skin, such as telangiectasia, irregular pigmentation, solar elastosis or skin atrophy.

Tar keratoses ('warts')

Tar keratoses are brown-coloured, flat-topped round or oval small plaques a few millimetres in diameter, with a tendency to be clustered [3]. Their surface may be smooth or warty. They tend to be seen on the dorsal aspects of the hands, the forearms (Figure 2) and around the face. Tar keratoses are related to exposure to coal tar, pitch, shale oil and products of the distillation of coal. They may appear some years after the period of exposure.

Arsenical keratoses

The keratotic lesions seen with arsenic ingestion can be pathognomonic. The punctate keratoses seen on the

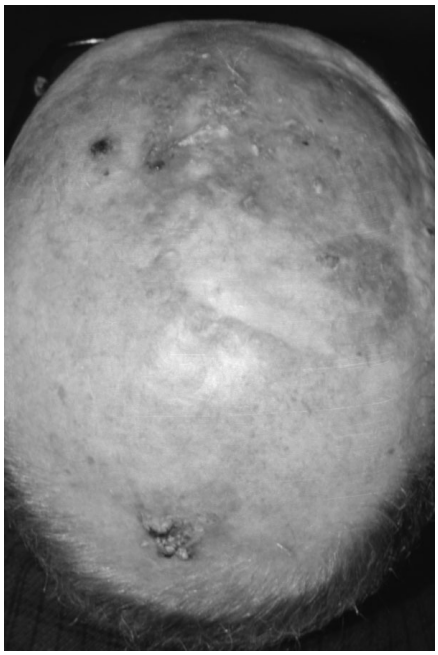

Figure 1. Actinic keratoses: usually develop in sun-exposed sites such as the unprotected bald scalp. This patient has had a squamous cell carcinoma excised and a skin graft applied. (Colour versions of all the figures are available as supplementary data at *Occupational Medicine* Online.)

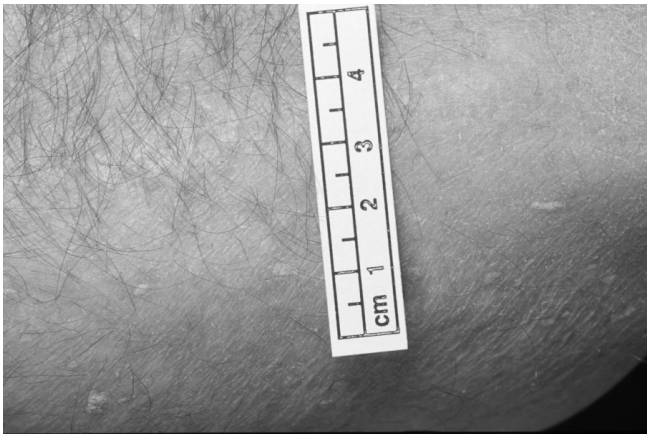

Figure 2. Tar keratoses: occur in workers exposed to coal tar products on sites such as the forearms.

palms of the hands and soles of the feet in subjects exposed to arsenic are not seen with any other condition. They are usually multiple and may progress to squamous cell carcinoma. Intra-epidermal carcinoma or multiple basal cell carcinomas may be associated.

Keratoacanthoma

Keratoacanthoma is a rapidly growing dome shaped nodule up to 2 cm in diameter, with a central keratinous plug, that is usually found in sun-exposed areas such as the face, dorsa of hands and the forearms. Histologically, they resemble squamous cell carcinomas, but spontaneous resolution may occur. It is associated with sunlight and tar exposure [4].

Intra-epidermal carcinoma (Bowen's disease)

Intra-epidermal carcinoma is *in situ* squamous cell carcinoma. It occurs as scaly red plaques up to several centimetres in size, located on the sun-exposed sites of the lower legs, face or arms (Figure 3). Progression to invasive carcinoma may occur. It is typically associated with arsenic ingestion.

Lentigo maligna

Lentigo maligna is a proliferation of melanocytes that have the potential to develop into a malignant melanoma. The lesion of lentigo maligna occurs in sun-exposed sites, typically on the face (Figure 4), as a pigmented macule that may show some irregularity in the degree of pigmentation or in outline [3]. It may grow slowly in size. Transformation into a malignant melanoma is signified by the onset of a papular growth within the macular area, by pigmentary change, or by acceleration in its growth. Lentigo maligna is typically associated with prolonged exposure to sunlight, usually over a period of many years, in somebody employed in outdoor work.

Basal cell carcinoma

Basal cell carcinoma is a malignant tumour of the basal cells of the epidermis, which can invade through adjacent tissues, but rarely metastasizes. There are four types of basal cell carcinoma. The nodular and cystic variants are usually found on the face, and are up to 10 mm or more in diameter. The morphoeic type shows scarring and a diffuse edge and is often found on the face too, whereas the multicentric superficial tumours, which can extend to several centimetres in diameter (Figure 5), typically occur on the trunk [3].

Exposure to the sun, to ionizing radiation and to chemical carcinogens including tar products can be involved in the causation of basal cell carcinoma [4]. Basal cell carcinomas make up about three-quarters of non-melanoma skin cancers (squamous cell carcinoma makes up most of the rest). In Europe, basal cell carcinomas are commonly seen in individuals over the age of 40 years, more frequently in men and in those with a fair skin type (who show easy burning and poor tanning ability in the sun). In Australia, basal cell carcinomas may be seen in individuals as young as in their 20s. The exact association between sunlight exposure and basal cell carcinoma is unclear, although a relationship does seem to exist.

Figure 3. Intra-epidermal carcinoma (Bowen's disease): frequently seen on the legs or trunk.

Figure 4. Lentigo maligna: often found on the face in someone who has had an outdoor occupation.

Squamous cell carcinoma

Squamous cell carcinoma is a malignant tumour of keratinocytes that usually arises in people over the age of 55 years. It is three times more common in men than women. It may metastasize. The prevalence of all cases of non-melanoma skin cancer in the USA in those of European extraction is ~230/100 000/year. There is little information on the number of cases that are occupational in origin.

Squamous cell carcinoma is a cancer that may be related to exposure to sunlight or other sources of irradiation, including localized heat. There may be a delay of two or three decades between the period of sun exposure and the onset of the cancer. Scarring from a variety of causes and chemical carcinogens including coal tar products are other potential aetiological factors [4]. The tumour often develops in skin that shows other signs of sun damage (Figure 6). Early squamous cell carcinoma presents as a small papule that may progress to ulcerate, crust and expand.

Malignant melanoma

Malignant melanoma is a cancer of melanocytes, the pigment cells of the epidermis. The malignant potential of a malignant melanoma is related to the thickness of the tumour: thicker lesions have a greater propensity for distant metastasis. The prevalence of malignant melanoma in the UK is ~10/100 000/year.

Sun exposure has a role in the aetiology of malignant melanoma, but it is more difficult to explain than for squamous cell carcinoma. In malignant melanoma, it seems that acute sunburn [5] is more important as an aetiological factor than prolonged sun exposure, which rather perversely does not seem to be a risk factor (except for the case of lentigo maligna). Clinically, malignant melanoma should be suspected when there is a change in the pigmentation, shape or regularity of the outline of an existing pigmented lesion or the development of a new pigmented lesion. Outdoor workers who have sustained repeated episodes of severe sunburn might be at risk of malignant melanoma.

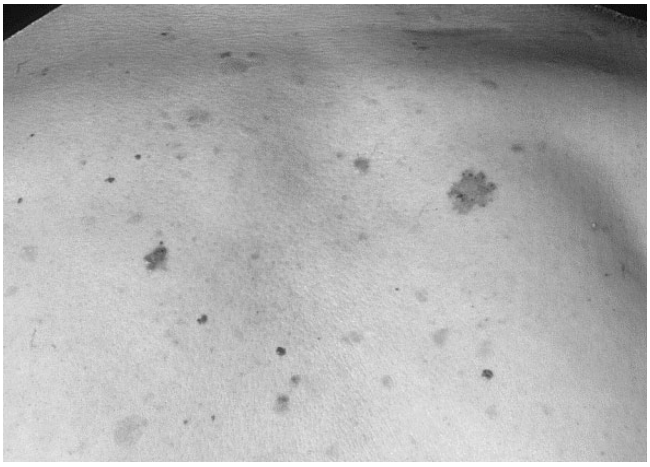

Figure 5. Basal cell carcinoma: multiple and superficial. This patient had been exposed to therapeutic X-irradiation several years ago as a treatment for ankylosing spondylitis.

Occupational exposures causing skin cancer

Arsenic

Arsenic in the form of As (III) is used in a variety of industrial processes, including glass production, the making of semiconductors and the manufacture of

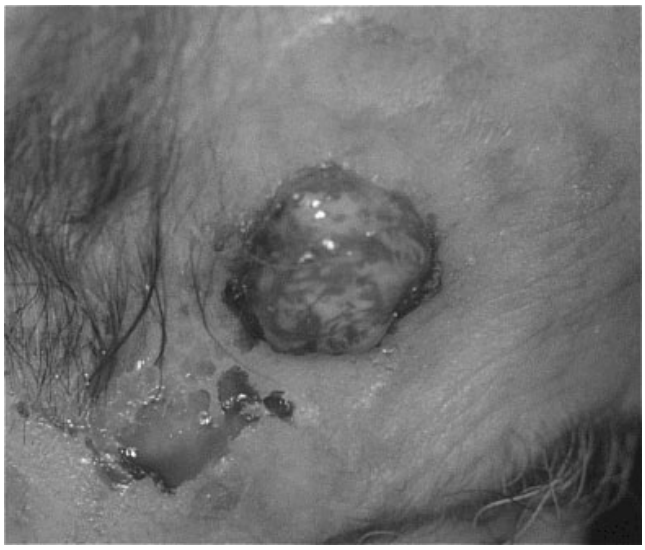

Figure 6. Squamous cell carcinoma: often develops on sun-exposed sites and in skin that can show other features of sun damage.

Table 1. Occupations at risk for occupational skin cancer

Causative agent	Occupation
Arsenic	Manufacture of insecticide or herbicide
	Agricultural exposure to pesticide
	Smelting of copper, lead, zinc
	Mining of arsenic
Polycyclic hydrocarbons	Distillation of coal tar
	Manufacture of coal gas
	Working with shale oil, creosote, asphalt and chimney soot
Ultraviolet irradiation	Outdoor work, e.g. agriculture, driving, fishing and construction
	Welding
	Laser exposure
	Certain printing processes
Ionizing radiation	Nuclear plant operations
	Diagnostic X-ray work
	Uranium mining
Burn	Welding

insecticides and herbicides [6]. It is also produced as a by-product in the smelting of copper, lead and zinc. Workers may also be exposed to arsenic in its mining and smelting (Table 1). Arsenic in pesticides represents a potential skin cancer risk for farmers [7].

The clinical signs of arsenic exposure are arsenical keratoses, which may progress to squamous cell carcinoma, and basal cell carcinoma [8]. Systemic absorption via ingestion is believed to be the mode of exposure rather than a transdermal route. Arsenic is a strong mutagen as it induces large chromosomal mutations [9], but it also seems to act as a co-carcinogen with ultraviolet radiation [10].

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) chemically are made up of two or more benzene rings: benzo[*a*]pyrene is a typical example. Exposure to PAH is mainly by inhalation but also through skin contact [11]. Industries in which PAH are produced include gas production from coal, coke plants, aluminium production, steel and iron foundries and exposure to diesel engine exhaust fumes [11]. PAH from shale oil, creosote, asphalt and chimney soot have all been associated with skin cancers [12–15].

Ultraviolet radiation may be a co-carcinogen [16], but this is not invariably so (e.g. in the case of scrotal cancers). The main carcinogens in coal tar products, including tar, pitch, soot and raw paraffin, are PAH [17]. Basal cell and squamous cell carcinomas and pre-malignant lesions may result.

PAH have been shown to affect the p53 tumour-suppressor gene in lung cancer, but the mechanisms involved in the causation of skin cancers have not been confirmed.

Ultraviolet and ionizing radiation

Ultraviolet radiation is usually encountered in the form of sunlight, but potentially occupational exposure could occur from ultraviolet tubes. Ultraviolet exposure was believed to be the main cause of the skin cancer in all but 4% of the 1608 cases reported over 6 years in the British reporting scheme [1]. There have been several studies that have looked at the prevalence of skin cancers in outdoor workers. It might seem obvious that outdoor workers would have an excess of skin cancers compared with those who work indoors, but results have been contradictory. Green *et al.* [18], in Australia, found a lack of correlation between skin cancer and outdoor work, possibly because subjects with skin types likely to burn in the sun and hence be more prone to skin cancer, self-selected for indoor work.

Freedman *et al.* [19], from the USA, found that for non-farm outdoor workers in 24 US states, there was only a slight occupational risk of outdoor work for skin cancer. However, Lear *et al.* [20], in England, did find a significant association between skin cancer and outdoor occupation, while Suzuki *et al.* [21], in Japan, detected an excess of actinic keratoses in outdoor employees. Ultraviolet radiation from welding is a potential factor in non-melanoma skin cancer in welders [22].

Ionizing radiation is well-recognized as having the potential to cause squamous cell carcinoma and pre-malignant changes from the experiences of the first scientists and physicians to use X-rays and radiation sources [23]. The latent period may be two or three decades or even longer [23]. Exposure to ionizing radiation sources is now well-controlled and supervised, so no excess of skin cancers is anticipated in radiographers. None the less, a recent report highlighted a higher risk of malignant melanoma in radiological technologists who had first worked before 1950 and in those who did not customarily use a lead apron when they first started working [24].

Recently, several authors have reported a high prevalence of malignant melanoma among airline pilots and flight attendants, who are exposed to cosmic radiation, although some observers feel this is due more to lifestyle effects (e.g. sun exposure from sunbathing) than to cosmic radiation exposure [25–27].

Ultraviolet irradiation induces mutations in the p53 tumour-suppressor gene and this is believed to be one mechanism through which it may have a carcinogenic effect [28].

Trauma

Skin cancer may occasionally follow an industrial injury such as a burn sustained from welding or contact with a hot metal fragment and resulting in a scar. The usual tumour is a basal cell carcinoma [29]. The latent period may be a few months to 2 years, or sometimes longer [29].

Prevention and future issues

A better understanding of the risks and improvements in industrial processes, coupled with a reduction in the amount of distilling of coal tar products in Western Europe and care in the handling of sources of ionizing radiation has resulted in a lessening of the risk from exposure to chemical carcinogens in most European countries. The risk from exposure to natural solar ultraviolet irradiation remains and is largely ignored as a predisposing factor, except in countries (such as Australia) where skin cancer in people with pale non-tanning skin is a major public health issue. Improvements in the advice given to outdoor workers with regard to covering up bare skin with protective clothing and the use of sun protective creams is a desirable objective, coupled with educational projects to

encourage and facilitate the early recognition and management of premalignant and malignant skin lesions in the at-risk work force.

Supplementary data

Colour versions of the figures are available as supplementary data at *Occupational Medicine* Online.

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