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TREATMENT OF ACUTE RADIATION INJURY UNDER MEDICALLY AUSTERE CONDITIONS

April, 1967

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OCD Subtask 2431F

TRC-67-21

TREATMENT OF ACUTE RADIATION INJURY UNDER MEDICALLY AUSTERE CONDITIONS

ABSTRACT-SUMMARY

The TRIMAC Committee (Committee on Treatment of Acute Radiation Injury under Medically Austere Conditions) was convened at the request of the Office of Civil Defense, Department of Defense, and the National Radiological Defense Laboratory, San Francisco, California. The committee's task has been to define, in light of present knowledge, the best plan for medical management of large numbers of radiation casualties under austere medical conditions and to evaluate specific courses of medical research which would most adequately improve our ability to cope with civil defense aspects of radiation sickness. The committee's report consists of two parts.

Part I. SHELTER CONDITIONS AND CARE OF RADIATION CASUALTIES: General assumptions underlying the presently planned shelter conditions are summarized. Radiation exposure accumulated from fallout fission products is reviewed briefly in order to emphasize the importance of the decay rate in determining the period of austerity.

The total period of austerity would include an initial period of severe austerity of 2-3 days duration, corresponding to the period when fallout would be deposited and dose rates from fission products would be relatively high. There would be strict confinement to shelter during this period. During the ensuing 11-12 days, confinement could be less strict.

The population at risk is considered to be representative of the civilian population of the United States.

Radiation injury is viewed as only one of a number of noxious agents which might be expected to act cumulatively or synergistically under the shelter conditions postulated. The medical significance of pre-existing disease and disability in the shelter population and the medical effects of confining large randomly selected groups of persons under the austere conditions postulated are emphasized throughout.

The NCRP (Report #29) classification of categories of radiation injury has been used in the report as a basis for discussing therapy of radiation injury. Simple laboratory procedures most likely to aid in evaluating degrees of injury are discussed briefly.

Measures most likely to influence ultimate radiation-related mortality include management of infection and of hemorrhagic manifestations of radiation injury, and management of surgical problems. Presently available chemical "protective agents" are mentioned but the committee doubts their effectiveness in preventing radiation mortality under the shelter conditions postulated.

Part II. RECOMMENDATIONS FOR FURTHER STUDY: The following recommendations are made with respect to operations:

- Existing civil defense plans for fallout shelters should be reviewed and summarized in light of questions raised in the report.

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- Space and water are the most important requirements for survival under the conditions postulated, and the need to revise present allocations is emphasized.

- Liaison between O.C.D. and civilian groups responsible for disaster control in the event of flood, fire, tornadoes, and the like should be strengthened so that plans for various types of disasters may be compatible. The most probable number of shelters without 1) a physician and 2) a non-M.D. with medical skills is estimated for various ratios of the two groups of medically trained persons to shelters. Estimates such as these should be considered in disaster control planning.

- A committee should be convened to consider the care of the sick generally under shelter conditions as defined after completing the review of operations.

Research recommendations, which would be subject to change depending upon the outcome of operations recommendations, are as follows:

- Additional research should be carried out to compare the clinical pictures as well as morbidity and mortality rates after irradiation when doses are delivered a) over a period not longer than approximately six hours and b) at changing dose rates that would mimic the rapid initial build-up of radiation levels as fallout is deposited, followed by decreasing levels as fission products decay.

- Additional research should be carried out to document, if possible, the beneficial effect of rest and the extent to which animals may exert themselves after irradiation and during protracted irradiation without significantly increasing the mortality rate.

- Additional research should be carried out to evaluate the effects of crowding, dirty environment and extremes of environmental temperatures on mortality rates of irradiated animals.

- Library and experimental research should be carried out to determine the most reliable clinical indications of infection under conditions where fever is likely to be induced by high environmental temperatures.

- Some means should be found to assure that a supply of tranquilizers, analgesics and, probably, narcotics would be available to a trained medical officer in a shelter.

- Research on methods of increasing shelf life of major antibiotics and vaccines and on alternative ways to administer major therapeutic agents that must now be administered by injection should be promoted.

- Thermistors or other durable, easily disinfected devices for measuring temperature should be evaluated as possible additions to shelter stocks and simple procedures for measuring body temperature with the devices selected should be developed and incorporated into the medical manual.

- Promising ideas about simple, rapid methods for estimating both total leukocyte and absolute lymphocyte counts should be explored and developed if they continue to look promising.

- Methods for tagging or identifying individuals in some way and for recording, serially, information such as daily body temperature, should be sought. These should be suitable for use under shelter conditions.

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April, 1967

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This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

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TREATMENT OF ACUTE RADIATION INJURY UNDER MEDICALLY AUSTERE CONDITIONS

PART I

SHELTER CONDITIONS AND CARE OF RADIATION CASUALTIES

INTRODUCTION

The committee's task has been to "define in detail, whatever is considered on the basis of the present state-of-the-art to be the most sensible plan for the austere medical management of large numbers of radiation casualties and to evaluate several specific courses of medical research which will most adequately improve our ability to cope with the civil defense aspects of radiation sickness."

Time for completion of the assigned task was limited to one year and the committee was encouraged to complete the assignment even sooner, if possible. The first meeting of the committee was held the last week in February, 1966.

It became apparent very early in the committee's discussions that extensive assistance from the Office of Civil Defense (OCD) would be required in order to define the postulated "austere conditions" so that they would accurately reflect current civil defense plans. Such assistance was generously given, not only in an extensive briefing session in which experts in various aspects of civil defense planning provided detailed information for the assembled committee, but also through assistance in locating and providing copies of the offical reports, and in providing ready answers to the committee's recurrent questions about concepts underlying Civil Defense planning. For this most competent assistance the committee is indeed grateful.

The report was developed in the context of necessary simplifying assumptions, within the framework of existing OCD policy. It is urged that the problems considered be continuously reevaluated in the light of evolving concepts underlying civil defense plans and regimens to be employed during confinement in shelters.

DESCRIPTION OF AUSTERE CONDITIONS

General Assumptions: The austere conditions to be considered are based on current civil defense planning (1) and the assumptions are implicit in the problem formulated for the committee by the Office of Civil Defense.

The physical site under consideration is a previously designated and stocked shelter area housing approximately 1000 persons and providing 8 feet^2 of floor space (no bunks) per person. Services such as light, heat and cooling are provided sporadically if at all.

It is assumed that the persons housed in the shelter reach that building before fallout and that their total exposure in the shelter is from radiation from fallout deposited outside the shelter. The typical accumulated radiation exposure from fallout fission products from a nuclear weapon is shown in Table I. This table was calculated for a single weapon of conventional design (2). Only γ radiation exposure is considered. Multiple weapons detonations with fallout arrival times distributed over many hours or several days would substantially alter the values shown in the table.

TABLE I

PERCENTAGES OF THE INFINITY RADIATION

DOSE RECEIVED FROM 1 MINUTE TO VARIOUS

TIMES AFTER DETONATION (2)

Time	Percent of Infinity Exposure
1 hr.	55
2 hrs.	62
4 hrs.	68
6 hrs.	71
12 hrs.	75
1 day	80
1 week	89
1 month	94
1 year	98
10 years	99

Note that most of the exposure occurs very early because of the very fast decay during the first few hours. For example, if one were in a well shielded location for only the first hour after exposure, his total (infinity exposure) dose would be reduced by over 50%.

No separate area would be available for decontamination of body and clothing and it is assumed that such contamination would represent a negligible problem. It is further assumed that radiation delivered by ingested or inhaled particulate fallout would be negligible when compared with external radiation. It is unlikely that fallout entering the shelter in the ventilation air would cause any appreciable increase in radiation dose. The very simple procedure of minimizing shelter ventilation during the short period of fallout deposition would avoid in-shelter contamination from this source. It would be reasonable to recommend that ventilation be kept to a minimum while dose rates observed in the shelters were increasing -- that is, while fallout was accumulating on the outside of the shelter. Once the observed dose rates have stabilized or begun to decrease, the fallout in the ventilation air would not significantly add to the exposure of the shelter occupants.

Period of Austerity: The period of severe austerity is considered to be of 2-3 days duration, during which all living occupants of the shelter remain strictly confined to it. This would be the period when dose rate from fallout fission products would be high, when fallout would be accumulating outside the shelter and when ventilation would be kept to a minimum. During the ensuing 11-12 days, no outside help would be available, but confinement to the shelter could be somewhat less strict and ventilation would not be restricted. Thereafter, some type of hospital facility, e.g. portable emergency hospital, would be available and the population could leave the shelter at will.

Population at Risk: The casualties under consideration are "representative" of the civilian population of the United States, including adults and children. The ratio of physicians to total population is assumed to be approximately 1:1000, based on the average ratio of physicians to population in the U.S. and assuming no selective loss of physicians. The ratio of other medical personnel to total population is considered to be approximately 10:1000, based on the average ratio for U.S. These personnel would include dentists, veterinarians, technicians and nurses. The incidence of acute and chronic diseases in the group would be that in the U.S. as a whole.

It is assumed that there would be an effective early warning system and that the population would have been conditioned(primarily by rapidly mounting international tension in the immediate past) to consider attack both likely and imminent. It is further assumed that most persons in the shelters, which would be outside the zone of direct weapons effects, would not have severe lacerations, burns, fractures, or other injuries and that their only physical injury would be due to radiation exposure. During the period of modified austerity (after the first two weeks), many persons would be doing fairly heavy work, often engaged in unfamiliar tasks, and minor injuries such as lacerations and puncture wounds might be fairly common.

Austere Conditions: Austere conditions are summarized briefly in Tables II, III, IV, V and VI. Supplies and facilities listed in the tables represent current Civil Defense planning at the national level. Although there may, in fact, be regional variations in planning and stockpiling, the Federal Civil Defense Guide has been taken as the authoritative source in defining austere conditions (1).

TABLE II

AUSTERE CONDITIONS IN FALLOUT SHELTER*#

Period of strict confinement	2-3 days
Total period in shelter	2 weeks
Space per person	8 ft.^{2} floor space (no bunks)
Population at risk	Civilian population in area (adults and children); 1000 persons (spaces)
Power supply	Muscle power only
Food	10,000 calories/space (see Table III)
Water	14 quarts/space
Sanitation	17 and 1/2 gallon drums to store 3 and 1/2 gallons/space (see Table IV)
Medical	Medical kits for units of 50-65 or 300-325 spaces (see Table V)
Radiation dosimetry	Battery operated CDV-715 survey meter and personnel dosimeters plus instruction manual and simple repair instructions

* Based on current civil defense planning as stipulated in Federal Civil Defense Guide (1).

\# Possible modifications are discussed in the present report.

TABLE III

FOOD AND WATER IN FALLOUT SHELTER*#

Amount of food	5 lbs. (10,000 calories) per space
Type of food	Biscuit, cracker, bulgar wafer and carbohydrate supplement (various combinations)
Food packaging	Hermetically sealed cans and fiberboard cases
Amount of water	3 and 1/2 gallons (14 qts.) per space
Packaging	17 and 1/2 gallon drums with polyethylene liners; separate dispensing spout; 70 cups and lids/50 spaces

* Based on current civil defense planning as stipulated in Federal Civil Defense Guide Appendix 1, January, 1965 (1).

Possible modifications are discussed in the present report.

TABLE IV

SANITATION SUPPLIES IN FALLOUT SHELTERS*#

Description	Kit III (per 25 spaces)	Kit IV (per 50 spaces)
Paper, toilet tissue (rolls)	5	10
Seat, commode, plastic	1	1
Opener, can (hand operated)	1	1
Pads, sanitary heavy (dozen)	1	2
Pads, sanitary, regular (dozen)	2	3
Hand cleaner[1], waterless, pint (can)	1	1
Gloves, polyethylene (pair)	1	1
Spout, dispensing water	1	1
Tie wires, bag closures	1	1
Cups and lids	35	70
Commode chemical (liquid, bottle)[2]	1 pt.	1 qt.
Commode chemical (granular, packet)[2]	6	12
Bag liners, polyethylene, commode	1	1
Instruction sheet	1	1
Fiberboard boxes	2	2
Fiber drum	1	1

[1] This item is not being included in later procurement.

[2] Only one of these items if furnished per kit. Initial procurement provided a liquid commode chemical with an iodine base. Later procurement provided a granular quarternary compound in packets of 10 grams each.

* Based on current civil defense planning as stipulated in Federal Civil Defense Guide (1).

#Possible modifications are discussed in the present report.

TABLE V

MEDICAL SUPPLIES IN FALLOUT SHELTER[1*#]

Acetylsalicylic acid tablets: 5 gr. (aspirin); 500's, 1000's
Cascara Sagrada ext., tablets (laxative): 4 gr.; 100's[2]
Eugenol (toothache remedy): 1 oz.
Eye, nose (and ear) drops: 1/2 oz.
Isopropyl alcohol (dilute for rubbing alcohol): 1 qt.
Kaolin and pectin mixture (diarrhea medicine): 1 pt.
Kaolin-pectin powder (alternative items): 40 gm.
Penicillin G, tablets USP, 250,000 units; 100's
Petrolatum, white (Petroleum Jelly): 1 lb.
Phenobarbital tablets: 1/2 gm.; 500's, 1000's
Soap, surgical with 2% hexachlorophene: 1 and 3/4 oz.
Sodium bicarbonate: 1 lb.
Sodium chloride: 1 lb.
Sulfadiazine tablets: 7 and 1/2 gms.; 500's, 1000's
Tablet, water-purification, iodine (this item no longer stored with medical kit, but will be in sanitation kit)
Bandage, gauze, roller, 2" x 6 yd.; 12's
Bandage, muslin, triangular, 37 x 37 x 52"
Cotton, purified: 1 lb.
Pads, gauze, surgical 4 x 4", 200's
Applicator, wood, cotton-tipped end, 1/2 x 6"; 100's
Depressor, tongue, wood; 100's
Forceps, splinter, tweezer, 3 and 1/2"
Pin safety, 1 and 1/2", 12's
Scissors, pocket, straight 4", double blunt
Syringe, fountain, plastic, and attachment[2]
Thermometer, human clinical oral, stubby bulb with case

[1] Based on current civil defense planning as stipulated in the Federal Civil Defense Guide (1).

* Two medical kits are furnished, Kit A with supplies for 50 to 60 spaces and Kit C for 300 to 325 spaces. The kits contain identical items varying only in quantity. The supplies are packed in weather-resistant fiberboard boxes.

\# Presumably, modifications would be necessary.

[2] This item is not included in later procurement.

TABLE VI

*RADIOLOGICAL MONITORING INSTRUMENTS IN FALLOUT SHELTERS**

Instrument	Number per Kit**	Description
CDV-700	1	Radiological survey meter, Geiger counter, probe type, beta-gamma discriminating, 0-0.5, 0-5 and 0-50 mR/hr.
CDV-715	1	Radiological survey meter, gamma only, 0-0.5, 0-5 0-50 and 0-500 R/hr.
CDV-742	2	Radiological dosimeter, self reading, gamma only, 0-200 R.
CDV-750	1	Radiological dosimeter charger

* Based on current civil defense planning as stipulated in Federal Civil Defense Guide (1).

** The complement of instruments appropriate for shelter monitoring is assembled into a "Shelter Radiation Kit" CDV-777-1. A shelter planned and stocked for 50 to 1000 persons would be equipped with one kit; a shelter for 1,001 to 3,000 persons would have two kits.

DEGREES OF RADIATION INJURY

The degree of injury due to radiation would have to be estimated on the basis of the clinical picture, even though instruments for radiation detection and dose rate monitoring would be available to evaluate the radiation environment within a fallout shelter. A nearly uniform radiation field may be anticipated inside most well designed shelters; hence, it would be possible to estimate the general level of radiation dose received by the shelter occupants. Because of variations in exposure geometry, however, these data would have only limited value as a guide for medical treatment. Biological variables are also important in determining the injurious effect of a given dose. Chronically ill patients and small children, for example, are probably more susceptible than healthy adults.

A classification of categories of radiation injury is needed in order to discuss treatment in a meaningful fashion. Such categories have already been devised in several reviews and reports (3, 4, 5, 6, 7, 8). The classification used here is that in the NCRP report (4) which was derived from several of the other publications cited.

The salient characteristics of the clinical manifestations and leukocyte picture following the various degrees of injury are summarized in Table VII:

TABLE VII

LABORATORY AND CLINICAL OBSERVATIONS
(Single Short-Term Exposure)

Degree of Injury	Nausea	Vomiting	Diarrhea	Fever	Lymphocytes (per mm^3 at 48 hrs. or later)	Total Leukocytes (per mm^3)
Patient Group I	±	±	0	0	not lower than 800	minimal change
Patient Group II	++	++	±	±	not lower than 400	Neutrophils variable on days 1 and 2; decreased to ~ 3000 by days 5-10.
Patient Group III	+++	+++	± to +	+	not lower than 200	Transient rise in neutrophils and total WBC count within few hrs followed by precipitous drop to ~ $1000/mm^3$ at 10 days.
Patient Group IV*	++++	++++	++++	++++	< 200	Greater neutrophil and WBC increase, then a fall to < $1000/mm^3$ in less than 1 week.

*The severely injured patients in Patient Group IV would have an extremely poor prognosis and therapy other than that for relief of symptoms would not be indicated.

The laboratory and clinical observations presented in Table VII are those observed following single, short-term exposures, i.e. exposures over a period not longer than approximately six hours. We would emphasize that doses equivalent to total doses in the NCRP report, accumulated under fallout conditions would not necessarily produce the same degree of injury. Under the shelter conditions postulated, the entire body probably would not be irradiated uniformly. Furthermore, the dose would be delivered over a period of days, rather than hours. This protraction would allow recovery mechanisms to reduce the degree of injury produced by a given dose. In other words, a larger dose is required to produce a given degree of effect if the dose is delivered gradually. Precise quantitative data on this phenomenon are not available for man. Approximate values have been estimated for doses delivered at a relatively constant rate over prolonged periods, however, and are summarized in the report, Exposure to Radiation in an Emergency: Recommendations of the National Committee on Radiation Protection and Measurements (4).

Combined Injury: The hypothetical shelter conditions postulated are probably unrealistic to some extent in that they preclude the presence of patients with severe burns, lacerations, fractures or other types and combinations of injury not due to ionizing radiation. In this respect, the clinical descriptions of degrees of radiation injury may be misleading.

There is likely to be an unduly high index of suspicion with respect to radiation injury as a cause of any gastrointestinal symptoms, malaise and fever. It is particularly important to reserve judgment about the degree of radiation injury in acutely ill patients who have sustained severe burns, fractures and the like. Severely burned patients will probably become nauseated and vomit; so may patients with fractures. Shock may obscure the symptoms and clinical signs of radiation injury in the severely traumatized patient. Little information about acute radiation injury in infants and children is available, hence a high degree of caution in accepting nausea, vomiting and diarrhea as infallible signs of severe radiation injury is indicated when evaluating pediatric patients. An objective attitude about the relative importance of radiation as a cause of observed symptoms would help allay patients' anxiety when it stems from fear of radiation injury.

SIMPLE LABORATORY PROCEDURES MOST LIKELY TO AID IN DIAGNOSIS

It is conceivable that in some shelter situations, the degree of austerity might be flexible enough to permit some relatively easily performed laboratory tests. Such a situation might exist if the shelter area were in a hospital or medical office building, for example, where skilled technical personnel as well as appropriate facilities might be available. Of the simple laboratory studies that might be possible, serial estimations of the number of granulocytes and lymphocytes in peripheral blood would be most helpful in assessing degree of radiation injury. These estimations approximately every three days would have considerable value when considered in light of the total clinical picture. Leukocyte counts would also be of help in deciding whether a given patient's symptoms and signs could reasonably be attributed to radiation injury. The absolute lymphocyte count is particularly helpful in assessing the degree of radiation injury because the degree of lymphopenia is, in general, proportional to the degree of radiation injury following whole body exposure.

Although total leukocyte counts might aid in evaluating the severity of radiation injury, they could be seriously misleading if they were grossly inaccurate. Accurate blood counts would not be possible and counts should not be attempted unless trained personnel were present to do them.

As indicated in the section describing the population in the shelters, approximately ten paramedical personnel would be expected among every 1000 randomly selected persons. If simple equipment were available for blood cell counting these persons could not only do many counts but might also be able to teach selected persons to assist them. Estimates of total leukocyte counts without differential leukocyte counts might be misleading during the early stages of response to radiation injury when high total leukocyte counts may exist in the presence of marked lymphopenia. Additional comments about blood counts in shelter situations are included in the section on research recommendations (page 27).

MEASURES LIKELY TO INFLUENCE ULTIMATE RADIATION-RELATED MORTALITY

General Measures: Ideally, one would like to keep irradiated patients at rest in a clean environment, insure scrupulous attention to good hygiene and personal cleanliness, and isolate the patients from potential carriers of infection. Under austere conditions these measures clearly would not be possible.

The unalterable deterrent to rest, cleanliness and isolation would be the severe crowding which would even make it impossible for more than a relatively small percentage of those in the shelter to lie down at any one time.

Considered in the context of crowded shelter conditions, selected health statistics showing the estimated national frequency of common, transiently debilitating illnesses assume considerable significance. Table VIII summarizes the national annual frequencies of common illnesses causing one or more days lost from work or school during 1963-64 (9). A more detailed summary, listing specific diseases and injuries according to age groups, sex, and urban, rural (non-farm), or farm residence, is presented in Report of Ad Hoc Committee on Medical Care in Public Fallout Shelters (10).

At any one time, a random sample of 1000 persons from a representative U.S. population would contain both injured patients and patients with infectious illnesses. Under the austere shelter conditions described in the present report, the common diseases would almost certainly have considerably greater impact than they do in present civilian life.

Management of Infection: Immunization to prevent infection, and antibiotic or antibacterial therapy to treat infection should offer some hope for increasing survival.

Immune responses would likely be altered in irradiated patients (11,12,13). If active immunization is to be undertaken, the earlier the immunizing agent is administered, the greater the probability of an adequate response. Live vaccines probably should not be administered to irradiated patients.

TABLE VIII

The Division of Health Interview Statistics obtains data on a wide variety of health topics. These data are reported from household interviews conducted during each year in 42,000 households consisting of about 134,000 persons. The estimates presented below are annual averages based on interviews conducted during July 1963-June 1964. The data refer to the civilian, noninstitutional population of the United States. In 1963-64 this population averaged 185,797,000 persons of whom 40,956,000 were 6-16 years of age and 119,868,000 were 17 years or older.

In general, the items listed follow commonly accepted definitions. Technical uses of the data and more detailed information about the topics are given in the report entitled "Health Survey Procedure" (*Vital and Health Statistics*, Series 1, No. 2).

Table 26. Selected health statistics

Health topic	Estimated national annual frequency
Number of acute conditions:[1]	
Infective and parasitic diseases	55,283,000
Common cold	103,393,000
Other acute respiratory conditions	100,907,000
Acute digestive conditions	20,608,000
Injuries	55,226,000
All other acute conditions	51,941,000
Number of days of disability:[2]	
Restricted-activity days	3,005,550,000
Bed days	1,123,809,000
School-loss days (ages 6-16 years)	204,373,000
Work-loss days (ages 17 years and over)	385,189,000
Number of persons with limited activity due to chronic disease or impairment:	
With any degree of limitation of activity	22,560,000
Unable to work, keep house, go to school	4,152,000
Medical and dental care:	
Number of physician visits	844,347,000
Home visits	45,671,000
Office visits	589,654,000
Other visits or consultations	209,022,000
Number of dental visits	293,750,000
Number of persons who visited dentist within a year	78,069,000
Number of persons injured:[3]	
In moving motor vehicle accidents	3,841,000
In work accidents	9,992,000
In home accidents	25,077,000
In all other accidents	17,338,000

[1]The frequencies include only acute conditions for which a doctor was consulted or which caused the person to restrict his normal daily activities for at least 1 day.

[2]The figures are not mutually exclusive. A work- or school-loss day may also be a bed day. Work-loss days, school-loss days, and bed days are included in restricted-activity days.

[3]The frequencies include only persons whose injuries required medical attention or resulted in at least 1 day of activity restriction. The classes of accidents are not mutually exclusive, e.g., a person injured in a moving motor vehicle while at work is classified in both categories.

From DHEW/PHS Publication 600 (Rev. 1965)

Tetanus prophylaxis should decrease the mortality of those who have open wounds on entering the shelter as well as those who are injured in the shelter or after the period of close confinement. The most effective prophylaxis would be a toxoid booster for those previously immunized. If supplies were available, a routine booster for all the sheltered would have some merit. In the absence of prior effective immunization, subsequent completion of the immunizing course would provide protection against tetanus during the hazardous existence which would invariably follow a nuclear disaster. Although adequate debridement of necrotic tissue is the only really effective way to ensure against the development of tetanus, in most shelters this measure could not be carried out safely on an extensive wound. The incidence of tetanus could be reduced by cleansing wounds as soon as possible and by antibiotic prophylaxis. Tetanus antitoxin is definitely not advised because of its potential danger and its doubtful efficacy. For those not actively immunized who have sustained injuries most likely to result in tetanus, human immune globulin would be the ideal treatment. The present relatively scarce supply and cost, however, would definitely limit the availability of immune globulin.

In the absence of adequate diagnostic capability, antibiotics should be administered to any patient showing definite clinical signs of infection (especially if the signs include definite fever). The existing clinical and experimental evidence indicates that several antibiotics should be available and that after a trial of a few days on one, the antibiotic should be changed if there is no response. The availability of several antibiotics would also permit switching therapeutic agents when resistance to one antibiotic developed, a frequent observation in irradiated experimental animals. Antibiotic therapy should not be given prophylactically, for in the absence of clinical indications of infection, antibiotics would likely be of more harm than help.

Since elevated body temperature would be one of the most reliable early corroborative signs of serious infection, body temperature should be measured daily or oftener in patients whose signs or symptoms suggest impending infection. If possible, temperature measurements should be made by some means other than conventional clinical thermometers, which might easily convey infectious agents from person to person. Small, stable, battery operated thermistors are available and might be the best choice of instrument for estimating body temperature. Holding the probe in the axilla for 2 minutes with upper arm firmly against the lateral chest wall would give a temperature reading comparable to rectal temperature. Umbilical temperatures also indicate body temperature accurately (14). Since the temperature of the surface of the exposed skin is greatly influenced by ambient temperature, it is not a reliable indication of internal body temperature.

Temperatures should be taken by persons assigned to this task. Each patient's temperature should be recorded in some reasonably indelible form, preferably on the body of the patient. This might be done very simply by using inexpensive ball point pens which write easily on skin, leaving inscriptions that are difficult to remove, especially if soap and water are not available for washing. Temperature measurements could readily be recorded in this way on the lateral surface of the upper arm, starting at the shoulder and recording each day's results in sequence below that.

"Definite fever" in adult patients would be axillary temperature of 100.5° F. or higher on two consecutive days or temperature of 100.5° F. or higher at one time followed by continued or increasing elevation when measured again after approximately six hours.

Since children under the age of 2 years may have relatively high temperatures (102° - 104° F.) for brief periods at the onset of very mild respiratory diseases, one might elect to wait for 24 or 48 hours after detecting the first temperature elevation of this magnitude to see whether the fever abates with the onset of a typical cold. Temperature elevations of this magnitude beginning or persisting after symptoms of a cold should be considered a definite indication for therapy. High temperatures (in the 102° - 104° F. range) are much less common prodromal signs of common colds and similar mild infectious disease in children older than 4-5 years, and criteria of "fever" in adults might be applied in these and older children.

Situations in which fever may be less reliable as a corroborative sign of infection are discussed in Part II of the present report.

Measures to minimize cross infection among the population in the shelter would include, 1) protection of the water supply, and 2) some method of chemical disinfection of the toilets. Collapsable, disposable individual water containers that could be filled daily by responsible, careful persons selected for the task would have important advantages over simpler dispensation systems fashioned after the village well. Careful dispensing in this way would help to prevent waste of water supplies and would go far toward assuring that each person received his full share of the critically important water.

Every effort should be made to keep the water supplies and toilets isolated as much as possible. Whenever possible, plastic bags of excreta in the commodes should be securely closed with ties before disposal and the closed drum containing the full bag pushed outside the shelter. The possibility of an epidemic of infectious hepatitis following the period of austerity deserves further careful analysis by a group knowledgeable in the field of infectious disease and epidemiology. For prevention of hepatitis and other life-threatening viral disease likely to occur with increased frequency after exposure to crowds under conditions of poor sanitation, gamma globulin prophylaxis might be advisable. It is not possible to make specific recommendations to this effect at this time.

During World War I, epidemiological studies on servicemen living under far less close confinement than that proposed for fallout shelters indicated that if barracks space is reduced to less than 40 ft.^{2} per man, the rate of occurrence of meningicoccal carriers may be expected to increase to 25%, and this when close confinement is limited to periods in the barracks (15). The likelihood that some of the shelter population would be meningococcus carriers should be considered when selecting antibiotics for stockpiling and when writing the medical manual.

Many therapeutic agents that might ordinarily be considered "symptomatic" therapy might make an important and direct contribution to control of infections in the crowded shelter conditions. For example, cough suppressants and sedation would be expected to reduce sleeplessness and promote needed rest not only for the patient with the cough, but also for

others in the crowded conditions. Agents to control diarrhea (whether benign or related to radiation injury) might be expected to reduce contamination of the skin of the afflicted patient and of the space he occupies and the objects he touches. In severely irradiated or injured patients this might effectively reduce the frequency of potentially life-threatening complications.

Tranquilizers, administered judiciously to the overly anxious, might also be expected to increase the individual's acceptance of the situation, dull the edge of anxiety and promote compliance with regulations and discipline imposed in the shelter. Under austere conditions, such effects would be enormously helpful.

Shock Aggravated by Severe Pain: Some patients, especially those severely traumatized, might require narcotics. Careful planning for storage of narcotics and accounting for them would be required, but exclusion of all narcotics from the medical supplies would be a serious error. Severely traumatized patients in group I (Table VII), for example, might be in greater immediate danger from shock aggravated by severe pain than from subsequent manifestations of radiation injury, and narcotics might make it possible to sustain life in these patients until first aid measures or definitive therapy could be undertaken and the danger of irreversible shock decreased.

Hemorrhagic Manifestations: Hemorrhagic manifestations of radiation injury would be unlikely during the first two-week period of severe austerity, but the general condition of the patient during that period might significantly influence the severity of hemorrhagic lesions during the subsequent period. The probability of hemorrhage within the central nervous system might be decreased in patients with increasingly severe thrombocytopenia by administering cough suppressing and anti-diarrheal agents, e.g. codeine and paregoric. These could be administered, when indicated, to control coughing and straining at stool and to prevent the resulting sudden increase in intracranial pressure.

The close relationship between infection and hemorrhage is well documented in the literature describing studies on animals (16, 17). Control of infection in general might be expected to decrease the severity of hemorrhagic manifestations of radiation-induced thrombocytopenia should they develop subsequently (three to four weeks after exposure), and control of thrombocytopenia would, in turn, be critically important to successful antibiotic therapy of concurrent infection.

Specific therapy for hemorrhagic manifestations of radiation injury (three to four weeks after exposure) is the administration of fresh platelets at the rate of 2 or more units per day for several days or until bleeding is controlled. The efficacy of platelets, in the absence of antibiotics, for the hemorrhagic diathesis in severe radiation injury remains to be evaluated. It is highly unlikely that bone marrow transplantation would have any place in treatment of radiation casualties under austere conditions.

Since cortisone and radiation tend to have similar detrimental effects, cortisone is contraindicated as a therapeutic agent for acute radiation injury.

Surgical Problems: Urgent surgical problems should be managed without regard to the possibility of radiation injury. If the supplies of skin cleansing agents and tetanus toxoid are limited they should be reserved for patients with open wounds. In a crowded shelter, cleansing and the application of a simple dressing would be the best procedure to prevent infection. Since the iodine-PVP antiseptics (e.g. Betadine) are relatively benign to injured tissue, and since they are as effective against staphylococci and far more effective against gram negative bacteria than are the hexachlorophenes, they would be the preferred antibacterial cleansing agent. If supplies were limited, these iodine-PVP agents could be used quite effectively in a dilution of at least 7:1.

Chemical Protective Agents: Certain chemical agents have been found to increase survival of experimental animals subjected to single, very large (lethal range) short-term exposures to ionizing radiation if the chemical agents are given shortly before exposure (18, 19). Much of the research on these compounds has been directed toward military and civil defense needs for "radiation protective" agents. Unfortunately, it appears unlikely that the chemical agents presently available would materially reduce morbidity or mortality from the type of radiation exposure under consideration in the present report. The reasons for this are:

1. Chemical agents provide protection against radiation injury only if they are present in the tissues during exposure. Presumably, they would have to be present throughout protracted exposures.

2. The effective agents have prominent inherent toxicity which is greater for large animals, including man, than for the usual small test animals.

Virtually nothing is known about the effectiveness of the protective agents during radiation exposures in which the dose rate corresponds to that expected from weapons fallout. Similarly, the toxicity of the compounds when administered over a sufficiently long period to counteract the major part of the radiation dose from weapons fallout is unknown.

One should, however, bear in mind the possibility that one or more "protective" agents might eventually be found which could, for example, double the number of humans surviving an otherwise lethal dose of γ radiation from weapons fallout. Such a chemical agent would have an enormous effect on requirements for medical care, for many persons surviving an otherwise lethal dose would subsequently develop clinical signs and symptoms consistent with exposure to some dose less than that actually received. Thus, it is possible that chemical protective agents might sharply decrease mortality and at the same time increase the number of patients able to respond to therapy and increase the need for medical care proportionately.

Partial Body Shielding: Partial body shielding during exposure is another protective measure that has effectively reduced lethality among experimental animals following large, brief exposures (20, 21). Small lead shields completely surrounding the epicondyle of the humerus (elbow) in the dog have been shown to afford significant protection(20). The complex geometrical considerations under shelter conditions, where individuals move about and change position relative to the radiation source, make it difficult to predict whether or not small partial body shields would appreciably

benefit a shelter population. It is not possible at this time to recommend what part or proportion of the body should be shielded in order to achieve significant protection under shelter conditions.

CONCLUDING COMMENTS, PART I

The committee would emphasize two major considerations with respect to shelter conditions and care of radiation casualties, namely:

1. The medical effects of confining large randomly selected groups of persons under the austere conditions postulated must be known before the effects of superimposed radiation injury can be analyzed accurately. One should have the best available information, for example, about the frequency of occurrence of persons harboring pathogenic microbial agents in the population under consideration. Antibiotics for stockpiling should be selected against a background of such data as well as the best available data on the rates and patterns of emergence of various diseases in large groups of persons confined under crowded conditions.

2. The relationship between response to protracted radiation doses and response to single non-protracted doses is poorly understood at present. In the present report, the clinical picture and hematological changes after exposure to radiation from weapons fission products have been discussed as though they were the same following short term and protracted exposure, although total doses required to produce the various degrees of injury probably differ greatly in the two situations (22,23,24,25).
More accurate description of degrees of radiation injury due to γ radiation from fallout would require much more extensive clinical data from real or simulated exposures of this nature than are presently available.

TREATMENT OF ACUTE RADIATION INJURY UNDER MEDICALLY AUSTERE CONDITIONS

PART II

RECOMMENDATIONS FOR FURTHER STUDY

PART II: RECOMMENDATIONS FOR FURTHER STUDY

INTRODUCTION

From the outset, the most difficult part of the committee's task has been definition of the austere conditions under which radiation injury would be treated. Again and again, questions about medical management led to the realization that the answer would depend upon the specific situation in question, for, as we have tried to indicate in earlier sections of this report, the conditions of confinement would interact with injuries due to radiation or other agents in determining the clinical course.

It appears that in many cases, one would gain more by treating the patient's environment than by treating his illness. Recommendations that might seem to be indicated clearly in one set of circumstances might be inappropriate when applied to another set. For example, recommendations with respect to administration of antibiotics in the presence of malaise plus persistently elevated body temperature would appear to be sound, at first glance. If shelter confinement were in a hot climate and ventilation were poor, however, a large proportion of those in shelter might have elevated body temperatures, and the degree of elevation would vary with age, activity and so forth as well as with infection (26,27, 28, 29). Consequently, firm unqualified recommendations that body temperature be accepted as a cardinal clinical sign of infection and an indication for administration of antibiotics might result in wasted supplies of the valuable therapeutic agent, especially if the "medical officer" were not a physician or other professional person with clinical experience. Water requirements would clearly be affected by the local situation.

Although one might be tempted to recommend that research be undertaken to determine the most reliable clinical indications of early infection under conditions of extreme crowding and high environmental temperature, one would do so with more confidence if the probability of encountering such extremes were, in fact, reasonably high. Similar practical considerations might influence how strongly one would recommend other lines of investigation.

The research recommendations emphasize above all else, the need for precise definition of the operational aspects of the shelter program in various geographical areas, various types of buildings and so forth. The committee is aware that many highly qualified groups have worked on the various aspects of the problem long before the TRIMAC committee existed (30, 31, 32, 33, 34, 35, 36, 37, 38). Nevertheless, we have not found information about the probability of encountering various types of environmental extremes in fallout shelters in the United States. Until such information is available, specific research recommendations must be considered as preliminary and speculative; subject to revision, or cancellation. The recommendations made in this report are relatively broad and are divided into two categories: operational recommendations and research recommendations.

RECOMMENDATIONS: I. OPERATIONS: These recommendations should receive immediate attention. The outcome of operational studies would influence the research recommendations.

Review of existing plans: The most recent Civil Defense plans for fallout shelters at state and local levels in all parts of the country should be reviewed and summarized in a concise form that would show the present range of variability in requirements, as well as in planning, provisioning, staffing and shelter management. Existing manuals, (federal, state and local) on shelter management or medical care should be collected and compared as part of this undertaking. Inspection of shelter facilities and stockpiles of supplies should be carried out as necessary to determine the accuracy of the report. This should be done by experienced civil defense staff who are mindful of questions raised in the present report.

Improving liaison with civilian groups concerned with natural disasters: With the exception of the civil defense program, most existing civilian programs for medical management of patients in disaster situations are oriented toward management of mass casualties following major fires, flood, tornadoes and the like. Most of these programs are designed to cope with situations that differ markedly from that under consideration in the present report. Differences include the anticipated number of severely injured patients and the degree of urgency in providing skilled medical care, the location of disaster stations to which physicians are assigned and the management of the population generally in the two types of disaster situations.

Using established statistical techniques, the probable number of shelters 1) without a physician and 2) without a non-M.D. with medical skills can be estimated for various ratios of the two groups of medically trained persons to shelters. Appendix 1 to this report contains such an analysis and the data with respect to various physician/shelter ratios are summarized in Table IX.

The data in Table IX indicate that even if physicians were evenly distributed throughout the population and there were no selective loss of physicians, many shelters might be physicianless. If physicians were to go to disaster stations other than shelters, or if they were not equally distributed among the population for any reason, the percentage of shelters without physicians would be even greater. The likelihood of having a non-M.D., medically trained person in a shelter is considerably greater than that of having a physician. Estimates such as those summarized in Table IX should be of considerable help in anticipating the consequences of various plans for deploying medically trained persons during disasters. At present, many physicians have no disaster assignments or have forgotten them.

In general, existing civilian medical programs appear to include little planning for nuclear warfare. On the other hand, military medical plans for nuclear warfare are concerned primarily with the need to maintain troops and equipment in the field in functional condition, not with medical care of the civilian.

Ideally, those responsible for medical aspects of civilian defense should exchange information freely with both military defenders and civilian organizations responsible for medical management of patients and the population generally in non-military disasters. Communication between the Office of Civil Defense and military defenders has been assured by the organizational relationship of O.C.D. to the Secretary of Defense. There

TABLE IX*

Shelters Without a Physician -- 90% Limits

Number of Shelters**	Equal Number of Physicians and Shelters		Twice as Many Shelters As Physicians	
	Most Probable No. of Shelters Without a Physician	90% Chance No More Than This Number Without a Physician	Most Probable No. of Shelters Without a Physician	90% Chance No More Than This Number Without a Physician
10	3	4	6	8
50	18	22	30	36
100	36	42	60	69
500	184	200	300	321
1000	368	392	600	629

* Table III in Appendix I to this report

** The number of shelters in February, 1966 was approximately 70,800, having a capacity to shelter 63.7 million people. There are approximately 280,000 physicians in the United States.

remains, however, a need for improved liaison between O.C.D. and organizations concerned with medical care of civilians in natural disasters so that plans for various types of disasters may be compatible.

Review of population at risk: For maximum effectiveness, medical plans for fallout shelters should be based on the most accurate information available about the population to be expected in fallout shelters in various regions, at various seasons, and so forth. Data regarding the health characteristics of the population at risk are available -- for example, from the Division of Health Interview Statistics, DHEW/PHS (9). Annual frequencies of illness and volume of disability in the free living population may be reduced to terms of two weeks as a time base and one thousand as a population base as shown in Table X.

TABLE X*

Number of Conditions	Number/1000/2 weeks
Acute:	
Infective and parasitic disease	11.3
Common Cold	21.3
Other acute respiratory conditions	20.7
Acute digestive conditions	4.3
Injuries	11.3
All other acute conditions	10.8
Chronic:	
Severe chronic disease or impairment	22.3**

* Adapted from Table 26, reference 9
** Prevalence, rather than frequency, over a two week period.

A more detailed tabulation of the types of injuries and acute and chronic illnesses, classified according to age group and sex of the population and according to season and residence (urban, rural-non farm and farm) has been prepared by the NAS-NRC Ad Hoc Committee on Medical Care in Public Fallout Shelters (10).

Among acute conditions, the respiratory diseases, injuries and gastrointestinal disturbances are the most frequent. These figures are derived from nation-wide annual averages and they will vary, depending on local population characteristics, geographic location and season of the year. For example, in late winter and early spring there would be a higher frequency of acute respiratory disease in the north; a population containing a high percentage of elderly persons would have a higher frequency of chronic conditions.

Assuming that the shelter population were similar to the population of the surrounding area there would be, on the average, about 75 acutely ill or injured persons per thousand shelter population, plus perhaps 20 per thousand seriously disabled persons who might require assistance in their

activities of daily living. The normal forces of mortality would result in one death per two thousand five hundred persons in a two week period.

In addition to illness, there is the problem of viral and bacterial infection without obvious illness. Studies of the prevalence of infection in the free living population (39, 40, 41, 42, 43, 44) show that infected, though apparently well, persons would inevitably be introduced into the shelter environment. As a broad generalization, the respiratory infections, viral and bacterial, are most prevalent in the late winter and early spring weather, while the enteric bacterial and viral pathogens are most prevalent in the late summer and early fall months.

This leads to the recommendation that planning for the shelter environment provide some facilities for the severely and chronically disabled; that the introduction of acute respiratory and gastrointestinal illnesses and their etiologic agents be anticipated; that provision for the management of these as well as other disorders be made. This would influence considerations of space requirements, management of the environment, selection of antibiotics, and possible research into further methods for interrupting the transmission of microorganisms in a shelter type of operation.

Review of space requirements and facilities allocated: The most important recommendation in this report concerns the space allotment per person during confinement in the shelter. This allocation may be critical in determining survival. The recommended 8 ft.^{2} per person would not provide the facilities required for adequate medical treatment necessary to reduce morbidity and mortality associated with radiation injury.

Even though the period of strict confinement to shelter be only two days, during those two days -- even under relatively comfortable confinement conditions -- one would anticipate dissemination of bacterial and viral agents harbored by the shelter population. Should there be concomitant irradiation, it would depress immune processes, enhancing susceptibility to pathogenic organisms. The enhanced susceptibility would persist into the period of maximum leukopenia and thrombocytopenia, significantly increasing the hazard.

Most shelter studies have been done using relatively small groups of apparently healthy people. Under postulated shelter conditions, a population quite different from this would be assembled. According to current plans, there is little possibility of separating areas for sleeping, living, food preparation, disposal of excreta, sickness control and administration. We recommend that criteria used in arriving at space allocation be reviewed and that plans for optimal utilization of all available space (i.e. overhead as well as floor space) be developed.

Civil defense plans should include instructions for the populace about what to bring and what not to bring to the fallout shelter. (See other comments under "Review of medications for Shelters").

Review of environment (heating, cooling, ventilation, light): The environmental problems (e.g. climate) and methods for controlling the environment should be reviewed for various localities.

Studies by various experts on the effects of extremes of temperature on human physiology have shown that temperature, humidity and air flow are all important environmental variables. All three should be measured in shelters in various regions at various seasons. Using such data, it would be possible to predict what provisions should be made for regulating these variables.

Some light source would be necessary in the shelter so that it would be possible to read labels, instruments and manuals. Review of provisions for light should include the types of light available and possible hazards associated with certain light sources.

Provisions for odor control, probably through provision of effective disinfectants might properly be considered an important aspect of regulating the shelter environment.

Water requirements should be considered with reference to expected environmental temperatures and humidity, for requirements would vary greatly from one set of environmental conditions to another. Water requirements are discussed further on page 25.

Review of shelter management: Care of the sick and wounded should be considered in light of shelter management generally. The obvious requirements in the medical management of seriously ill patients, which might include those with trauma, those who complain of pain or are disoriented, and those representing possible infectious hazards, are: 1) to provide the best possible care for the sick without undue penalties to the well, 2) to prevent the spread of infectious disease, and 3) to cope with the psychological impact of pain, disorientation, illness and death.

It would be important to achieve some physical separation of acutely ill or injured patients from the rest of the shelter population and to have care of the sick delegated to persons able to manage it with minimum disruption of the shelter.

Priorities assigned to medical matters should be included in the review of shelter management. It is not unheard of for physicians and medical personnel to take the position that care of the ill, even if they are only a small part of the population, is more important than anything else; and one can conceive of a situation in which a domineering physician might insist upon policies that would not be for the common good. Medical problems should have high priority, but the shelter manager, having weighed the recommendations of medical personnel, is still responsible for making decisions for the benefit of the shelter population in general. Priorities assigned to medical problems, and decision making in situations where the relative importance of medical considerations must be weighed should be part of the training of shelter managers.

Review of medications: Financial and logistical constraints on initial shelter planning led to the following decisions with respect to stockpiling of medications:

1. Medications stockpiled in shelters would be those required by a normal, healthy group of persons during a period of approximately two weeks.

2. Medications for the chronically ill would not be stockpiled.

3. Little could be done under shelter conditions to improve survival of severely injured patients.

4. Special medications and supplies that could be used safely and efficaciously only by a physician would not be stockpiled.

Lists of medications that were stockpiled were reviewed by the NAS-NRC Ad Hoc Committee on Medical Care in Public Fallout Shelters in 1964, and some changes were recommended (10). The same committee emphasized that shelter plans should take into account the occurrence of persons with illness and injuries in any reasonably large random sample of the civilian population. The TRIMAC committee endorses most of the NAS-NRC committee's recommendations and recommends in addition, that the varieties as well as the quantity of medications that should be stockpiled in order to reduce radiation-related morbidity and mortality should be reviewed for various localities with respect to:

1. The size of the sheltered population.

2. The knowledge and experience of the most medically knowledgeable person in the shelter.

3. The extent to which the populace have been educated to bring with them medications that they require for maintenance therapy, e.g. insulin, digitalis.

4. The extent to which physicians, dentists and pharmacists have been educated to bring medical supplies to the shelters.

Review of manuals and guidebooks: Appropriately oriented guidebooks should be prepared and distributed forthwith. These guidebooks should include information on organization of shelters, designation of responsibility, priorities and decision making as well as technical information on many subjects such as ventilation, fallout radiation, medical problems, sanitation, handling of dead bodies, and so forth. They should contain simply worded instructions for the administration of medical supplies (e.g. antibiotics) and, where appropriate, warnings about possible adverse effects and how to avoid or control them. The guidebooks should be readily legible. All procedures should be presented in simple cook-book style and the manual should be extensively indexed.

RECOMMENDATIONS: II. RESEARCH: Research recommendations that seem most appropriate at this time are as follows:

Water: Together, space and water are the most important requirements for survival under the conditions postulated. Water requirements for healthy men under various environmental conditions have been studied extensively, but minimum allocations derived from such studies have proved to be too low when tested under shelter conditions even less rigorous than those postulated(38). Water requirements in overcrowded shelters that house injured and sick persons will inevitably exceed present shelter allotments. A literature search and additional research on healthy and irradiated experimental

animals confined under simulated shelter conditions would be expected to lead to revisions of proposed water rations. An increase would be necessary in any case if a significant part of the presently planned water supply were allocated to medical uses.

Therapeutic and prophylactic agents: With better control of the environment and with an adequate water supply, it is reasonable to suppose that mortality among persons receiving a radiation exposure otherwise lethal to 50% or less of the population could be at least halved if two or three antibiotics were available (16).

To determine the most reliable clinical indications of infection under conditions where fever is likely to be induced by some agent other than infection, a literature search and experimental research should be encouraged. These would provide the information required to obtain maximum benefit from antibiotic therapy.

There should be a review of efforts presently being made to increase the shelf life of major antibiotics, analgesics and immunizing agents, especially tetanus toxoid. If relatively little effort is being expended, research in this area should be promoted.

Efforts presently being made to find alternative ways to administer important therapeutic agents that must now be administered by injection should be reviewed. If insufficient effort is being expended, research in this area should be promoted.

If space and water requirements were met and antibiotics were available for seriously injured patients with infection, methods for preserving and stockpiling platelets would be important in further improving ultimate survival, for stored supplies might be shipped from remote areas to treat patients with severe thrombocytopenia when platelet counts were maximally depressed three to four weeks after exposure. Several research groups are presently actively at work on the problem of platelet preservation (45).

Experiments to study biological effects of exposure to radiation from fallout: There is relatively little available information that could be used as a guide in estimating prognosis on the basis of clinical signs and symptoms in patients receiving their total dose from fallout gamma radiation after detonation of a nuclear weapon. Additional research should be carried out to compare morbidity and mortality associated with short term single exposures with morbidity and mortality after exposure to radiation delivered at changing rates that would mimic the high initial build-up of radiation levels as fallout is deposited, followed by decreasing radiation levels as fission products decay. These studies should be carried out using mammals that develop the classical acute radiation syndrome as it is seen in man. Results should be analyzed to determine the predictability of the clinical response to various doses of γ radiation administered to simulate exposure to γ radiation from weapons fallout.

Partial Body Shielding: The observation that small lead shields afford significant protection against lethal x-radiation in dogs is intriguing. Further investigations should be carried out to determine the effectiveness of such shields when exposure geometry and dose rates simulate those anticipated in a fallout shelter.

General measures supporting survival of radiation casualties: During protracted exposure, recovery processes become active while injury is accruing. This situation emphasizes the importance of obtaining additional information about certain general measures that have long been considered basic in therapy of radiation injury; measures that may be effective primarily in promoting recovery rather than reducing injury. These are rest, cleanliness, adequate nutrition and hydration.

Documenting the therapeutic effect of rest is truly a challenge. Representative data from the few experiments that have been conducted are summarized in Table XI. These data suggest that prevention of exhausting activity might be effective in reducing mortality following exposure to large doses of radiation. Additional research should be carried out to determine whether or not rest is indeed of major importance in improving survival. Studies should be designed to determine the extent to which animals may exert themselves during and after protracted exposure without significantly increasing the mortality rate.

Beneficial effects of cleanliness on survival following severe radiation injury are probably due to reduced incidence of infection. This has been discussed earlier in the present report. Effort should be expended to determine the probable gain (in terms of reduced mortality) that could be expected if facilities were provided for cleaning superficial lesions, and for cleaning hands before handling food or water and after defecation.

Observations of the effects of crowding animals in cages are perhaps the closest experimental approach to evaluating the importance of cleanliness. Experiments of this type might profitably be extended with the analogy of crowded shelter conditions in mind. These studies should include experiments to determine the effect of environmentally induced hyperthermia on the incidence of generalized infection and mortality in irradiated animals under simulated shelter conditions.

Aids to health assessment: In a shelter environment which could, by itself, cause temperature elevation, identification of fevers indicative of infection would require temperature measurements on a large sample of the shelter population. Since many measurements of body temperature would be necessary in such a situation, procedures for taking temperatures should be simple, the measuring devices used should be easy to clean between measurements, and they should not promote spread of infection. Conventional clinical thermometers would not meet these specifications.

Thermistors or other metal devices for measuring body temperature should be evaluated as possible additions to shelter stocks. Simple, convenient procedures for measuring body temperatures with the devices selected should be developed and incorporated into the manual on medical care.

If persons reasonably skilled in hematological techniques were present in the shelter, it would be helpful if methods of estimating both the leukocyte count and absolute lymphocyte count were available. These determinations should not be attempted nor the results interpreted by inexperienced persons. Promising ideas about methods of making such estimations, using simple, durable equipment (other than conventional microscopes, for example)

TABLE XI

EFFECT OF EXERCISE ON RESPONSE TO WHOLE BODY IRRADIATION

Species	Radiation	Exercise	Effect
Man (46)	Hiroshima A-bomb (1000 M from hypocenter)	Survival and rescue activities	a. WBC fell to lower levels and remained depressed longer in enlisted men than in non-commissioned officers (who did less heavy work). b. Sick patients unable to be active showed less hematological damage than persons (at same distance from hypocenter) who were active after the detonation
Dog (47)	2000 KV X-ray a. 250 R (12 dogs) b. 300 R (46 dogs) LD_{30} c. 400 R (3 dogs)	treadmill (daily)	a. No increased mortality with exercise. b. 5/18 unexercised and 19/28 exercised dogs died after 300 R. No hematological, clinical or histopathological differences. c. All 3 died (9th, 11th, 13th days). There was suggestive evidence that exercise every other day was less harmful than daily exercise
Rat (48)	X-ray; W.B.* a. 600 R b. 700 R c. 860 R	Exhausting swimming 5 days/week after irradiation	a. 50% of exercised rats died; none of non-exercised receiving 600 R. b. 92% of exercised; 44% of non-exercised died after 700 R; exercised rats died earlier. c. Exercised rats had much shorter survival; developed rough coats, diarrhea, crusted nares earlier. All died, with or without exercise
Mouse (49)	a. 400 R W.B. 170 or 200 KV b. 600 R WB (30 min.) 170 or 200 KV	+Rotating cage 8 consecutive hrs./day or 3 evenly spaced periods of 3 hrs./day. Rotating cage 8 hrs./day for 3 days starting one day post-exposure.	a. No significant decrease in tolerance of mice to irradiation. b. Seven of 30 exercised mice died during 3 days of exercise, first deaths among unexercised mice on 6th day. Mortality in those surviving 3 days was not significantly different from mortality in unexercised mice

* W. B. - Whole Body exposure

\+ Author reports that when cages were rotating, mice either walked rapidly forward and rode back with the cage, walked steadily or clung to cage for entire revolutions. There is no information about the percent of time the mice in any group actually walked.

should be explored and developed if they seem sufficiently promising.

Methods should be sought for identifying persons and recording, for each person, information such as temperature, medical treatment and food and water intake.

CONCLUDING COMMENTS, PART II

The committee would emphasize the following considerations with respect to recommendations for further study of operations:

1. The most important recommendation in this report concerns the space allotment per person during confinement in the shelter. The recommended 8 ft.^{2} per person would not provide the facilities required for adequate medical treatment necessary to reduce morbidity and mortality associated with radiation injury.

2. More precise information than that presently available about operational aspects of the shelter program will be required before firm recommendations can be made about medical management of acute radiation injury under shelter conditions. Operational aspects of civil defense plans for fallout shelters should be reviewed with respect to space requirements and facilities allocated, the probability of encountering various types of environmental extremes, the population at risk, shelter management, medications, and manuals and guidebooks.

3. Liaison between O.C.D. and civilian groups responsible for disaster control in the event of flood, fire, tornados, and the like should be strengthened so that plans for various types of disasters may be compatible.

The committee would emphasize the following considerations with respect to recommendations for research, with the understanding that the recommendations are subject to revision depending on the outcome of the review of operations:

1. Water requirements in overcrowded shelters that house injured and sick persons will inevitably exceed present shelter allotments. These allotments should be revised.

2. Additional research should be carried out to compare morbidity and mortality associated with short term single exposures with morbidity and mortality after exposure to radiation delivered at changing rates that would mimic the high initial build-up of radiation levels as fallout is deposited, followed by decreasing radiation levels as fission products decay.

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TREATMENT OF ACUTE RADIATION INJURY UNDER MEDICALLY AUSTERE CONDITIONS

Appendix I

SOME "UNPERTURBED" DOCTOR-FALLOUT SHELTER DISTRIBUTIONS

by

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SOME "UNPERTURBED" DOCTOR-FALLOUT SHELTER DISTRIBUTIONS

by

Carl M. Unruh

One can calculate the unperturbed distributions of doctors and paramedical personnel in a fallout shelter grid system by established statistical techniques. It is not intended here to ponder the reality of the unperturbed distributions; however, a range of distributions is given so that one may note the magnitude of the variations in the distributions as the ratio of the number of doctors or paramedics to the number of shelters changes. These changes can be thought of as perturbations introduced into the distribution of doctors resulting from a wide variety of causes, such as doctors reporting to hospital facilities instead of shelters, localized residential districts where there is a high percentage of doctors' homes, selective variables that prevent doctors from going to shelters, and others.

To examine the problem, let us assume that "r" doctors occupy "n" fallout shelters totally at random. Then:

(1) The probability that <u>exactly</u> "j" shelters have no doctors is:

$$P_j(r,n) = \frac{n!}{j!(n-j)!} \sum_{i=o}^{n-j} (-1)^i \frac{(n-j)!}{i!(n-j-i)!} \left(1 - \frac{j+i}{n}\right)^r$$

(2) The probability that "m" or less shelters have no doctors present is:

$$P_m(r,n) = \sum_{j=o}^{m} \frac{n!}{j!(n-j)!} \sum_{i=o}^{n-j} (-1)^i \frac{(n-j)!}{i!(n-j-i)!} \left(1- \frac{j+i}{n}\right)^r$$

(3) The most probable number of shelters without a doctor is:

$$\lambda = ne^{-r/n}$$

(4) When λ is equal to about 20 or more, the probability that "m" or less shelters have no doctors present is:

$$P_m(m,\lambda) \simeq \int_{-\infty}^{\frac{(m+1/2-\lambda)}{\lambda^{1/2}}} (2\Pi)^{-1/2} e^{-x^2/2} dx$$

Equations (3) and (4) are of practical interest for assessing the most probable number of shelters without doctors and for assessing the probability of that number or less occurring.

The following summary statements can be made:

(1) For an equal number of doctors and shelters the most probable percent of shelters without a doctor is 30. There is a 50 percent probability that this distribution will occur.

(2) For paramedics, when they outnumber shelters by 10 to 1, the most probable percent of shelters without a

paramedic is 0.004.

(3) For a variable ratio of doctors and shelters, the most probable percent of shelters without a doctor is given in Table I.

TABLE I

Most Probable Percent of Shelters Without a Doctor

Ratio Doctors/Shelters	Most Probable Percent of Shelters Without a Doctor*
1	30
0.9	40
0.8	40
0.7	50
0.6	50
0.5	60
0.4	60
0.3	70
0.2	80
0.1	90

*The probability of this percent or less occurring is about 50 percent.

(4) For a variable ratio of paramedics and shelters, the most probable percent of shelters without a paramedic is given in Table II.

TABLE II

Most Probable Percent of Shelters Without a Paramedic

Ratio Paramedics/Shelters	Most Probable Percent of Shelters Without a Paramedic*
10	0.004
9	0.01
8	0.03
7	0.09
6	0.2
5	0.6
4	1
3	5
2	10
1	30

*The probability of this percent or less occurring is about 50 percent.

To return briefly to the perturbed actuality of doctors going to fallout shelters, it is clear that this is not a random process as assumed here. It appears to be clear that the perturbations operating on this system will tend to prevent doctors from going to shelters or will tend to concentrate doctors in some shelters. In actual experience these influences will result in a higher number of shelters without doctors since these calculations show the net results of a totally random distribution between doctors and shelters.

Table III provides some additional insight into the distribution probabilities. In this table the number of doctorless shelters which would not be exceeded 90 percent of the time is shown for both an equal

number of doctors and shelters and for a perturbation that results in only one-half as many doctors as shelters.

It would appear that the only way to improve significantly the distribution of doctors to fallout shelters would be to make firm shelter assignments for each doctor.

Acknowledgment:

The statistical equations presented here, and which form the basis for this summary, were derived by T. M. Beetle, of the Battelle-Northwest Mathematics Department.

TABLE III

Shelters Without a Doctor - 90% Limits

Number of Shelters	Equal Number Of Doctors and Shelters		Twice As Many Shelters As Doctors	
	Most Probable % of Shelters Without a Doctor	90% Chance No More Than This Number Without a Doctor	Most Probable % of Shelters Without a Doctor	90% Chance No More Than This Number Without a Doctor
10	3	4	6	8
50	18	22	30	36
100	36	42	60	69
500	184	200	300	321
1000	368	392	600	629

APPENDIX II

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This report summarizes the work of a committee convened to define, in light of present knowledge, the best plan for medical management of large numbers of radiation casualties under austere medical conditions and to evaluate specific courses of research which would improve our ability to cope with civil defense aspects of radiation sickness. Radiation injury is viewed as only one of a number of noxious agents which might be expected to act cumulatively or synergistically under the shelter conditions postulated. The medical significance of pre-existing disease and disability in the shelter population and the medical effects of confining large randomly selected groups of persons under the austere conditions postulated are emphasized throughout. Measures most likely to influence ultimate radiation-related mortality include management of infection and of hemorrhagic manifestations of radiation injury, and management of surgical problems. Presently available chemical "protective agents" are mentioned but their effectiveness in preventing radiation mortality is considered to be doubtful under shelter conditions postulated. Space and water are the most important requirements for survival under shelter conditions, and present allocations should be revised. Recommendations for specific research are made but these recommendations would be subject to revision, depending upon the outcome of the recommendations with respect to operations.

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