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● *Medical Aspects*

LOCALIZED LESIONS INDUCED BY ^{137}Cs DURING THE GOIÂNIA ACCIDENT

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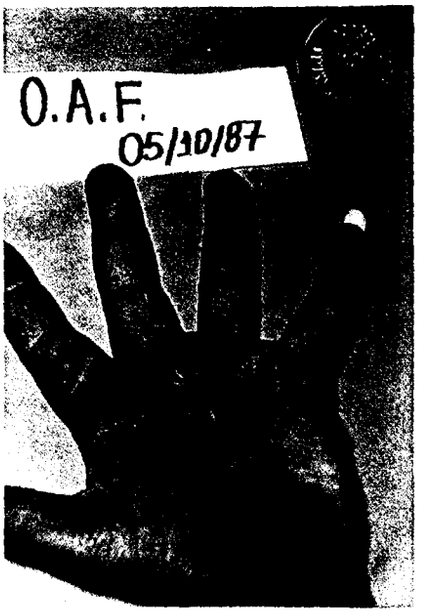
***Abstract*—A description is given of initial symptoms and clinical observations regarding acute localized radiation lesions in 28 persons exposed to ^{137}Cs during the Goiânia radiological accident. Specialized procedures to estimate the extent and gravity of the lesions and establish a therapeutic strategy, as well as to anticipate the prognosis in each case, are briefly discussed. Measures taken for reduction of pain and inflammation are noted, and an explanation is given for difficulties encountered due to adverse working conditions and the serious clinical manifestations presented by various patients concomitantly with their lesions. Also noted is the difficulty in obtaining credible information regarding exposure, such as source-to-object distance, duration of exposure, and source activity, which precluded dosimetry studies in most cases.**

INTRODUCTION

ACCIDENTS involving the use of ^{137}Cs in industry, medicine, or research are rare. In a recent review, we identified only four cases of high exposure to this radionuclide (Oliveira 1987). In two instances, the nuclide was used for suicidal purposes (Geller 1963; Vassileva and Kruschkov 1978). The third case was a worker who inadvertently put an industrial radiographic ^{137}Cs source in his right and left trouser pockets, successively. The severe lesions provoked on both thighs, with radionecrosis of the femoral arteries, made amputation of both legs necessary (Beninson et al. 1969). In the fourth case, a child was deliberately exposed to an industrial source by his father, which resulted in severe radiolesions on various parts of his body (Collins and Gaulden 1980).

In the Goiânia accident, 28 people showed localized lesions induced by ^{137}Cs radiation when they handled the source housing or fragments of the source itself or, attracted by the blue luminescence it produced in the dark, rubbed powdered Cs on their bodies (IAEA 1988).

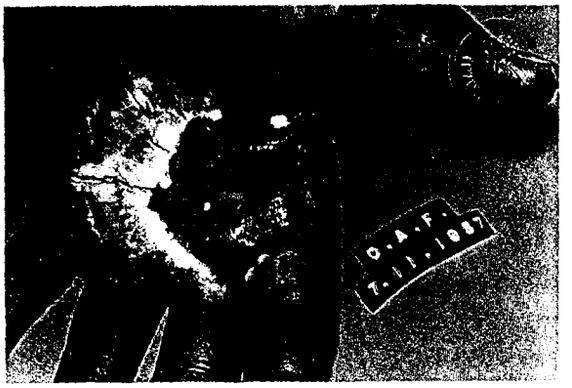
Victims who handled the container received γ radiation partly attenuated by the protective shielding material. Localized injuries caused by β-plus-γ radiations were observed in those who handled the unshielded source. Various parts of their bodies, including oral mucosa, had been in direct contact with the radioactive material. Information from the patients themselves regarding the accident was very meager, probably because of their fear of being held responsible for what had occurred. These aspects represented a constant challenge to the medical team in their attempts to reconstruct each individual's exposure to ^{137}Cs.



(Fig. 1)

(Fig. 2)

(Fig. 3)



(Fig. 4)

(Fig. 5)

Fig. 1. Ten days after exposure. Left hand of a patient who rubbed Cs powder on his palm. A diffuse secondary erythema is noted on the region proximal to fingers 2, 3 and 4. Delineation of bulla formation is barely visible.

Fig. 2. Fifteen days after exposure. A large, tense bulla associated with edema limited finger movement. (Reproduced from *The Radiological Accident in Goiânia*, 1988, with permission by the International Atomic Energy Agency.)

Fig. 3. Twenty days after exposure. Note rupture of the bulla, with dead skin becoming whitish and the surrounding epidermis showing areas of dry desquamation.

Fig. 4. Fifty days after exposure. After debridement of necrotic epidermis, bright red denuded derma is covered with a thin layer of fibrous exudate. Note sparse islands of epithelialization and centripetal aspect of the healing process.

Fig. 5. One-hundred days after exposure. Resulting scar tissue is atrophic and retractile. Telangiectasis are observed under the translucent epidermis. A central, irregular, necrotic zone is evident in this unhealed injury.

CLINICAL OBSERVATIONS

The symptoms described initially by the most serious cases related to the areas directly affected by radiation and coincided with the onset of erythema. Burning pain, sensation of local heat, tingling, itching, and an increase in sensitivity were the most frequent complaints. For patients less affected, this phase was followed by a latent period with relatively few symptoms, but this latency did not occur in the severe cases. For them, onset of the acute period followed rapidly, with appearance of a typical secondary erythema, and rough demarcation of the irradiated areas that resembled a thermal burn of moderate intensity (Fig. 1).

Significant edema was noted. Two to three days afterwards, bullae developed in the areas previously limited to erythema (Fig. 2). For some patients, instead of bulla, blisters of different sizes developed. Due to constant pain and tension, the larger bullae required drainage, a procedure usually followed by debridement of the necrotic epidermal tissue (Fig. 3), which showed a bright red, swollen dermis. A process followed of very slow concentric granulation proceeding from the outer edges of the lesions inward. In one case, a lesion on the central part of the palm was covered by a fibrinous exudate, which was firm and relatively adherent to the underlying tissue. Where evolution was favorable, the denuded areas were progressively covered by granular tissue that exhibited a few epithelial islands scattered over the dermis (Fig. 4). After about 3 mo, the injured area was practically regenerated, but the resultant epithelium was thin, inelastic, atrophic, and translucent (Fig. 5). In the adjacent areas, the skin presented pigmentary changes, and the hair had an abnormal aspect.

In six cases, significant ulceration developed after a rapid period of erythema and blistering, and there was no latency phase. For one patient, this process progressed rapidly; 5 d after exposure, necrosis was observed on the right thigh, where a source fragment had remained in contact with the skin surface for about 40 min.

For the majority of patients, the injuries evolved favorably, with complete, or nearly complete, recovery within a few months after the accident. Skin atrophy associated with hyperpigmentation was observed around the lesions. In black people, a definite depigmentation could be seen. These pigmentary changes were usually accompanied by loss of hair and skin dryness. Through the newly formed epidermis, spidery vessels (telangiectasis) were easily observed. In cases where lesions occurred on hands and fingers, atrophy and sclerosis had involved underlying structures, such as tendons, subcutaneous adipose tissue, aponeurotic sheaths, and cartilage (Sweet 1962, 1964).

A clear limitation of flexion in the proximal and distal joints of the fingers was experienced by these patients, caused not only by the fibrotic process and tissue atrophy, but by edema. Lesions affecting fingertips were always difficult to handle even when they showed signs of healing because these locations were subjected to frequent trauma, causing recrudescence of the lesions and bringing on excruciating and continuous pain. Two such injuries were erradicated surgically by amputating the digital extremity. Usually this procedure was solicited by the patient himself. Some months after irradiation, patients with moderate-to-severe radiation-induced injuries experienced a new inflammatory process (vasculitis), characterized by the appearance of a late erythema, pain, edema, and reopening of the apparently healed wounds. As a rule, recovery occurred within a few weeks of the relapse.

DOSE ESTIMATION

Any attempt to estimate the magnitude of local exposure was bound to be an arduous task. It was evident from the very beginning that such attempts, whether by physical calculations or reconstruction of exposure, could have little credibility. The majority of victims had been subjected to several exposures over a period of days, each varying in time from a few seconds to several minutes. Distances between the source and subject were not consistent, varying in time from one exposure to another. It was clear, however, that there had been direct corporal contact with the radioactive material. For these reasons, attempts at dose reconstruction were limited to one case where exposure conditions could be established (Oliveira et al. 1990).

Another difficulty with such reconstruction was the time-lapse between the accident and the history obtained from each patient. Data and information necessary for dosimetric reenactment were overlooked during the critical phase when the most important task was providing intensive care for the patients whose lives were at risk. Still another problem was the additional exposure caused by powdered Cs. Victims with injuries provoked by penetrating radiation concomitantly showed superficial lesions appearing randomly on the body surface. Caused either by β rays or by attenuated γ exposure, these superficial lesions were the first indication that we were dealing not just with the exposures from a sealed, highly radioactive source, but also with the direct effects of material from that source.

LABORATORY STUDIES AND TREATMENT

All patients were subjected to ample clinical and laboratorial trials that included cytogenetic dosimetry and internal dose evaluation through bioassay techniques and whole-body counting (see other sections in this issue). Patients who developed moderate-to-severe lesions on palms and fingers received vascular scintigraphies with ^{99m}Tc red blood cells. These studies showed an undoubted vascular distress involving the distal part of the forearm, with reduction in, or disappearance of, the silhouettes of compromised fingers. In one case, amputation of the member was indicated due to complete absence of uptake of labeled blood cells by the injured forearm, hand and fingers, together with the existence of necrosis and a toxemic condition (Costa et al. 1988). During the inflam-

matory phase, a striking increase of the blood flow to the injured region was observed.

Magnetic resonance imaging (MRI) was particularly revealing in cases of lesions involving areas with massive musculature, such as the thigh. For a patient who developed a severe radionecrosis in the right thigh, MRI showed important compromise of the tissues subjacent to a deep ulceration and a marked perivascular edema involving the femoral artery. The irradiated segment of the femoral bone marrow presented a reduction in density. For superficial lesions, however, MRI provided little information.

X-ray examinations, aside from showing evidence of demineralization (osteoporosis), indicated in one patient a late radiation-induced fracture in a segment of the distal phalanx, which was later surgically removed.

In patients who agreed to have sperm counts, a reduction or total disappearance of spermatozoa in the semen was found, especially in those who received high doses in the lower parts of the body. For some of these patients, sterility was observed even 2 y after exposure. Ophthalmological studies performed 6 mo after irradiation showed no evidence of lens opacity, except in one 56-y-old patient who had received a total body irradiation of approximately 5.0 Gy.

From a therapeutical standpoint, the medical team adopted the conservative approach in treating patients showing dry or wet epithelitis, as well as for cases of superficial ulceration or local inflammatory reaction. Their objectives were pain relief, reduction of inflammation, prevention of infection, acceleration in healing, and promotion of functional improvement of the affected regions. A surgical approach was reserved for refractory cases resistant to conventional therapy.

The problem of pain relief, especially urgent in cases of deep ulceration, presented difficulties and involved psychologists as well as medical specialists. Along with local analgesia, central action analgesics including morphine derivatives (meperidine) were employed, either per os or parenterally. Continuous peridural anesthesia was used for one patient who complained of intense piercing pain and manifested suicidal intentions. To reduce skin dryness, hand and finger injuries were immersed in Thierch solution. To reduce inflammation, creams and ointments based on prostaglandin antagonist substances (Aloe Vera) were applied generously to the wound. Also, drugs with healing action (allantoin) were used.

Attempts were made to increase blood flow to the injury by using systemic vasodilators as well as drugs intended to improve local microcirculation, but the results were negligible. Creams with fibrinolitic and proteolitic properties were applied freely to superficial lesions. When blisters or bullae ruptured, the hyperalgesic-denuded dermal surfaces were managed with nonadherent neomycin dressings. Although the majority of lesions presented bacterial colonization, there were surprisingly few cases of infection during hospitalization. However, during the outpatient period, nonobservation of basic hygiene rules on the part of some patients whose lesions had not entirely healed resulted in late secondary infections.

Deep ulcerations and necrosis, commonly unresponsive to conventional therapy, were treated surgically. Usually the irradiated tissue was excised and the open wound covered with a skin graft or thick abdominal flap, which provided immediate pain relief (Gongora and Jammet 1983).

DISCUSSION

The acute local radiation injury constitutes a well-known etiological and physiopathological entity whose clinical evolution, although dependent on dose rate and radiation penetration power, is directly related to the cellular renovation capacity of the different types of tissues affected. It appears that in the cutaneous tissue, the sebaceous glands are the structures with the most radiosensitivity, followed by hair follicles, epidermis, and sweat glands, respectively (Fajardo and Berthrong 1981). This may be the reason why hair loss and skin dryness were observed in almost all cases. Any attempt to classify clinical evolution of the injuries was hampered by the relatively small number of individuals involved.

Nevertheless, four different phases could be identified. The early phase was characterized by transitory and atypical erythema extending roughly beyond the areas actually irradiated. Since this initial erythema was not observed in the less-severe cases, it proved to be a useful parameter for anticipating the appearance of severe lesions later on. Complaints of changes in sensitivity, burning pain, intense itching, and paresthesia were also recorded. The latent phase, with its duration in reverse ratio to the dose received locally, was characterized by absence of clinical symptoms and signs. In the more severe cases, it did not occur.

The acute or critical phase was characterized by pain and inflammation, with edema and secondary erythema. The latter was the forerunner of a wet epithelitis, with blister or bulla development. The blisters eventually coalesced into one large, tense bulla, which either ruptured spontaneously or was subjected to surgical drainage, releasing large quantities of hyaline liquid. The fourth, or chronic phase, involved crises of vasculitis, usually provoked by trauma, sharp temperature and pressure changes, and emotional stress. It was characterized by the appearance of a late erythema, pain, edema, and the subsequent reopening of the lesions.

Laboratory evaluation proved to be the most useful and informative resource for diagnosis and prognosis. Blood pool imaging with ^{99m}Tc RBC represented the best tool for estimating the extent of the damage. These scintigraphic studies were performed during the critical phase, when the inflammatory process, which normally preceded opening of the injuries, was exacerbated. MRI studies of injuries involving thick muscular structures were highly illuminating in regard to the depth and extent of the compromised tissue.

It is evident that the clinical course of the lesions was not substantially modified by any of the various forms of treatment adopted. The decision for surgery was taken on the assumption that it would reduce the patient's suffering as well as prevent the possibility of secondary infection. We emphasize that pain control is of paramount importance and recommend recourse to any preventive measure, whether clinical, pharmacological, or psychotherapeutic, as soon as the symptom manifests itself. The use of systemic vasodilators for two patients with severe injuries on their thighs showed poor results in our experience. We believe further studies should be undertaken in this field, if possible, regarding drugs capable of improving microcirculation at the seat of the injury.

Regarding severe lesions, repair surgery is only beneficial if their depth and extent can be properly evaluated. A punch biopsy of the subjacent tissue is recommended as a guide prior to any surgical procedure, since apparently healthy and viable tissues can mask areas of low blood supply caused by progressive and nonreversible obliterative damage. Certainly this damage plays a special role in the slow and problematic recovery as well as in the vulnerability of the affected tissues. Nonobservation of clinical, laboratory, and dosimetric evaluations for demarcating the entire lesion can lead the surgeon to perform successive and ever-increasing resections of part or all of the member.

An improved knowledge of the physiopathology of these lesions and their final outcome suggests that early and definite intervention would limit the period of discomfort, physical disability, and convalescence. While necrotic ulcerations indicate potential cases for surgery, what to do and how to select a specific surgical strategy constitutes a decision of the plastic or repair surgeon based on the above-mentioned evaluations. Lessons learned from other accidents indicate that most deep ulcerations with unequivocal ischemic distress will benefit from ample excision of the irradiated tissue, followed by application of a full-thickness skin graft.

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