This paper proposes a regional approach to the management of radiation accidents, by using a regional treatment center together with the resources of supporting facilities.

A REGIONAL APPROACH TO THE MANAGEMENT OF RADIATION ACCIDENTS

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Introduction

Radiation accidents, as compared to other industrial accidents, are characterized by their infrequency and complexity. Few physicians and hospitals have experience in the care of these patients. With the increasing use of nuclear radiation sources in medicine, industry and research, the medical profession needs to take a fresh look at its preparedness to manage the many facets of radiation accidents.

The infrequency of major radiation accidents is exemplified by the experience of the Atomic Energy Commission. Between 1943 and 1967, there were 3 fatalities due to radiation exposure, compared to 273 accidental deaths due to other causes. During this period there were 35 workers involved in lost-time accidents, of which 24 showed clinical manifestations attributable to radiation; 2 people in this group were permanently disabled due to their radiation injuries. Three patients had digits amputated because of deposition of plutonium which could not be otherwise removed.1

In 1967, three research assistants, while working with a Van de Graaff electron generator, received mean radiation doses of about 600, 400 and 100 rads.2 Subsequently they developed systemic and local signs of radiation injury. The patient who received 600 rads was treated with bone-marrow transplant from his identical twin brother. This was probably a major factor in saving his life. However, necrosis in his massively exposed distal extremities necessitated amputations.

Between 1957 and 1966, five cases of an overdose of medically administered radionuclides have been reported. Two of these resulted in an acute radiation syndrome with severe hematopoietic depression.3

It is true that there has not been a drastic increase in major accidents in recent years. However, it can be anticipated that non-life threatening accidents and suspected exposures will happen more often. These, too, must be handled expertly.

Sources of Radiation Exposure

As we were trying to approach the problem of accident preparedness in our area, the mid-Atlantic region, we conducted a survey of the numbers and kinds of radiation sources present, and analyzed the types of potential exposures.

Within about a 250-mile radius of Philadelphia there are in operation, under construction, or planned for the 1970s, thirty-five nuclear power reactors. There are 20 research reactors located
Approximately 150 major industrial firms produce or utilize ionizing radiation. For example, one company has an inventory of 15,000 curies of Iridium-192 and 15,000 curies of Cobalt-60 for the manufacture of gamma sources used in industrial radiography. There is a nuclear fuel reprocessing plant in the area. Within this region are eight large accelerators. Finally, there is an untabulated number of medical facilities using radionuclides in diagnosis and treatment.

It was clear that a potential for small or large accidents involving radiation workers was present, and that there was a definite need for a reorientation as to the medical needs created by this situation.

Types of Radiation Exposure

From a medical point of view, radiation accidents can be classified according to the source relationship to the patient and to the clinical picture evoked by this relationship (Figure 1).

**Whole Body Exposure**

The usual result of irradiation by a large radiation source outside and not in contact with the body is whole body exposure. This kind of exposure may occur in criticality accidents or with large x-ray or gamma sources. These patients are not in themselves radioactive. They do not constitute a hazard to the attendants. Clinically, whole body exposure is characterized by the appearance of signs resulting from a depression of the hematopoietic system: general weakness, decreased resistance to infections, and increased bleeding tendency. With low doses, i.e. under about 100 rad, these signs (if any) will be minimal. With very high doses, i.e. over about 1,000 rad, the clinical picture is entirely determined by extensive anatomical and functional damage of the gastrointestinal tract, leading to a severe and practically irreversible disturbance of the electrolyte equilibrium in the body.

**Partial Body Exposure**

In partial body exposures, the source is usually very near the body. In this type of exposure, for obvious reasons, the affected parts of the body (usually the extremities) receive a much higher dose than the rest of the body. An example of this situation is the industrial radiographer who attempts to manually return a radiation source to its shielded storage. In other situations, severe finger exposures can occur during the adjustment of an x-ray diffraction apparatus.

The clinical picture of local radiation injury consists of erythema, edema, vesiculation and, with high doses, tissue necrosis.

**External Contamination**

The presence of radioactive materials on the body or clothes is external con-
tamination. In the absence of other external exposure to penetrating radiation, external contamination represents predominantly a risk to the skin, as the dose to superficial layers of the body is much higher than that to deeper-lying organs. From a practical point of view, externally contaminated patients represent a risk to both attendants, and the medical facility itself, because of possible spread of radioactive materials.

**Internal Contamination**

Inhalation, ingestion or absorption of radioactive materials causes internal contamination. Depending upon the biochemical behavior of the nuclides concerned, these materials will either be deposited throughout the entire body, or be concentrated in specific organs. In the great majority of cases, the total body dose will be too low to cause an acute radiation syndrome, but the dose to the organs in which radionuclides are deposited may be appreciable. Unlike the externally contaminated patient, the patient with an internal contamination is not a hazard to other people or to the hospital. The amount of radioactivity excreted in feces and urine is usually too small to present a hazard. The diagnosis and treatment of internally deposited radionuclides, however, is a special problem in itself.

**Special Cases**

*Special cases* are those in which a combination of exposures, or the existence of concomitant non-radiation injury, require complex measures to ensure both optimal medical care and protection of attending personnel. An example of a special case is the patient who, as a consequence of an explosion involving radioactive materials, has a radioactive foreign body embedded in his abdomen.

**Management of Radiation Accidents**

It is evident that all types of radiation accidents can create severe demands on any hospital, even the best equipped and staffed medical center. Those created by the presence of external contamination are the most complicated ones to manage, because there is not only a potential hazard to attendants, but the risk of spreading radioactive materials is very real and could inevitably result in a functional and economical loss to the hospital. Unpreparedness may lead to an unjustified “radiation scare” and over-rating of the real dangers involved. Thus, a minor problem could be parlayed into a major disaster.

Furthermore, the diagnosis, prognosis and treatment of radiation injuries require skills, expertise and equipment not present in most hospitals. Preparing all medical facilities to manage radiation accidents, is virtually impossible, and economically unsound.

We concluded that the only reasonable and practicable course of action would be to develop a regional approach to the management of radiation accidents.

**The Regional Approach**

In this approach, three levels of medical care are envisioned (Figure 2). (1) first aid at potential accident sites; (2) emergency medical care and initial evaluation at nearby hospitals; (3) definitive evaluation and treatment at a regional Radiation Medicine Center.

The regional center assumes the responsibility for the total medical management of any radiation accident, i.e. acts as the central control point from which all required actions are directed and coordinated. Medical and health physics services and emergency assistance are supplied from this center. An Emergency Medical Assistance Plan (EMAP) designed in close cooperation with all parties involved, coordinates the medical...
resources in the region to manage an accident. Periodic visits and exercises ensure that accident preparedness is kept in a high state of readiness. Special attention is given to an effective system of communications to implement the assistance plan at all hours. Pre-planned means of transportation, air and ground, are available round-the-clock. Pilots and ambulance drivers have been instructed in the special problems connected with transportation of contaminated patients.

Above all, we felt that a clear and logical assignment of duties and responsibilities, wilfully accepted by everyone concerned, was an absolute necessity for a workable plan. Recognizing that nothing wears off faster than proficiency unused, we have kept the development of special skills and knowledge at plant sites and supporting hospitals at a minimum. Instead, we rely on the availability of a regional Radiation Emergency Medical team to assist these outlying areas.

The Regional Radiation Medicine Center

The development of a Radiation Medicine Center, able to exercise the functions outlined above, is a time-consuming, complex and costly process. As the facilities and equipment required for such a center would only rarely be used for major accidents, they should be designed with a dual purpose in mind.

In order to manage any type of radiation accident, the center should have available:

1) a Radiosurgery Decontamination Suite;
2) a Radiation Exposure Treatment Suite;
3) a Radiation Exposure Evaluation Laboratory;
4) a Radiation Emergency Medical Team;
5) a means for transportation of contaminated patients.

A Radiosurgery Decontamination Suite is an area in which decontamination and major surgery can be performed on a radioactively contaminated patient. Because of cross contamination with resulting loss of the area during clean-up operations, the regular surgery suites or emergency room should not be used for contaminated patients. The area chosen should have direct access from the outside. Access and egress to and from the area should be easily controlled (Figure 3). The suite should have abundant water supply and showers for decontamination of patients and attendants. A system to either filter or collect contaminated water and air is necessary. The suite with shields to protect attendants from unnecessary exposure should be able to sustain a major surgical procedure. Finally, non-availability of the area for a few days or more during clean-up should not seri-
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ously hinder normal hospital operations.

At the Hospital of the University of Pennsylvania, we have established a Radiosurgery Decontamination Suite in conjunction with the Physical Medicine and Rehabilitation Department. With minor modifications the Hubbard Hydrotherapy tank with movable shields is used as an operating table. Extra doorways to adjacent rooms have been constructed to establish a traffic-flow pattern which minimizes the spread of contamination. A water purification system has been designed and installed.

The Radiation Exposure Treatment Suite is meant for treatment of the patient who has received a serious overexposure to radiation. Such a patient is primarily a problem in management of infection, bleeding and electrolyte balance. His treatment requires special facilities, equipment and techniques. In particular, these include (1) reverse isolation, (2) bone-marrow transplant and (3) white blood cell separation and transfusion.

At the University Hospital, we are installing a laminar air flow reverse isolation suite and a cell separator. In conjunction with the Hematology Department, the Radiation Medicine Center is initiating a bone-marrow transplant program which will utilize these facilities. This program insures that, if the need arises, the techniques and facilities to treat the overexposed patient will be immediately available.

The Exposure Evaluation Laboratory consists of high and low level radiochemistry and counting facilities, a mobile shadow shield whole body counter, emergency film processing and TLD systems. Phantom mock-up and instrument calibration are additional capabilities. The laboratory is equipped for complete bioassay and environmental radionuclide analyses. Determination of chromosome aberrations in lymphocytes to give a biological indication of the absorbed dose is a necessary adjunct to physical dose evaluation.

A “Radiation Emergency Coordinating Committee,” on which there is a member from the Departments of Radiology, Hematology, Medicine, Surgery, Nursing and Hospital Administration, periodically reviews procedures, equip-

Figure 3—Traffic pattern for control of contamination

PATIENT

Decontamination → Treatment

Control

Change Administration
Storage

Decontamination ← Treatment

Control

Change Administration
Storage

ATTENDANTS
ment and treatment methods for handling accidents. It is also engaged in designing and conducting exercises to ensure a high state of readiness.

To insure continuity of patient management, the medical and health physics resources at plant sites and supporting hospitals are coordinated with those of the Center at the Hospital of the University of Pennsylvania. A Radiation Emergency Medical Team (REM Team) consisting of qualified physicians and health physicists is available on a 24-hour basis to assist plant sites and supporting hospitals in radiation accidents involving personnel. The team’s equipment consists of emergency medical and decontamination supplies, and portable health physics instrumentation for area monitoring and for field analysis of environmental and biological samples.

The transportation of highly contaminated patients from accident sites to a hospital requires special procedures and equipment. These include cocoonizing material (plastic sheets) and shadow shields to control the contamination of the vehicle and protect the vehicle operator and medical attendant from an overexposure. In our region, we have equipped and trained ambulance units and helicopter companies to assist us in evacuating this type of patient.

**Plant Sites and Supporting Hospitals**

Within the framework of a regional plan and a Radiation Medicine Center, the requirements and responsibilities of plant sites and nearby hospitals can more easily be defined. The plant or laboratory site should be equipped and trained to administer first-aid, perform initial gross decontamination, and prepare the patient for evacuation.

As a minimum, the supporting hospital should perform resuscitation and stabilization, continue simple decontamination, evaluate the patient, and prepare him for further evacuation. To do this, the hospital should have:

1. an isolated area to which to admit the patient;
2. a means to identify gamma radiation from contamination;
3. simple procedures to use time and distance for controlling attendant exposure;
4. procedures to confine all personnel and equipment in the area to control spread of contamination;
5. assistance of the Center’s REM Team to evaluate the patient and conduct clean-up operations.

It is anticipated that some hospitals are already staffed, equipped and interested in more extensive care of radiation accidents. In this case, only close coordination with the Radiation Medicine Center would be required so that they would know what additional consultative and laboratory services are available to them.

**Conclusion**

In our conviction, a regional approach to the management of radiation accidents represents a feasible and practical answer to a major challenge associated with the nuclear age. By coordinating the medical response of a regional treatment center with those of supporting hospitals and potential accident sites, this plan appears to be the most effective means of discharging the nuclear community’s obligation to the public, and the medical profession’s responsibility to the nuclear community.

**REFERENCES**

Cross-Cultural Study of Aggression and Crime

Dr. Martin G. Allen, assistant professor of psychiatry at Georgetown University, has completed a cross-cultural study of aggression and crime. He rated the expression of adult aggression for 57 cultures and the incidence of crime-delinquency in 49 of these cultures. The ratings were, in turn, correlated with ratings of adult ego strength, and with variables of childhood experience and of social structure. Aggression was defined in terms of whether it was direct and appropriate, or indirect and displaced onto a substitute object.

Dr. Allen found that high frequency of crime will tend to occur in societies with high levels of indirect, displaced aggression, large extended families, and child training emphasizing high achievement and high sexual satisfaction. On the other hand, child training in responsibility, self-reliance, and other measures of childhood satisfaction and anxiety (including aggression) are not associated with crime.

Other findings show that directness of aggression is associated with high productivity and creativity, low anxiety, low deviance-conformity, and low incidence of crime, suicide, and mental illness. The more direct the aggression, the lower the rate of crime. (Georgetown University, 37th and O Streets, N.W., Washington, D. C. 20007.)