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The 1976 Hanford Americium Accident

K. R. Heid
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January 1979

Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
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SUMMARY

This report presents the 2 1/2-year medical course of a 64-year-old Hanford nuclear chemical operator who was involved in an accident in an americium recovery facility in August 1976. As a result of the accident, he was heavily externally contaminated with americium, sustained a substantial internal deposition of this isotope, and was burned with concentrated nitric acid and injured by flying debris about the face and neck. The immediate and longer-term medical care given the patient, including the decontamination efforts and clinical laboratory studies, are discussed.

Special in-vivo equipment and techniques were used to measure the americium deposited in the patient. These and subsequent in-vivo measurements were used to estimate the dose rates and the accumulated doses to body organs.

Urinary and fecal excreta were collected and analyzed for americium content. The interpretation of these data was complicated by the fact that the intake resulted both from inhalation and from solubilization of the americium embedded in facial tissues as a result of the accident. A total of 1100 μCi was excreted in urine and feces during the first 2 years following the accident.

The long-term use of diethylenetriaminepentate (DTPA), used principally as the zinc salt, is discussed including the method, route of administration, and effectiveness. To date, the patient has apparently experienced no complications attributable to this extensive course of therapy, even though he has been given approximately 560 grams of DTPA.

CONTENTS

THE 1976 HANFORD AMERICIUM ACCIDENT

INTRODUCTION

On August 30, 1976, at 2:55 a.m., a 64-year-old nuclear chemical operator was injured by the chemical explosion of an ion exchange column used for americium recovery. The explosion occurred in a waste treatment facility operated under the auspices of the United States Energy Research and Development Administration (now the Department of Energy) in the state of Washington. The primary materials in the resin column were concentrated nitric acid, cation exchange resin, and americium. As a result of the impact of flying acid and debris, the operator sustained chemical burns of the face, eyes, neck, and right shoulder as well as lacerations and embedded foreign bodies in these areas. He was heavily externally contaminated with americium and inhaled a significant quantity of the element.

PATIENT CARE AND DATA ANALYSIS

INITIAL MEDICAL CARE AND FINDINGS

The injured operator was assisted from the scene of the accident by coworkers, who were also contaminated with americium but to a much lesser extent. A health physics technician and a fellow operator, in protective clothing and respirators, removed the operator's contaminated clothing and began decontamination by flushing his face and eyes with water. Two registered nurses assigned to the area, wearing protective equipment, continued decontamination. An ambulance designed to handle contamination cases then transported him 40 km (25 miles) to the Emergency Decontamination Facility (EDF)[a] in Richland, Washington, where he arrived about 2 hours after the accident. Upon his arrival at the EDF, 1 g of calcium diethylenetriaminepentate (Ca DTPA) was administered intravenously and the operator was decontaminated further with soap and water in a shower. Removal of superficial foreign matter from the face and neck and irrigation of the eyes with normal saline were carried out by attending physicians and nurses. Surgical and opthalmological consultations were obtained.

Physical examination revealed chemical burns of the face, scalp, neck and shoulder with more severe involvement of the right than the left side. The surfaces of the eyes were hyperemic. The eyelids were swollen and marked eyelid spasm was present. Crude testing indicated that vision was intact in both eyes. The blood pressure was 115/60 and the pulse 60/min with an occasional dropped beat (this condition had been present before the accident). The remainder of the examination was essentially normal.

(a) The EDF is a detached facility adjacent to the Richland community hospital. It was built in 1963 by the United States Atomic Energy Commission as an emergency support facility for the Hanford production site. The EDF consists primarily of a large windowless room with supporting facilities for radiation and contamination control. The room has thick shielding walls and two heavily shielded enclosures to protect attending personnel against penetrating radiation; such protection was not necessary in this case. The ventilation system provides heating and cooling, and exhausts through two banks of high-efficiency particulate air filters. All radioactive liquid wastes are collected in a holding tank. Storage space and change and wash rooms for support personnel are also present in the facility.

Administration of DTPA was continued, with several doses given daily for the first month (Figure 1). DTPA chelates americium and other heavy metals, minimizing their deposition in the body and promoting their excretion in urine.[1] Since long-term therapy with this agent was anticipated, it was deemed advisable to switch at an early date from Ca DTPA to Zn DTPA. The rationale for the change to Zn DTPA was that prolonged frequent administration of Ca DTPA has been shown to cause major bodily depletion of Zn. At high levels of administration, the adverse effects observed have been more severe in experimental animals treated with Ca DTPA than in those treated with Zn DTPA.[2-6] Zn DTPA had been used clinically abroad but had not previously been approved for human use in the United States. The United States Food and Drug Administration provided permission to use Zn DTPA in this case.

Fluid intake was encouraged to promote urinary excretion. Liquid and solid intake and output were recorded, and all urinary and fecal specimens were collected separately for radiobioassay. The chemically burned areas on

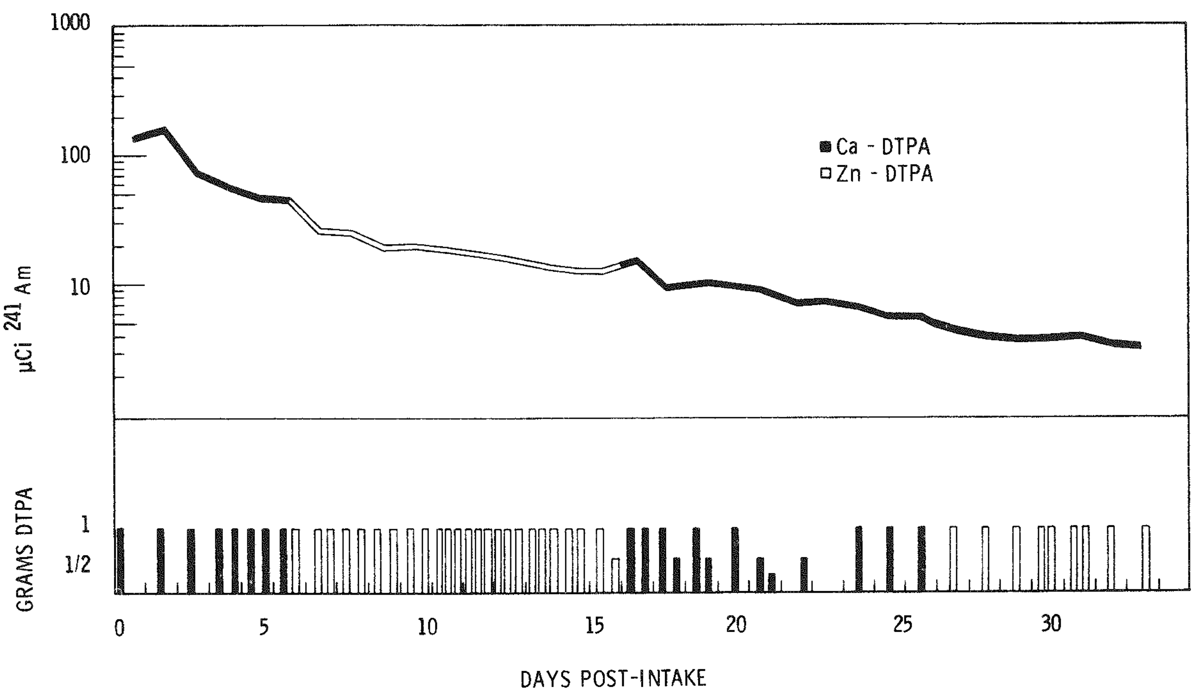

FIGURE 1. Early Urinary Excretion and DTPA Administration

the face, neck, and right shoulder were left exposed; no dressings or external medications were used. Ophthalmic steroid-antibiotic ointment was instilled into each eye several times daily.

Facial contamination was monitored during the first few days by means of alpha radiation survey meters. However, since much of the contamination was embedded in the tissues of the face, primarily about the right eye and in the wound on the forehead, it soon became necessary to use more sophisticated equipment to measure the total burden present in the face. Based on measurements made using a sodium iodide detector, about 3000 μCi of americium were estimated to have been deposited on the face, with an additional 300 μCi embedded in the facial tissues. Another detector was used to measure the 3-, 17-, and 60-keV photons. The ratio of these emissions was used to estimate an average depth of 0.7 mm for the facial deposition.

One surgical effort using local anesthesia had been attempted during the first week to remove some of the larger and more deeply embedded foreign bodies from the face; a gamma-detecting probe was used to locate the deposited material. This effort proved unsuccessful because the larger foreign bodies identified by x-ray examination were apparently no more radioactive than the surrounding skin and subcutaneous tissue.

DECONTAMINATION PROCEDURES

Decontamination procedures were undertaken twice daily for the first week after the accident; after this time, the same procedures were used once daily. During the decontamination procedure the patient, clothed in a disposable plastic suit, sat in a shower room that was filled with steam to promote sweating. The steaming was followed by a bath during which he was scrubbed and rinsed by properly protected attendants. During the bath, the patient's body was flushed with a DTPA solution[a] while he protected his eyes with soft washcloths. (Antibiotic ophthalmic ointment was applied to the eyes prior to the

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(a) Ca DTPA was used in the external decontamination solution, mixed initially in proportions of one third DTPA (25%) solution and two thirds normal saline. Later, Shubert's solution[7] (a DTPA solution with other chelates) was prepared and used for external decontamination.

bath.) The DTPA solution was flushed off with water. Detergent soap (pHisohex®) was then scrubbed on the body and rinsed off with water. Because the patient's facial skin was tender from the chemical burns, he washed his face, including the area around his eyes, using diluted baby shampoo on soft toweling. The face was then flushed and the procedure repeated several times. A Water-Pik® was used to clean the ears and the surrounding skin.

Baths as described were discontinued after 2 months, but daily showers for decontamination and general hygiene were continued. All decontamination solutions and wash liquids were collected in a holding tank, analyzed, and found to contain a total of about 4500 μCi of americium. The hair of the patient's head and eyebrows was shaved during the first week because it could not be decontaminated. The hair and eyebrows subsequently grew back normally.

LONG-TERM MEDICAL CARE AND FINDINGS

For the first 4 months, daily superficial debridement of the patient's face and neck was performed without anesthesia to remove scales, crusts, scabs, and extruded foreign bodies. The frequency of debridement was then decreased. Over a period of several months, metallic, plastic, cloth, and glass foreign bodies measuring up to 0.5 cm were extruded spontaneously or teased out with tweezers as they reached the skin surface.

An indolent superficial ulcer that occurred in the area of highest americium concentration (below the medial aspect of the right eybrow) healed after 1 year, leaving a scar. Foreign matter was spontaneously extruded from the area prior to complete healing.

During the first month after the accident, multiple daily doses of Ca or Zn DTPA were administered intravenously; the patient was then given single 1-g doses of Zn DTPA daily until July 1977, when the frequency of administration was reduced to three times per week.

Laboratory studies were conducted daily during the first 3 months and less frequently afterwards. They included complete blood counts, urinalyses, and blood chemistry (SMA 12/60) and fecal occult blood studies. The results of the studies were normal except that the peripheral blood lymphocyte count declined from 1860/mm^3 on the day of the accident to 530/mm^3 1 week later. The average lymphocyte count was 943 (range: 590-1640) for the next 8 months and 1522 (range: 728-3170) for the following 15 months. Previous lymphocyte counts had been 1520 in January 1976, 2332 in 1973, 2805 in 1970, and 3151 in 1967. Serial chest x-rays, pulmonary function tests, and electrocardiograms have shown no significant findings.

Special studies included several analyses of peripheral blood lymphocyte chromosomes, a facial skin biopsy, and a bone marrow examination. Radiation-induced cytogenetic lesions in lymphocytes were observed. (Variation in the frequency of radiation-damaged lymphocytes as a function of time after the accident will be the subject of a separate report.) The skin biopsy revealed scattered alpha "stars"; all other changes were compatible with the patient's age. The bone marrow examination was performed 2 weeks after the accident and was normal. None of these studies indicated the need for a change of therapy.

The staff pyschologist was involved early in the care of the patient and has continued to provide advice to the staff and care to the patient and his family.

After 2 1/2 months of treatment in the windowless room of the EDF, the patient was transferred to a 9-m-long (30-foot-long) travel trailer adjacent to the EDF, which provided a transitional controlled environment before his return home. While the patient, his wife, and their dog lived in the trailer, wastes were collected and measured for radioactivity, and routine surveys of the environment were made. From mid-November 1976 until his discharge home in late January 1977, no americium contamination was found in the trailer.

The principal medical problem since the accident has involved the patient's eyes, which suffered corneal nitric acid burns and contained a few superficial corneal and conjunctival foreign bodies; the latter were excised or spontaneously extruded over a period of several months. In addition, a traumatically induced cataract began to develop in the left eye several months after the accident and was surgically removed in February 1978. The cataract had none of the characteristics usually associated with radiation induction. The patient was fitted with glasses and has been able to obtain a renewal of his state motor vehicle driver's license. His visual acuity has been improved by the use of special eyeglass covers with multiple perforations that reduce distortion caused by the chemically induced corneal irregularities.

RADIOISOTOPE DOSIMETRY EVALUATION

Early in-vivo measurements were difficult to make accurately because of the gross external contamination. Interpretation of the measurements was further complicated by the fact that the intake resulted from both inhalation and solubilization of the americium embedded in the facial tissue. Special equipment and techniques that will be described in a later report were improvised, and measurements of the americium deposited in the patient's chest, liver, and bone were initially obtained 3 days after the accident.

A cone-shaped, collimated sodium iodide (NaI) detector 1 mm thick and 5.1 cm in diameter was used to measure the 241 isotope of americium in each lung and in the liver. A lead shield was placed between the patient's head and chest to eliminate scattered radiation from the face, which otherwise greatly increased the count rate in the detector.

Forty μCi of americium were measured in the lungs on day 3 after the accident, indicating a dose rate of 11 rad/day to the lungs. Subsequently, routine measurements of lung activity were made to determine the rate of clearance from the lungs (Figure 2). After 300 days, the activity remaining was largely attributed to americium in the ribs. The cumulative average dose to the lungs through 1978 was estimated to be 200 rad.

The liver burden on day 3 post-intake was 40 μCi. Clearance from the liver was rapid (Figure 3) and the activity remaining after 300 days was also considered to reside in the ribs. The DTPA chelation therapy was largely responsible for the rapid clearance, which reduced this dose rate from 7 rad/day on day 3 to less than 0.03 rad/day at the end of 1978. The cumulative dose to the liver through 1978 was estimated to be 160 rad.

Initially, the activity in a small section of bone directly below the knee cap was measured using an NaI detector, and was related to the total

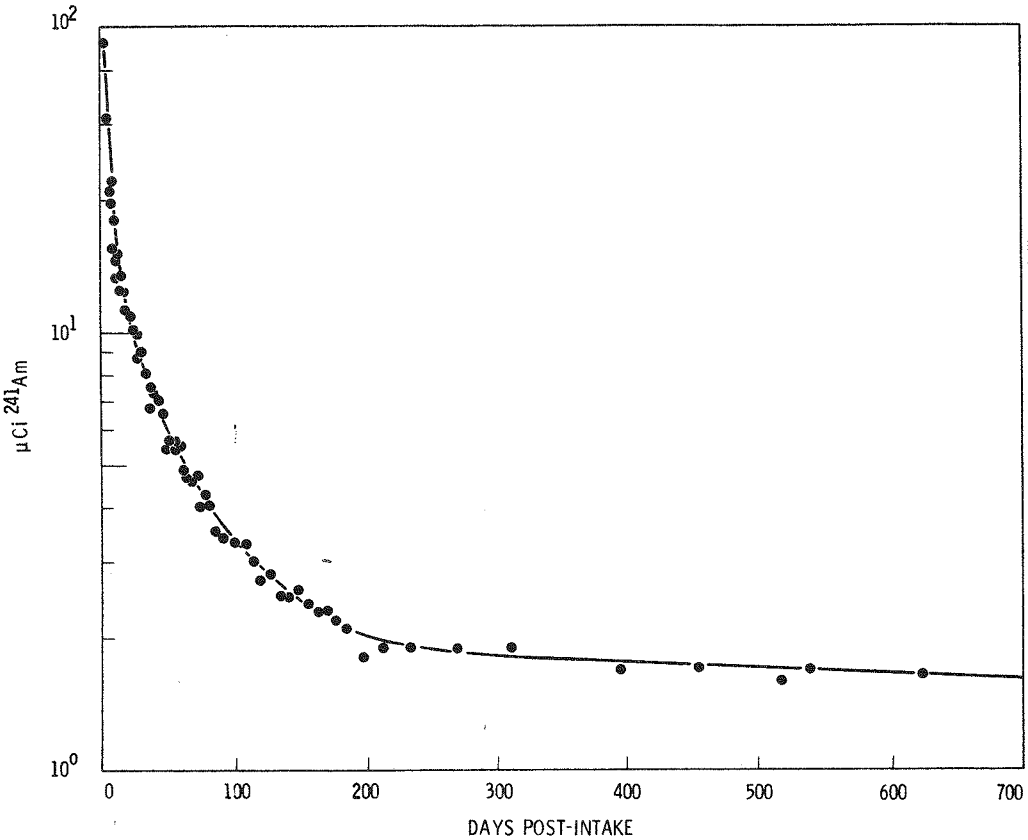

FIGURE 2. In-Vivo Chest Counts

bone burden using a model based on data from baboon studies.[8] Through this technique, the bone burden on day 3 post-intake was estimated to be 40 μCi. Subsequently, the counting procedure was calibrated by distributing americium sources uniformly on the inner bone surfaces of a cadaver leg. Using this technique, the estimated bone burden for day 3 was revised to 70 μCi, which indicates a dose rate of about 3 rad/day. By day 30 post-intake, the bone burden had decreased to approximately 25 μCi (1 rad/day) and has remained at that level. The estimated cumulative bone dose was about 860 rad through 1978, and we expect the dose to continue at a rate of 1 rad/day. Without DTPA therapy, the bone burden would be expected to increase substantially over time because of the translocation of americium from the soft tissue of the face.

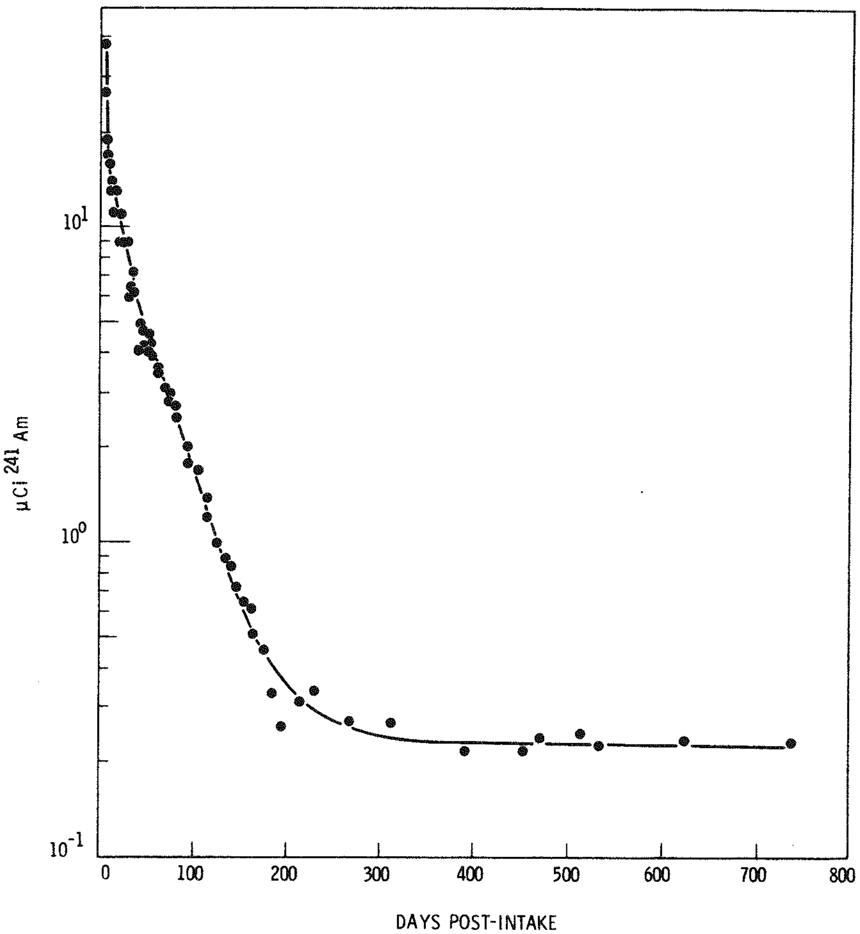

FIGURE 3. In-Vivo Liver Counts

The dose to the lens of the eye was calculated to evaluate the possibility that the cataract that developed was due to radiation. The maximum initial dose rate of about 4 rad/day decreased sharply with time. The estimated cumulative dose to the lens of the eye was 140 rad through 1978. This is significantly less than the 500 rad or more associated with cataract formation.

BIOASSAY DATA AND EFFECTIVENESS OF DTPA THERAPY

All urinary and fecal specimens were collected and analyzed for americium content prior to the patient's discharge home and, subsequently, on an intermittent basis. Treatment with DTPA, which was started within 3 hours of the accident and has continued ever since, drastically alters the usual patterns of americium excretion. Therefore, the bioassay data could not be used to estimate the systemic burden. However, these data were useful in determining the effectiveness of the DTPA therapy and the need for continuing treatment.

The amount of americium initially available for deposition in the body may be estimated by adding to the amount excreted in the urine and feces the quantity estimated to remain in the bone, liver, and facial skin. The calculated total is about 1100 μCi of americium. (See Table 1 for a summary of the deposition and excretion data.) Using models derived from animal experimentation, we estimate that a total of 760 μCi would have been deposited in bone and liver if DTPA therapy had not been available. Since only about 25 μCi were retained (see Figure 4), we believe that the DTPA was better than 95% effective in reducing the anticipated body burdens. The early data on urinary excretion, shown in Figure 1, indicate that Zn DTPA was as effective as Ca DTPA in the decorporation of americium. Neither clinical nor laboratory findings showed evidence of toxicity from the use of DTPA.

TABLE 1. Fate of Americium in Microcurie Quantities

	Time Post-Intake					
	Day 1	Day 3	Day 10	Day 60	1 Year	2 Years
Burdens						
Facial skin	3000	--	300	150	35	20
Chest	--	40	15	5	2	1.5
Bone	--	70	30	25	25	25
Liver	--	40	16	4	0.2	0.2
Cumulative Excretion						
Urine	150	400	600	840	880	890
Feces	0	130	180	185	190	200

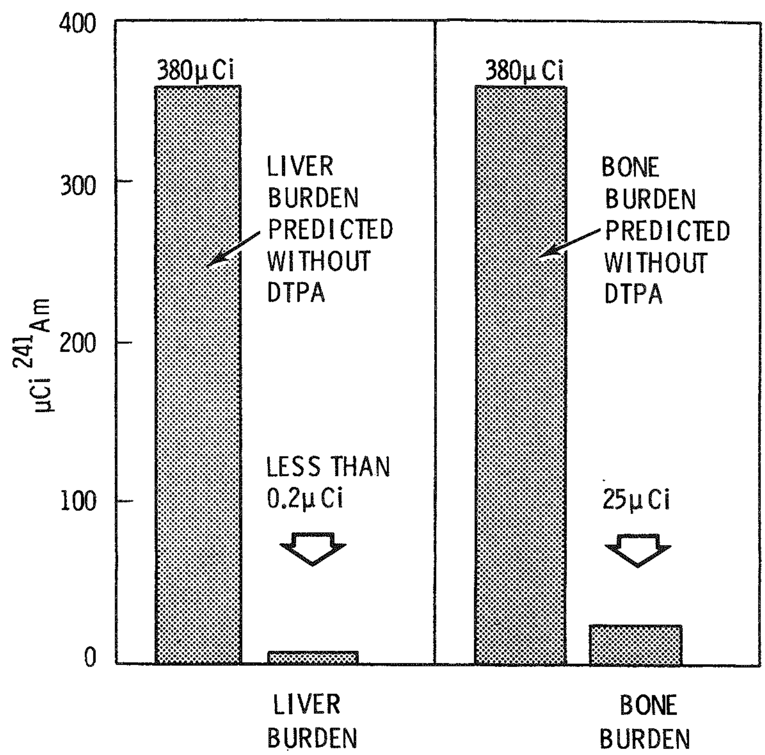

FIGURE 4. Effectiveness of DTPA in Reducing Liver and Bone Burdens.

CURRENT CLINICAL STATUS

More than 2 years after the accident, the patient is experiencing no symptoms definitely attributable to the radiation exposure. There is no evidence of functional impairment in the bone, lung, or liver; the cumulative doses to these organs are, respectively, 860, 200, and 160 rad. The patient continues to have visual difficulty as previously outlined, but the condition is stable.

CASE MANAGEMENT

TEAM APPROACH TO DECISION-MAKING

A team approach was used to arrive at decisions regarding treatment and arrangements for the patient's care after his discharge. The team, which consisted of the patient, staff and consulting physicians and radiobiologists, the staff psychologist, health physicists, nurses, and radiation monitors, met frequently and many of the procedures and methods used were based on the consensus of the assembled group. Including the patient in the decision-making process was invaluable, not only in obtaining his concurrence in the choice and application of procedures but also in giving us the benefit of his knowledge, based on his long experience in the industry. His understanding, willing cooperation, and concern that his experience benefit others were exemplary.

PUBLIC RELATIONS

The case aroused national and international interest, both in the scientific community and in the communications media. In the days immediately after the accident, time demands by the media were great and required careful control to prevent interference with the proper care of the patient. The situation was further complicated by the need to secure the patient's privacy and prevent the dissemination of privileged information. From the beginning, public relations professionals worked closely and effectively with the medical and scientific staff. The importance of carefully organizing the public relations aspects of such an emergency cannot be overemphasized.

CONCLUSIONS

1. Unusually high levels of americium deposition have not caused any demonstrably harmful effects in the patient during a 2-year period of observation.

2. Prompt and intensive chelation therapy proved extremely effective in this case. Zinc DTPA appeared to be as effective as Ca DTPA in removing americium from the body and preventing its translocation. No toxicity from the DTPA therapy was observed over a 2-year period.

3. The "total" person must be treated. Not only medical and health physics concerns must be considered, but also psychological effects, the impacts on the responses of family and friends, and the effects on the patient of extended inactivity.

4. The use of a team approach to decision-making was highly successful and helped surmount the many difficulties encountered in this case.

5. The use of a transitional discharge regime (EDF - trailer - home) was beneficial psychologically and assured adequate control of contamination from bodily sources (i.e., contaminated skin flakes or scales, and excretion products).

6. Careful organization of the handling of public relations under the stress of an emergency is well worth the effort.

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Many scientists and health professionals at Hanford and across the United States contributed valuable recommendations on the management of the case. Individual contributions will be acknowledged in several papers being prepared for publication in the near future. We also wish to acknowledge the cooperation of the patient, who throughout his long and trying experience has done everything possible to ensure that his experience will be used to benefit others in the future.

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