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A Dermal Lesion from Implanted Plutonium

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Introduction

Alpha particle dermatitis is rare following exposure to externally emitted α-radiation, since most of such particles are stopped easily by the horny layer of the epidermis of man. Even the mild effects produced by the therapeutic use of solutions of thorium X [illegible] ointments of radon are not ascribable [illegible] α-particles alone. Larkin [1] described an erythema produced by accidental exposure to a 32 mev cyclotron beam consisting almost entirely of α-particles. This reaction failed to develop into a radiation ulcer such as that seen after x-ray or β-particle exposure of similar magnitude (estimated 70,000 r), although desquamation occurred and thickening of the epidermis persisted for more than [illegible] months. Witten et al.[2,3] showed that a surface dose greater than 55 kilorad of α-radiation from polonium was required to produce detectable erythema. Slight pigmentation was the only sequela to the transitory erythema in human skin exposed externally to 660,000 rad in these experiments.

Devik [4] studied the effects of exposure of the skin of hairless mice to massive doses of α-particles from a 10 mc. polonium source. Ulcerative radiodermatitis failed to occur, although maximum depth of penetration was about 37μ. Even with depth doses in excess of 100,000 r, cytologic evidence of damage to mitoses was only occasionally found and mitotic activity was suppressed only 1 to 2 days. Dermal appendages showed no evidence of damage. Nuclear vacuolization and pyknosis followed by atrophy of 1 week's duration were the only changes found after surface doses in excess of 500,000 r of α-radiation. In contrast, 1,650 r of x-radiation (50 kv., 2 ma., 1 mm. Al HVL) produced severe effects such as edema, desquamation, ulceration, exudation, and chronic radiation atrophy and dermatitis in these mice. This study led Devik to conclude

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that the epidermis contains cells not only capable of surviving doses of the order of 100,000 r of α-particles but also capable of normal mitotic activity 2 days later. He ascribed the mildness of the reaction to a lack of radiation-induced damage in the connective tissue of the corium. The case of α-particle-induced radiodermatitis described here is, in light of Witten's clinical and Devik's experimental observations, quite unusual and provocative, particularly since the bulk of the exposure was to the corium and to the basal layer of the epidermis.

Report of Case

The patient, a person engaged in machining plutonium metal, had had a radioactive foreign body removed from his hand 4 years and 3 months prior to his noticing a nodule at the site of the old puncture wound. At the time of the first debridement, the area had 20,000 surface α-counts per minute and postoperatively only 20 surface α-counts per minute. After unsuccessfully trying to remove the suspected new foreign body himself, he reported to the dispensary where a γ-spectrometer microprobe[5,6] revealed that 0.08μg. of plutonium was present.

The skin of the area was excised and fixed in 10% formalin. The wound, after excision, was spectrometrically within background counts. The excised piece of skin showed 0.078μg. of radioactive material in a second independent assay. While Pu-239 (half-life 24,360 years) emits α-particles 100% of the time with an average energy of 5.15 mev, it also emits a 17 kv. x-ray in the process of radioactive decay usable for the detection and assay of dermal wounds contaminated by this metal.[5,6]

Microscopic Examination

After fixation, the piece was embedded in paraffin in the usual way, sectioned at 4μ to 6μ, and stained by the periodic acid-Schiff (PAS) reaction. Autoradiographs were made from alternate sections which were not stained until after exposure and processing. Intense α-particle "bursts" were demonstrable after 96 hours on Kodak nuclear track plates, Type NTA (25μ thickness), using a modification of Williams' technique.[7]

The histologic appearance of perpendicular sections through the lesion is shown in Figure 1. Figure 2 is an autoradiograph of the same lesion seen in Figure 1. The α-emitting particles of plutonium are confined to the minute "hillock" of the corium that appears to extend into the epidermis. The PAS stain (Fig. 1) revealed that this area was composed of amorphous, strongly PAS-positive, proteinaceous material that appeared to stem from adjacent collagenous fibers undergoing liquefaction necrosis. The overlying epidermis was centrally atrophic and dyskeratotic. It was covered by a minute focus of parakeratotic squamae. In this area, there were no basal cells and no mitoses, but on each side of the "hillock," where the epidermis was normally thick, mitotic hyperplastic basal cells were present. A sudoriferous gland running through the center of this minute lesion (which filled half of a low-power field

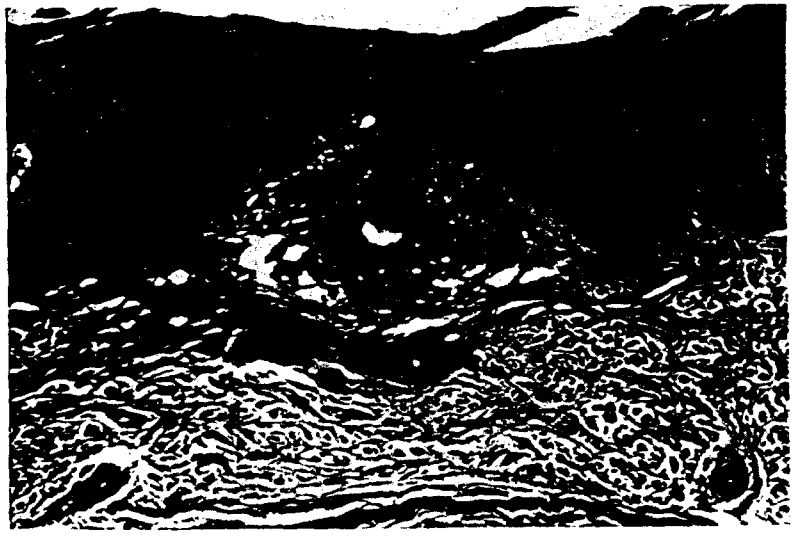

Fig. 1.—Photomicrograph showing subepidermal locus of PAS-positive amorphous degenerative material beneath an atrophic, dyskeratotic focus of epidermis. Reduced about 30% from mag. × 120.

Fig. 2.—Autoradiograph of the lesion in Figure 1, showing the restriction of the α-emitting particles to the severely damaged area of the corium. Alpha tracks can be seen extending into the damaged basal areas of the epidermis. Reduced about 30% from mag. × 120.

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and had a diameter of 375μ) showed similar atrophy and acanthosis. Occasional swollen and unusually large nuclei could be found. Some of these were hyperchromic, while others were definitely pyknotic. There was no leukocytic or other cellular exudation, and no changes were demonstrable in capillaries around the area. The lesion itself was not vascularized or organized. The impression was α-particle-induced chronic radiodermatitis, consisting of collagenous degeneration of the corium and epidermal dyskeratosis and atrophy.

Comment

The autoradiographs showed precise confinement of α-tracks to the area of maximum damage and their penetration into the basal areas of the epidermis, where epithelial changes typical of ionizing radiation exposure were present. The cause and effect relationship of these findings, therefore, seemed obvious. Although the lesion was minute, the changes in it were severe. Their similarity to known precancerous epidermal cytologic changes, of course, raised the question of the ultimate fate of such a lesion should it be allowed to exist without surgical intervention. Although no malignancies of the skin of man have ever been shown autoradiographically to be associated with such α-emitting foreign bodies, the changes here would seem to indicate that the development of such a lesion is possible. On the basis of Devik's experimental observations, the cytologic epidermal changes present in this lesion would require a dose rate in the order of 1,000 rad of α-particles per hour. Mathematical analysis, based on the size of this lesion and on the measured amount of plutonium present, revealed that the dose rate actually was 2,040 rad per hour. Since the plutonium particles were present for 4.25 years, the average radiation dose within the lesion during this exposure was 75,000,000 rad.* Such a dose rate over a 4-year period seems inconceivable but may explain the amorphous, dead, or cooked appearance of the corium containing the radioactive material. It implies, as Devik concluded, a fantastic resistance of epidermal cells to α-particles.

Summary

Histologic and autoradiographic examination of a piece of palmar human skin said

* Summary of analysis: Diameter of lesion=375μ. Volume of lesion=2.7×10^{-5} cu. cm. 1μg. plutonium gives 1.4×10^{5} α-disintegrations per minute. 0.08μg. plutonium gave 1.12×10^{5} α-disintegrations per minute.

Since 5.15 mev plutonium α-particles in this amount would deliver energy at the rate of 5.8×10^{4} mev per minute, or 9.3×10^{-3} ergs per minute, then 34 rads per minute, or 2,040 rads per hour, was the radiation dose rate.

to have been contaminated by a penetrating piece of plutonium revealed intense α-track concentration in a minute focus of subacute and chronic radiodermatitis. Although the penetration of the α-particles was minimal, the severe local effects seemed to indicate that a massive dose of α-radiation had been delivered to the area in the 4 years the contamination had been present.

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