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Three Mile Island: Medical and Public Health Aspects of a Radiation Accident

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Synopsis Abstract

The March 1979 accident at Three Mile Island provided physicians specializing in radiation medicine an opportunity to observe the field under conditions never seen before. Since no injuries occurred at the site or within the community, medical personnel were immediately involved in efforts to allay fear, provide accurate information, and replace labortory resources rendered ineffective by the release in the reactor building. Valuable insights concerning medical emergency planning are derived from the accident; suggestions are made for handling any future mishaps.

March 28, 1979 6 : 2 0 a.m.

"Hello. This is Dr. Brennan, Radiation Management Corporation."

"Dr. Brennan, this is the control room at Three Mile Island Nuclear Reactor. We are having a problem and have declared a site emergency." (*no anticipated off-site releases*)

"Have there been any injuries?"

"No. Nobody has been injured, but we want to alert your Radiation Emergency Medical Team just in case."

"Good! We will place our Emergency Medical Assistance Program on standby."

"Thank you. Good bye."

Radiation medicine, the radiological "sub-specialty" concerned with the diagnosis and treatment of radiation injuries, occupies an unusual place in medicine. Although the use of ionizing radiation in medicine and industry has grown tremendously since World War II, the handful of physicians actively involved in this field treat very few patients. Yet as the use and concentration of ionizing radiation increase, the need for competent medical surveillance of these sources becomes increasingly evident. What is required is definitive planning to cope with potential radiation injuries to occupational people, hospital personnel, and/or persons living near a potentially hazardous source.

Discussion of a response program for medical treatment of radiation injuries can only be considered after understanding some basic concepts concerning the nature of such injuries:

First, radiation injuries are seldom, if ever, life-threatening. Massive doses of radiation are required before irradiation becomes fatal. As exposure to radiation is usually measured and reported in dose rates expressed as rem or millirem per hour (1000 millirem=1 rem), the intensity of the exposure to any individual is markedly affected by time, distance and shielding. The longer the time over

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which the dose is delivered, the further away the source is from the person, and the greater the amount of shielding between the source and the person, the less the person is affected by the exposure. Laboratory studies and clinical experience show that cells, tissues and organs can repair and recover from radiation damage. Therefore, doses harmful in a single exposure may be less deliterious when protracted over an extended period of time, allowing normal cellular repair to take effect.

As shown in Table I (Exposure-Effect Relationships), exposure to less than a few thousand millirem is medically insignificant. No observable symptoms are evident below exposure levels of 75,000 to 100,000 millirem. At this level, radiation sickness will become evident. The patient will suffer flu-like symptoms of nausea, vomiting, and fatigue for a few hours after which there will be no further signs or symptoms. Although 600,000 millirem total body exposure deliverd in a matter of a few hours would be fatal withouttreatment to most individuals, modern medical treatment is capable of salvaging even those receiving up to 800,000 millirem exposure.

A second consideration to emergency medical response planning for radiation accidents is the fact that there is little in the way of emergency treatment following exposure—other than efficient, effective decontamination—that can influence the clinical course of radiation injuries. As the rays pass through the body, whatever damage they inflict has been accomplished. Once the source has been removed, the biological process cannot be reversed by emergency treatment.

Three concerns are involved in considering the long-range effects of radiation exposure: genetic damage, fetal daurage, and increased risk of cancer.

Table. 1. Exposure-Effect Relationships*

5,000mR	No Observable Effects
50,000mR	Blood Threshold Effects
100,000mR	Symptom Threshold Effects
350,000mR	50% Lethality
600,000mR	Approaching 100% Lethality Without Treatment

*For Total Body Penetrating Gamma or X-ray Occurring Within A Few Hours

There is no direct evidence that radiation has induced genetic damage in humans. Studies of the 71,000 offspring of parents who were irradiated at Hiroshima and Nagasaki[1] conducted by the Atomic Bomb and Casualty Commission have failed to demonstrate any increase in genetic defects attributable to irradiation, even though many of the parents were exposed to the point of acute radiation sickness **(75,000+millirem). There** is evidence that radiation in sufficiently high doses and dose rates can induce genetic damage in a variety of animal species,[2),3] however, and so we continue to be wary of potential genetic damage to humans exposed to doses of the same order of magnitude (25,000 millirem and above).

Irradiation of the fetus, particularly during the period of organogenesis in the first trimester, can result in abnormal fetal development.[4),5] Fetal neurogenic tissue is particularly sensitive to radiation. As the exposure level decreases, the risk also becomes less. Below exposures of 10,000 millirem the risk is so small that few physicians would consider a therapeutic abortion.

Increased incidence of cancer is the other fear expressed by the public when concerned about the effects of radiation. That radiation is a factor in the cause of cancer has been suspected and demonstrated since the early 1900s. Since then, no potentially hazardous material has been as exhaustively studied as radiation. In the past decade as a result of high public interest, most of the more important of 80,000 articles in the literature on bioeffects of radiation have been reviewed by eight separate committees of experts to analyze radiation as a carcinogenic agent.[6] The most conclusive evidence that radiation is a significant factor in the cause of cancer lies above 100,000 millirem exposure. There is very little convincing evidence that radiation protracted over days and weeks below levels of 20,000 millirem can induce cancer. That is not to say that there is no risk; but that the risk at low levels is vanishingly small, particularly when compared to the many other factors thought to be important in cancer development.

Recognizing the need for competent medical management of any potential injury resulting from radiation exposure, the Department of Radiology at the Hospital of the University of Pennsylvania joined with eight electrical utility companies in the East Coast area in 1969 to establish a radiation medicine program. Through this pioneer joint effort the personnel, equipment and facilities needed for the complete evaluation and treatment of radiation injuries were brought together in an organization which became known as Radiation Management Corporation (RMC). As a physician-directed organization, RMC offers a wide range of medical and environmental services for evaluating and resolving radiation health problems arising from the production of nuclear energy.

The radiation emergency plan developed by RMC in 1970 for the nuclear power industry is built on a three-level regional system.[7] The first level of care is the first aid available in the nuclear power plant itself. Equipment and trained personnel are ready to provide immediate care to the injured work and prepare him for evacuation if necessary. This first level care typically consists of a first aid team and a radiation technician team. A first aid room, equipped to render lifesaving measures and provide decontamination, is supported by a radioisotope laboratory which provides initial exposure evaluation of any patient. Should there be an injury requiring additional care, the local ambulance service is trained and equipped to transport a radioactively contaminated patient to the hospital.

The second level of the regionalized system is the nearby support hospital. The primary objective at this level is to support life, decontaminate the patient, and begin the initial evaluation of the patient's radiation injury. The hospital has a Radiation Emergency Area that is equipped and prepared to provide emergency treatment while controlling the spread of contamination and radiation hazard to attendants.

At the heart of the concept of regionalized medical care in the event of a major nuclear accident is the Radiation Medicine Center, the tertiary care facility providing the trained personnel and costly equipment needed for definitive evaluation and treatment of the patient injured by radiation. This center coordinates all three levels of care, provides backup support for the program, and maintains the preparedness of each level of care with a continuing calendar of scheduled visits, audits and training/exercises.

The tertiary care facility also provides a Radiation Emergency Medical Team (REM-Team) comprised of a physician experienced in radiation medicine, a health physicist, and a technician with sophisticated portable radiation measuring devices. On request, this REM-Team is dispatched to an accident site to assist in the evaluation and treatment of the *radiationinjury*, not in the treatment of traumatic injury. This is an important distinction. As radiation injuries are seldom life-threatening, the first two levels of care must focus on the traumatic injury in order to sustain life. Contamination and radiation exposure are of secondary consideration. Once the patient is decontaminated and in a regular bed at the support hospital, the patient's radiation injury is evaluated with the help of the REM-Team and the backup laboratories. After qualifying and quantifying the exposure a fairly accurate clinical course can be predicted. If the judgmeni is made to transfer the patient to the regional medical center hospital for more extensive definitive care, transportation needs are determined solely on the status of the patient's traumatic injury.

There is an emergency communications network with 24-hour support for the regional emergency system. Since equipment, supplies and procedures are standardized as far as is possible, a knowledgeable consultant in the center can do a great deal on the telephone to assist the plant and support the hospital personnel in their initial handling of a radiation injury.

March 28, 1979
7 : 00 a.m.
Control Room
Three Mile Island

"Dr. Brennan, we have just declared a General Energency. (radiation releases expected off-site). We have no injuries."

"Radiation Management Corporation is standing by to assist you."

With these words, direct communication was established with the plant and key personnel. The REM-Team was placed on advanced alert. The Radiosurgery Decontamination Suite was readied at the Hospital of the University of Pennsy lvania, and the hospital's Radiation Emergency Coordinating Committee notified. Other medical and health physics consultants throughout the country were alerted to assist if the situation required.

Closer to the plant, the support hospital prepared facilities and readied their disaster plans. RMC's whole body counter, an instrument used to detect internal contamination, was immediately pressed into 24-hour service to monitor plant personnel and was in continuous use for the ten-day emergency period.

By early afternoon of the first day of the accident, when it had been confirmed that no injuries had occurred either on-site or in the surrounding area, the medical support services expanded to serve other needs. The first requests were for additional supplies and equipment. RMC became the conduit for non-medical support at the accident site. Three hundred respirators and respirator testing equipment were gathered from other nuclear facilities and sent to TMI. Large quantities of boric acid were located for injection into the coolant water. The accident resulted in additional requirements for film badges and dosimeters for personnel and environmental testing. Another immediate task was to replace the on-site laboratory that had been rendered ineffective by background radiation in the building housing the reactor. The RMC laboratory in Philadelphia went on round-the-clock emergency operation. Bioassay and environmental samples were air-shipped to Philadelphia and the results telephoned to TMI. When the need for continuing laboratory support became clear, a rented truck was refitted as a mobile laboratory and dispatched to TMI to provide radiochemistry and radiocounting services.

As more workers were called to the plant to reduce individual exposure levels, there was a need for immediate instruction in personal protection procedures. Additional health physicists were sent to the plant to support the monitoring and evaluation of the exposure levels of the personnel.

Although early evidence indicated that no major radiation leaks had occurred, the Nuclear Regulatory Commission (NRC) and other governmental agencies required more detailed environmental monitoring than was available through the normal operational monitoring stations. The NRC requested that RMC install a Thermoluminescent Dosimeter (TLD) environmental system with 47 stations at a variety of locations within a 20-mile radius of the reactor. The equipment used is extremely sensitive, capable of detecting 1/10 millirem per day. These dosimeters gave daily accounts of the amount of exposure in the area and confirmed that the population's exposure during the ten day emergency was minimal. The average cumulative ten-day exposure was 1 to 2 millirem; the maximum cumulative dosimeter reading was 87 millirem, recorded at a location 0.5 miles northeast of the plant. Actual exposure to an individual or to the population was in all liklihood much less, since dosimeters hanging on trees and telephone poles cannot approximate the activities of people who continually move in and out of buildings and vehicles which provide shielding from the external exposure.

One of the most serious problems at TMI was the breakdown in the information cycle so necessary for making decisions. Off-site exposure data were slow in coming, often conflicting, readily mistruted, and received by untrained ears. What was needed were the answers to four basic questions:

1. What is being released from the plant?
2. What is the exposure dose?
3. What will be the effect effect of this exposure?
4. What, if anything, can/should be done to protect the public?

The communications problems were compounded by the fact the decisionmakers were new to their jobs. Both the governor of the state and his secretary of health had held their offices for only a few months. They had not yet learned what supporr agencies were available, much less how to use them. It became clear that those who had the responsibility to make decisions concerning public welfare lacked the basic knowledge concerning nuclear power and the nature of radiation effects. Any attempt to explain to these people or the press just what was happening had to be replaced with basic reviews of nuclear technology. Physicians from RMC spent a great deal of their time at TMI explaining the medical consequences of radiation exposure. The media people were of special concern. In pursuit of immediate dissemination of the news they often misunderstood or misinterpreted the facts. The conflicting reports received by the public through these sources only served to heighten public alarm. As the panic set in, over 85,000 residents voluntarily evacuated the area, including some emergency response personnel otherwise needed for disaster management. Had there been a real need for a general evacuation, the operation would have been severely hampered by this reduced volunteer staff. At one point, a local nursing home had to be evacuated--not because of radiation exposure, but because there were insufficient personnel to maintain support for the residents. For area hospitals, reduced staffing could have had serious consequences had large numbers of people appeared for decontamination or treatment of real or suspected radiation injury. As it was, children with "flu" symptoms were brought to emergency rooms by anxious parents who had to be reassured that they were not suffering from radiation sickness.

When it was realized that further deterioration of the plant could result in the release of radioactive iodine, consideration was given to protecting the public by administering stable potassium iodide (KI) that would serve the purpose of blocking the thyroid gland and thereby reduce the incorporation of I-131 and resultant radiation exposure of the gland. How many people would need KI? Which group (s) of people would be treated? Where can hundreds of thousands of doses of KI be obtained? How should the drug be distributed?

Never before had this problem been considered on such a large scale or with such short notice. A pharmac eutical firm was located which was willing to work around-the-clock through the weekend to package and ship some 250,000 doses of KI to TMI. It was questionable whether an effective means of distri bution of the drug could be developed in time for the drug to be effective. The psychological impact of asking thousands of people to take an unknown drug for an unexplained situation was, fortunately, one that did not have to be faced. It is suggested that KI should not be considered unless *expected* exposure of the thyroid gland to radiation exceeds 10,000 millirem.[9] This never occurred at TMI. Certainly, any future utilization of preventive therapy must-first consider a well-developed educational program and a pre-planned method of storage and distribution.

Another problem which arose as a result of a misunderstanding of the operation of nuclear reactors and the nature of radiation injuries was the potential need for hospitalization of large numbers of people. By Sunday evening, three days following the accident, civil defense authorities were discussing plans for hospitals to admit thousands of casualties. This situation never materialized and is expected not to do so even in the worst possible nuclear power plant accident-the meltdown.

Except for the automobile accidents resulting from hurried and disorganized evacuation, there will not be off-site traumatic injuries. Nuclear reactors do not blow up like atomic bombs. The nature of even the most serious accident at a nuclear power plant would be such that radiation releases would occur over a period of time: hours, and more likely, days. The exposure of the population would, therefore, be time-related and would vary considerably from individual to individual. Those downwind, continually outdoors, and closest to the plant would receive the highest exposure. These exposures could be considerably reduced by remaining in buildings, automobiles, depressions in the terrain, under bridges and overpasses, and finally, by evacuation. The contamination, though detectable, would likely be medically insignificant. It is exceedingly unlikely that large numbers of people would receive exposures (about 200,000 millirem within a few hours) that would require hospitalization. None would require emergency medical room treatment in the usual sense of the word.

Thus from even the worse nuclear power plant accident-the meltdown-the more likely situation the medical profession would face is large numbers of people who are slightly exposed, slightly contaminated, and exceedingly anxious. The medical management would consist of simple decontamination (bathing), either individually, at home, or in predesignated group facilities. The psychological impact will have to be attended to immediately and continuously by someone knowledgeable in radiation effects. Survey, decontamination, and a change of clothes can be accomplished in a timely and orderly manner. Within a few days to a week selective medical tests can be done to confirm exposures. These tests would include whole body counting, serial complete blood counts including platelets, chromosome analysis of circulating lymphocytes, thyroid I-131 uptake, and urine and fecal radioanalyses as required.

As the accident at TMI progressed, response systems became more coordinated. The Department of Energy and the Environmental Protection Agency of the Federal Government supported the data gathering operations of the plant, RMC and state agencies. The data gathered (Tables II and III) confirmed that the radiation emitted by the plant as a result of the accident had not raised the levels of exposure to a degree that was dange rous to the populace. As the data stabilized the public anxiety diminished, people returned to their homes, and the response programs wound down.

For those involved in response plans TMI provided valuable lessons. Most importantly, the accident demonstrated that the rationale underlying the management of radiation accidents is soundly based. What had been planned worked, both in

Table. 2 Exposure Comparisons (Mrem)

TMI Accident	1.5*
Symptoms	75,000
Cancer	20,000
Genetic	25,000
Fetal	10,000

*50 Mile Radius, 2 Million People, Cumulative Average Over 10 Day Period

Table. 3. Exposure Comparisons(Mrem)

TMI Accident	1.5
Chest X-ray	5
Abdomen X-ray	125
Background Radiation	125**
Fallout Radiation	2**
Television	1**
Nuclear Power Plants	0.05#

*50 Mile Radius, 2 Million People, Cumulative Average Over 10 Day Period.

**Per Year Annual Average To Persons Within 50 Mile Radius

terms of accident containment and medical preparedness. It confirmed that physicians and hospital facilities organized under the regional response program were in fact prepared to handle radiation-related injuries. But other important planning concerns should be considered for any future nuclear facility accidents:

The primary need in the event of any accident is for rapid, accurate accumulation of data concerning dose accumulation and assessment of the dose implications to public health. Protective action guidelines should be developed with graded responses to increasing doses. For example, perhaps at 5,000 millirem total body and 10,000 millirem thyroid exposure, people would be told to seek shelter and take potassium iodide; at a higher level, evacuation could occur and food supplies confiscated. These action levels should be easily understood; the public must be educated to understand and relate various levels of exposure to effect.

TMI also demonstrated a need for an emergency response capability that far exceeds any now maintained by a nuclearfacility. This capability should be regional, instantly available on a 24-hour readiness basis, and highly mobile. The equipment should include a laboratory that can be used for environmental and in-plant bioassay analyses. A mobile whole body counter is essential. Large quantities of equipment and supplies must be available for shipment to an accident site. These should include a variety of calibrated survey instruments, air monitors, respirators and respirator testing equipment, charcoal filters, sampling devices and protective clothing.

Immediately required chemicals will include boric acid, sodium hydroxide, potassium iodide, and various agents to decrease gastrointestinal absorption of common radioisotopes found in a reactor.

Immediately upon notification of a general emergency, this radiation support organization must be capable of placing hundreds of environmental dosimeters in pre-designated locations around the plant. This, however, is only the start of adequate monitoring efforts. We want to know not only the radiation exposure in the environment, but also the actual exposure to people, and more specifically to human organs. A selected group of individuals in their normal living and working environments should be "badged" to reflect ongoing exposure following an accident.

The influx of large numbers of personnel, many unfamiliar with the specific facility, will require some orientation in basic radiation protection training, security, and specific plant orientation. This can be accomplished through pre-packaged training films. A reliable personnel monitoring system and recordkeeping system capable of functioning accurately under the rigors of crisis is an absolute must.

Hospitals supporting nuclear reactors must be prepared to respond in even more practical terms. At the first indication of an emergency, a large auditorium should be prepared to receive the scores of people who anxiously seek care for real or imagined exposure. Again, a prepared film will assist in alleviating the fears of the populace by explaining the exposure-effect relationships inherent in radiation medicine. By clearly designating an appropriate gathering place, hospital officials demonstrate their preparedness and help allay a considerable amount of the public's anxiety.

Radiation information must be disseminated to medical personnel as well. Because physicians are often the source of reassurance in difficult situations of all kinds, it is important that they have an accurate understanding of the nature of radiation injuries.

Finally it should be emphasized that none of these measures will be effective without considerably improved efforts at educating the public. Radiation information must be disseminated long before any emergency has arisen. Printed materials, handouts, videotapes, must be prepared and used in an organized effort to communicate sound information concerning the subject. TMI taught that in the absence of good information rumor runs rampant.

Nuclear power accidents with serious off-site consequences will continue to remain a rare event. With foresight and the lessons learned at TMI, however, these accidents may prove to be among the easiest to manage.

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