Acute Radiation Injuries in Disaster Situations

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ACUTE RADIATION injuries do not present symptom complexes markedly different from those that the physician sees in his everyday practice. To suggest the methods and procedures that might be practical in an emergency, the therapy for such injuries described in existing medical and technical literature has been modified to fit a disaster situation in which there is a marked disparity between the need and the availability of resources and personnel. These recommendations are in line with accepted concepts of disaster medical treatment. The paper is concerned solely with acute exposure; chronic exposure or its effects are not discussed.

Radiation Injury

To recognize and treat acute radiation injury, little has to be known about radiation itself. Radiation involves energy. This energy can penetrate materials and can be transferred to these materials. This transfer may or may not have recognizable effects, depending on the material affected. In the human body, radiation injures to some extent all tissues with which it comes in contact. Some tissues are relatively resistant while others are relatively sensitive.

In event of acute radiation exposure of an individual some of the mature cells comprising his tissues may be killed outright; other mature cells may be injured to the extent that their function or survival is compromised; and some developing cells, not yet functional, may be slowed or halted in their development or killed. For any given organ system or tissue, outward appearance of health will continue until the aggregate loss of functioning cells is sufficient to interfere with the essential function of the specific organ or tissue; then symptoms will develop. If the failure is only temporary and the individual can be helped through the period of maximum tissue or organ system depression, then he may survive and recover.

The whole symptom complex is called the acute radiation syndrome. For a given acute dose of radiation that exceeds the clinical threshold dose for more than one organ system, the major factor is the injury effect on that essential organ system with the shortest latent period (the period between the prodromal stage and manifest illness). If the patient survives a first series of symptoms, he must still contend with a subsequent series, arising from injury to organ systems having longer latent periods. As a rule of thumb, the higher the dose required to produce symptoms from a particular organ, the shorter is the latent period and the more lethal the syndrome.

The three principal systems that react symptomatically in the acute radiation syndrome are:

Hematopoietic system—latent period of 10 to 20 days; may be lethal, depending on dose, treatment, and inherent radiation sensitivity of the patient.

Gastrointestinal system—latent period of 5 to 8 days; frequently lethal.

Central nervous system—latent period of ½ to 3 hours, but may be absent; invariably lethal.

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Intensive study of various nuclear criticality accidents and other human exposures has verified the desirability of classifying the acute radiation syndrome in this manner. It should be emphasized that these system manifestations of acute radiation injury are not unique. We could term them bone marrow depression, severe gastroenteritis, and encephalitis and still be essentially accurate. In other words, these symptom complexes are ones that the average physician sees on occasion in his everyday practice.

From the clinical point of view, the radiation injury patients fall into five general injury groups.

GROUP 1 (whole body dose up to approximately 200 rad). Most patients in this group are completely asymptomatic, although a few have minimal early complaints. Psychological reactions not related to physical damage may be present. Significant blood changes may occur in a small fraction of this group, and probably less than 5 percent will require medical care.

GROUP 2 (whole body dose of approximately 200 to 400 rad). These patients show a variable form of the syndrome. After early appearance of nonspecific symptoms, there will be laboratory and clinical evidence of bone marrow depression. Most of these patients will survive.

GROUP 3 (whole body dose of approximately 400 to 600 rad). Patients in this group will show severe bone marrow depression with serious complications. Some evidence of gastrointestinal damage may be seen, especially at the higher dose level. Many of these patients will not survive.

GROUP 4 (whole body dose of approximately 600 to 1,400 rad). This group will exhibit an accelerated version of the acute radiation syndrome. Gastrointestinal complaints are the most outstanding feature of their illness. The severity of the hematologic changes is related to the length of survival time. These patients will succumb.

GROUP 5 (whole body dose above 1,400 rad). These patients have received a lethal injury. Their clinical course may be marked by central nervous system impairment. No survivors should be expected.

It should be remembered that the approximate dose and the associated prognosis just stated refer to normal peacetime conditions in well-equipped hospitals prepared for the care of radiation injury cases. A dose of 800 to 1,000 rad is usually lethal in these situations despite any currently available therapy. In time of large-scale disaster, where resources and personnel are in short supply, the lethal dose may drop sharply. The imposition of additional injuries and illness, unrelated to radiation, will further depress this lower limit.

The doses producing the effects described previously are not known with accuracy; the ranges stated are approximate and based upon best available evidence. Biologically, persons may vary considerably in sensitivity to radiation injury and this factor should be taken into account.

Other Sources of Information

Further information concerning radiation, radiation injury, and disaster medical care may be obtained from the following sources.

U.S. Atomic Energy Commission: Living with radiation—fundamentals. U.S. Government Printing Office, Washington, D.C., price 45 cents.

U.S. Atomic Energy Commission: Eighteen questions and answers about radiation. U.S. Government Printing Office, Washington, D.C., price 25 cents.

National Academy of Science–National Research Council: The biological effects of atomic radiation—summary reports—1960. Printing and publishing Office, 2101 Constitution Ave. NW., Washington 25, D.C., free.

Gustafson, P. F.: Assessment of radiation dose due to fall-out. Radiology 75: 282 (1960).

Bond, V. P., Fliedner, T. M., and Cronkite, E. P.: Evaluation and management of the heavily irradiated individual. J. Nuclear Med. 1: 221, October 1960.

Gerstner, H. B.: Acute clinical effects of penetrating nuclear radiation. J.A.M.A. 168: 381 (1958).

Thoma, G. E., Jr., and Wald, N.: The diagnosis and management of accidental radiation injury. J. Occup. Med. 1: 421 (1959).

Medical aspects of civil defense. (Series of special articles reprinted from J.A.M.A.) Council on National Emergency Medical Service, American Medical Association, 535 North Dearborn St., Chicago 10, Ill.

National Committee on Radiation Protection and Measurements: Exposure to radiation in an emergency. Report No. 29. Section of Nuclear Medicine, Department of Pharmacology, University of Chicago, Chicago 37, Ill., price 50 cents.

The acute radiation syndrome has four stages.

Prodromal stage. This stage usually occurs up to 6 hours after exposure and is characterized by various degrees of anorexia, nausea, vomiting, malaise, fatigue, and sweating. Symptoms and signs reach maximal severity in 6 to 8 hours, and then gradually subside during a period of 24 to 48 hours. These manifestations can be influenced by and can mimic the psychosomatic manifestations which may be present in disaster situations. Groups 4 and 5 patients usually are affected within 1 hour after exposure, groups 2 and 3 patients by 2 hours, and group 1 patients within 4 hours. Early development of symptoms may not always be a reliable index to the extent of radiation injury because of the psychological factors previously noted. Patients in groups 3, 4, and 5 may show conjunctivitis, skin erythema, and paresthesias during the prodromal period. If at all possible, early laboratory studies should include a relatively complete blood count (white blood cell count, absolute lymphocyte count, red blood cell count, hematocrit, platelet count). The lymphocyte count is the most important, and the platelet count next. A lymphocyte count above 1,500 at 24 hours after exposure usually means that injury is relatively slight, while a count below 1,200 usually indicates some hematopoietic damage. If serial counts are possible, a drop of 50 percent within 24 hours from the initial count has the same significance as a single count below 1,200.

Latent period. Following remission of prodromal symptoms, there is a period of well-being lasting a variable length of time. Patients in group 2 or 3 may be capable of some beneficial activity, although patients in group 4 and those in group 3 who received a radiation dose in the upper portion of the range may well exhibit marked fatigue. Group 5 patients will often have no latent period, as the prodromal stage may merge with the manifest illness stage. The latent period will vary with dose and thus with injury group: minutes to hours in group 5, 3 to 6 days in group 4, 7 to 14 days in group 3, and 16 to 20 days in group 2. Group 1 patients will have no further symptoms. If facilities are available, further blood studies should be done at intervals, including white blood cell and platelet counts. The sedimentation rate may provide the first clue to infection and the onset of the third stage.

Manifest illness. Evidence of the various symptom complexes becomes apparent. Group 5 patients show central nervous system signs and symptoms accompanied by prostration, shock, skin erythema, diarrhea, and vomiting, proceeding to coma and death. Patients in group 4 have primarily gastrointestinal symptoms, with nausea, vomiting, and diarrhea reaching massive proportions. There is a slough of virtually the entire intestinal mucosa. If these patients survive the resulting tremendous fluid and electrolyte imbalance, they must still contend with severe hematopoietic derangement. They may exhibit purpura, hematuria, overwhelming infection, and septicemia before their demise.

Groups 2 and 3 patients may exhibit systemic evidence of infection, such as fever, chills, headaches, and sore throat. About this time, temporary epilation will begin, usually preceded by scalp pain for 1 to 2 days. Bleeding from the gums and into the skin may occur, with ulceration of the pharynx. In more severe cases bleeding from various orifices will occur. Frank infections develop.

Group 3 patients will show these symptoms to a more severe extent than patients in group 2. Some patients in group 3, after about 2 weeks of illness, begin to develop gastrointestinal symptoms, with cramps, distention, bloody diarrhea, and prostration. When this occurs, the prognosis is extremely poor. Laboratory tests will provide little information that will not be evident from the clinical course. If the total white blood cell count falls below 1,000, however, the patient should be considered to be in group 4 or severe group 3.

Recovery. This will occur only in patients in groups 1, 2, and those in group 3 who received a radiation dose in the lower part of the range. Group 1, of course, will recover after cessation of the prodromal period. Remission of symptoms may begin at about 30 to 40 days after exposure in groups 2 and 3. A number of these patients will have persistent weakness up to 6 months or longer. Otherwise, physical recovery appears to be complete, except for possible prolonged sterility. An increasing platelet count

at 27 to 30 days after exposure is considered a good omen.

Treatment

The symptoms and signs of radiation injury are not new. They are present in several types of illnesses encountered in the average medical practice. All that is different, basically, is the cause. Treatment is nonspecific and consists largely of symptomatic and replacement therapy. With these general principles in mind, more detailed recommendations can be given.

Group 1 patients. No treatment other than reassurance is necessary. Mild oral sedatives, such as sodium phenobarbital, or tranquilizers might be helpful, if available. Antiemetics and antidiarrheal agents can be useful. Fluid replacement may possibly be indicated. Tea, coffee, or a similar fluid can be used, or a simple electrolyte replacement solution containing 1 teaspoonful of salt (3 gm.) and ½ teaspoonful of baking soda (1.5 gm.) per quart of water can be prescribed for consumption ad lib.

Group 2 patients. In the prodromal stage, treatment is the same as for group 1. With the onset of manifest illness, rest and good nursing care are beneficial. Close adherence to adequate sanitation and good personal and facility cleanliness is important. Nutrition and fluid balance should be maintained as well as possible. The simple electrolyte replacement solution suggested for group 1 is also ideal for patients in group 2. Available antibiotics should be used when indicated for specific infection but not for prophylaxis. Local measures, such as incision and drainage, are also appropriate. Fresh whole blood would be of help in treating red cell, platelet, and white cell blood deficiencies, but may not be available. Usually reliance will have to be placed on the avoidance of infections.

Group 3 patients. Treatment will be basically the same as for group 2. If gastrointestinal complications ensue, the likelihood of a patient surviving under disaster conditions is remote.

Group 4 patients. Little can be done in a practical way for these patients. The requirements for massive fluid replacements alone present a terrific therapeutic problem. Basic general care to keep the patient as comfortable as possible is advised, and sedatives or tranquilizers may be helpful, if available.

Group 5 patients. These patients have received a lethal injury. Basic general care to keep the patient as comfortable as possible is advised.

Fallout Contamination

Before specific treatment can be started, some orderly procedure for the handling of patients must be developed. It will be necessary to set up four controlled access areas: evaluation or sorting area, decontamination area, medical treatment area, and disposition area. The physician should make use of all who are able to give service and should delegate to allied health professionals the routine patient care.

People exposed to radioactive fallout do not become radioactive in any practical sense. They only have radioactive materials in or on them. It is thought unlikely that any individual survivor will accumulate enough radioactive material (fallout) on himself to become seriously hazardous to other people by the time of admission to a medical facility. However, fallout particles are essentially dust, and dust can be spread about by contact or through the air. If decontamination procedures are not possible, a treatment area might become contaminated, thus forcing evacuation of patients and personnel for a period of time. Certain procedures should be followed, therefore, to avoid this situation.

All patients should be monitored in the sorting area before they enter the treatment area. Anyone who is contaminated should be sent to a decontamination area immediately.

In disasters, usable water supplies may be limited. Therefore, basic reliance for decontamination may have to be placed on removal of the clothing and firm wiping or brushing of the exposed skin surfaces. Hair is an excellent collector of dirt and dust and, therefore, of fallout particles. The hair should be thoroughly brushed and, if necessary, clipped. Crease areas of the body also are important and should be conscientiously cleaned. Eyelids and mouth should preferably be rinsed with saline solution, if possible, or with water.

If adequate uncontaminated water supplies happen to be available, then detergent and water

showers with thorough scrubbing of the body and washing of the hair is the procedure of choice.

If a patient is so injured that he cannot perform the decontamination procedures himself, the decontamination personnel must do them for him. Open wounds should be covered during the decontamination activities and then prepared as well as possible for secondary closure later. Preferably this is done by flushing with water, making sure the edges are spread.

The decontamination procedures must not injure the skin. They should be continued until the patient is as free from contamination as possible. Exit from the decontamination area should be at the opposite side from the entrance.

The need for protective clothing and careful procedural techniques for the decontamination personnel is obvious. Ideally, the entire body should be covered, and a mask used. All protective clothing should be removed and personal decontamination effected before going into "clean areas." If possible, separate shower or wash-water drainage and separate storage facilities for contaminated clothing and decontamination material should be provided. Ideally, the decontamination facilities themselves should be removed from the medical treatment and sorting areas.

Summary

Not much has to be known about radiation in order to recognize or treat radiation injuries in a disaster situation. No new symptoms or signs are present that have not been observed in ordinary clinical practice. This is not a mystery disease.

Little can be done for patients in the immediate period after exposure, except for reassurance, sedation, and, possibly, minimal fluid replacement. Patients who show radiation-induced skin erythema or conjunctivitis during the prodromal period usually will not survive under austere disaster circumstances. A drop in the absolute lymphocyte count to very low levels during the first few days after exposure also indicates poor prognosis. Appearance of definite central nervous system signs usually indicates a fatal course. Recurrence of diarrhea after the fourth day also usually means the patient is unlikely to survive. If infections and bleeding precede epilation, the course is more severe. Treatment will be essentially symptomatic and replacement in character, consistent with available resources.

Fallout contamination can be removed without significant hazard to decontamination personnel. A detergent and water shower with thorough scrubbing is the method of choice. However, in most situations, removal of clothing and firm wiping or brushing of the body will have to be relied upon, since adequate water supplies may not be available. Work techniques in the decontamination area should be strictly controlled to prevent spread of contamination to "clean areas."

Mouth-to-Mouth Resuscitation

And when Elisha was come into the house, behold, the child was dead, *and* laid upon his bed.

He went in therefore, and shut the door upon them twain, and prayed unto the LORD.

And he went up, and lay upon the child, and put his mouth upon his mouth, and his eyes upon his eyes, and his hands upon his hands: and he stretched himself upon the child; and the flesh of the child waxed warm.

Then he returned, and walked in the house to and fro; and went up, and stretched himself upon him: and the child sneezed seven times, and the child opened his eyes.—*II Kings 4:32–35.*