PROGNOSTIC SIGNIFICANCE OF CONCENTRATIONS OF FOUR CLASSES OF PROTEIN-BOUND CARBOHYDRATES IN THE SERUM OF DOGS
All aspects of investigative programs involving the use of laboratory animals sponsored by DoD components are conducted according to the principles enunciated in the "Guide for Laboratory Animal Facilities and Care", prepared by the National Academy of Sciences - National Research Council.
PROGNOSTIC SIGNIFICANCE OF CONCENTRATIONS OF FOUR CLASSES
OF PROTEIN-BOUND CARBOHYDRATES IN THE SERUM OF DOGS

A. S. EVANS
F. A. QUINN
K. M. HARTLEY

R. E. GEORGE
Commander, MSC, USN
Chairman
Radiation Biology Department

HUGH B. MITCHELL
Colonel, USAF, MC
Director

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
Defense Atomic Support Agency
Bethesda, Maryland

Approved for public release; distribution unlimited
TABLE OF CONTENTS

Foreword (Nontechnical summary) .................................................. iii
Abstract ......................................................................................... vii
I. Introduction ................................................................................. 1
II. Materials and Methods ............................................................... 1
III. Results ..................................................................................... 3
IV. Discussion ............................................................................... 8
References ...................................................................................... 11

LIST OF FIGURES

Figure 1. Milligrams protein-bound carbohydrates per 100 mg protein
(biuret) in the serum of dogs at indicated times relative
to receiving a 400-rad dose of mixed gamma-neutron
radiation ...................................................................................... 3

Figure 2. Milligrams protein-bound carbohydrates per 100 mg protein
(biuret) in the serum of dogs at indicated times relative
to receiving a 230-rad dose of mixed gamma-neutron
radiation ...................................................................................... 5

Figure 3. Milligrams protein-bound carbohydrates per 100 mg protein
(biuret) in the serum of dogs at indicated times relative
to receiving a 225-rad dose of mixed gamma-neutron
radiation ...................................................................................... 6

Figure 4. Daily percent change from overall mean of protein concentration
of each of various carbohydrates in individual dogs which
survived 225 rads of mixed gamma-neutron irradiation with
varying degrees of overt clinical symptomatology ..................... 7
To establish criteria for assessment of continuing prognosis of an individual, tests should be selected which measure changes directly proportionate with the gravity of his condition. As a corollary, it may be stated that, with good prognosis, these changes should be minimal or absent.

To make the testing procedure objective, numerical boundaries should be established so that crossing from one range to another is indicative of changes in the probable course of the patient.

In the first two reports of this series (AFRRI SR68-4 and AFRRI SR69-24) it was suggested that the plasma concentration of protein-bound carbohydrates as neutral hexoses (uncharged 6-carbon sugars) is of significant prognostic value in following the course of radiation injury in mice and dogs. Thus, in both species, the animals that died showed a marked increase in plasma concentration of these bound carbohydrates, while the survivors of identical doses deviated only slightly from their preirradiation base-line values.

The presently reported experiments were designed to supplement the previous work on protein-bound neutral hexoses and to obtain a clearer picture of the prognostic value of serum carbohydrate constituents in radiation injury. Therefore, alterations in additional classes of carbohydrates bound to protein (sialic acid, hexosamines, and fucose) were followed as a function of time relative to irradiation.

Three groups of eight dogs each were given doses of 225, 230, and 400 rads of mixed gamma-neutron radiation, respectively. The doses were delivered at a rate of
approximately 20 rads/minute from the AFRRI-TRIGA reactor. Blood specimens were taken before irradiation and at intervals thereafter for 15 or 20 days or until death intervened.

The proteins were separated from the serum by precipitating them with alcohol. The various sugars were selectively removed from the proteins, and their concentrations were determined by chemical methods.

The actual amount of carbohydrate being incorporated into the proteins was estimated by calculating the amount (milligrams) of the various sugars bound per 100 mg total protein. In this way, the influence of changes in the blood volume of the animal was eliminated. This derived number is referred to as the protein concentration of the carbohydrate.

Moderate to marked fluctuations were seen during the testing period in the protein concentration of neutral hexoses, sialic acid, and hexosamines, especially in the two lower dose groups. The protein concentration of the neutral hexoses gave the clearest warning of unfavorable prognosis in the animals which died and exhibited the greatest stability in those which survived. No significant changes in the concentration of protein-bound fucose were seen in any of the 24 dogs.

These data, when analyzed in terms of observed clinical condition of the animals and their ultimate fate (survived or died), suggested that the following boundaries could be set:

1. Protein concentration of neutral hexoses below 1.60 was evidence of good prognosis. Thus, all the animals which maintained less than 1.60 mg neutral hexoses per 100 mg protein survived without treatment.
2. The interval 1.60 to 1.80 was assigned as the "guarded" prognosis range. That is, entry into this range within the first 15 days postirradiation presaged impending deterioration, and, if treatment is to be instituted, it probably should be started immediately. Such a warning occurred in a number of the dogs as early as the 1st day postirradiation, and always appeared several days before the sharp terminal rise. More importantly, entry into the "guarded" prognosis range preceded appearance of overt symptoms.

3. Protein concentrations of neutral hexoses greater than 1.80 mg per 100 mg protein signaled the beginning of the terminal rise and probably indicated that irreversible damage had occurred.

These tentative ranges were tested in nine additional dogs and were found to be effective for prediction.

These boundaries are obviously applicable only to dogs. Differences among various animals in their "normal" levels of protein concentration of neutral hexoses will require that appropriate ranges be established for each.
ABSTRACT

Three groups of eight dogs each were given doses of 225, 230, and 400 rads of mixed gamma-neutron radiation, respectively. The doses were delivered at a rate of approximately 20 rads/minute from the AFRRI-TRIGA reactor. In animals with poor prognosis, the serum protein concentrations (milligrams carbohydrate per 100 mg biuret protein) of neutral hexoses, hexosamines, and sialic acid started to rise at varying times postirradiation, continued upward, and remained high until the death of the animal. Moderate to marked fluctuations in the protein concentrations were seen in the time course of all these carbohydrates, especially in the two lower dose groups. The protein concentration of the neutral hexoses gave the clearest warning of unfavorable prognosis in the animals which died and exhibited the greatest stability in those which survived. No significant changes in the concentration of protein-bound fucose were seen in any of the 24 dogs. Serum protein-bound neutral hexose concentrations offer promise for development of a relatively simple, objective prognostic test to supplement clinical observation in cases of radiation injury. Thus, numerical ranges of protein concentrations of neutral hexoses are proposed to indicate good, guarded, and poor prognoses for this species. These tentative ranges were tested in nine additional dogs and were found to be effective for prediction.
I. INTRODUCTION

Previous reports from this laboratory\textsuperscript{3,4} have indicated that the plasma concentration of protein-bound carbohydrates as neutral hexoses is of significant prognostic value in following the course of radiation injury in mice and dogs. Thus, in both species, the animals which died showed a marked increase in plasma concentration of these bound carbohydrates, while the survivors of identical doses deviated only slightly from their preirradiation base-line values.

Electrophoretic and chromatographic analyses\textsuperscript{3} revealed that a large portion of the increase in protein-bound neutral hexoses in moribund animals could be accounted for operationally in glycoproteins concerned with iron conservation, transferrin and haptoglobin. Other affected components were the $\beta_2$-glycoproteins and $\alpha_2$-macroglobulin.

With the object of supplementing previous work on protein-bound neutral hexoses and to obtain a clearer picture of the prognostic value of serum carbohydrate constituents in radiation injury, alterations in additional classes of carbohydrates bound to protein were followed as a function of time relative to irradiation.

II. MATERIALS AND METHODS

Healthy, AKC registrable beagles of both sexes, 2-3 years of age, were the experimental animals.

Three groups of eight dogs each were given midline tissue doses of 225, 230, and 400 rads of mixed gamma-neutron radiation, respectively. The doses were delivered at a rate of approximately 20 rads/minute from the AFRRI-TRIGA reactor. The characteristics of the exposure field have been described previously.\textsuperscript{5}
During irradiation, the dogs were restrained in plastic boxes and positioned on an isokerma (free-in-air) curve with the center line of the animals approximately 400 cm from the vertical axis of the core. At the midpoint in time for each exposure the restraining boxes were rotated through 180° to achieve bilateral irradiation.

Blood samples (1–2 ml) were taken from the dogs prior to irradiation and at intervals thereafter for 15 or 20 days or until death intervened. The blood was allowed to clot; the serum was recovered by centrifugation and was stored in an ultra-low temperature freezer (−85°C) until analyzed.

Total protein was estimated by the biuret method using a commercial, stabilized reagent.* Commercially prepared, crystallized human albumin† was used as the standard.

To quantify the protein-bound neutral hexoses (as galactose and mannose) the sulfuric acid–orcinol technique of Weimer and Moshin7 was used.

Protein-bound hexosamines (as glucosamine) were quantified by Rimington’s modification of the Elson-Morgan method.6

The concentration of protein-bound sialic acid (as N-acetylmuraminic acid) was estimated by Winzler’s modification8 of the procedure of Ayala et al.1

Protein-bound fucose concentration (as 6-deoxy-L-galactose) was determined by the method of Dische and Shettles.2

All of the determinations were made in duplicate on each sample. To eliminate any influence of hemodilution or hemoconcentration, the concentration of each class

* Hycel No. 201A, Hycel, Inc., Houston, Texas
† Dade Division, American Hospital Supply Corporation, Miami, Florida
of carbohydrate was converted to milligrams of carbohydrate per 100 mg biuret protein. For brevity, this value will be referred to as the protein concentration of the carbohydrate.

The dogs were observed for overt clinical signs of acute illness (alertness, response to handling, respiration rate, mobility, etc.) several times each day.

III. RESULTS

All of the dogs which had received 400 rads of mixed gamma-neutron radiation died on or before the 11th day postirradiation. At this overwhelming dose, the protein concentrations of neutral hexoses, sialic acid, and hexosamines as a function of time were similar (Figure 1). Thus, in the seven animals which survived to the 10th or 11th day, these values started to increase on the 6th postirradiation day, continued upward at almost identical rates, and remained high until the death of the animal. These three classes of carbohydrates also followed a similar pattern in the one animal which died on the 4th day postirradiation, but significant increases over preirradiation values did not occur until the day of death.

Figure 1. Milligrams protein-bound carbohydrates per 100 mg protein (biuret) in the serum of dogs at indicated times relative to receiving a 400-rad dose of mixed gamma-neutron radiation. Open symbols: died on 4th day postirradiation. Closed symbols: died on day 10 or 11. ○,● = neutral hexoses; △,▲ = hexosamines; ◻,■ = sialic acid; □,▼ = fucose. The number of animals represented by each curve is in parentheses.
Seven of the eight dogs which had received 230 rads died. In the animals which
died, the protein concentrations of neutral hexoses, sialic acid, and hexosamines as
a function of time were similar to those seen in the 400-rad experiment (Figure 2A-C).
The time courses of these protein-bound carbohydrate concentrations, however, did
not parallel one another as closely as in the higher dose group (Figure 1). The one
surviving animal of the 230-rad group (Figure 2D) was acutely ill during the 2nd week
postirradiation. When the neutral hexoses went above 1.60 mg carbohydrate per
100 mg protein and continued to creep upward, this animal was given a high protein,
soft diet, and special hygienic measures were taken to control routes of sepsis in its
environment. While it remained high, the protein concentration of neutral hexoses
stabilized after the 11th day, and clinical improvement continued for the remainder of
the 40-day observation period. At the end of this time, the concentration of protein-
bound neutral hexoses had returned to preirradiation levels.

At the lowest dose, 225 rads, three of the eight dogs died during the 40-day
observation period. In the animals which died, moderate to marked fluctuations were
seen in the protein concentrations of neutral hexoses, sialic acid, and hexosamines
during the course of the radiation sickness and terminated in a sharp rise shortly
preceding death (Figure 3A-C). The five survivors, taken as a group, exhibited no
remarkable changes in any of the protein-bound carbohydrate concentrations (Fig-
ure 3D). Clinically, however, there was considerable variation in the severity of the
radiation sickness among these survivors, and these differences were reflected in the
time course of protein-bound neutral hexose concentrations in the individual dogs (Fig-
ure 4). In Figure 4, the daily percent change in the protein concentration of each
Figure 2. Milligrams protein-bound carbohydrates per 100 mg protein (biuret) in the serum of dogs at indicated times relative to receiving a 230-rad dose of mixed gamma-neutron radiation. A, died on 9th day postirradiation; B, died on day 12 or 13; C, died on day 14 or 15; D, survived (with treatment).

- neutral hexoses; △ hexosamines; □ sialic acid; ○ fucose.

The number of animals represented by each curve is in parentheses.
class of carbohydrate from its overall mean for the 15 days was plotted. Thus, while variations follow the same course as a function of time as the raw data, the shift of coordinates permitted direct comparability in that all the carbohydrate concentrations are referenced to the same horizontal line, y = 0.

No definable pattern was seen in the moderate to marked fluctuations in the sialic acid and hexosamine concentrations of the survivors. The neutral hexose concentrations, however, were relatively stable as compared with the other carbohydrates,

Figure 3. Milligrams protein-bound carbohydrates per 100 mg protein (biuret) in the serum of dogs at indicated times relative to receiving a 225-rad dose of mixed gamma-neutron radiation. A, died on 16th day postirradiation; B, died on day 19; C, died on day 36; D, survived. • = neutral hexoses; △ = hexosamines; □ = sialic acid; o = fucose. The number of animals represented by each curve is in parentheses.
and when ordered according to increasing variability (Figure 4A-D) the animals were at the same time ranked according to increasing observed clinical difficulty. The fifth survivor of this dose group (not shown) fell in the midrange between 4B and 4C when ordered by the same criteria.

No remarkable changes were seen in the protein-bound fucose concentration in any of the 24 animals of the three dose groups.

Figure 4. Daily percent change from overall mean of protein concentration of each of various carbohydrates in individual dogs which survived 225 rads of mixed gamma-neutron irradiation with varying degrees of overt clinical symptomatology. The broken line represents the level at which 1.60 mg neutral hexoses per 100 mg protein would fall for each individual.

- • = neutral hexoses; △ = hexosamines; □ = sialic acid.
IV. DISCUSSION

To establish criteria for assessment of continuing prognosis of an individual, tests should be selected which measure changes directly proportionate with the gravity of his condition. As a corollary, it may be stated that, with good prognosis, these changes should be minimal or absent.

To make the testing procedure objective, numerical boundaries should be established so that crossing from one range to another is indicative of changes in the probable course of the patient.

The lack of response of the protein-bound fucose concentrations, together with the wide day-to-day fluctuations encountered in the protein concentrations of hexosamines and sialic acid, eliminated their usefulness in delineating the required boundaries.

The comparative stability of the neutral hexose concentrations in the survivors and their response in the diers, however, have enabled establishment of tentative levels which meet the requirements set above.

These data, when analyzed in terms of observed clinical condition of the animals and their ultimate fate (survived or died), suggested that the following boundaries could be set:

1. Protein concentration of neutral hexoses below 1.60 was evidence of good prognosis. Thus, all the animals which maintained less than 1.60 mg neutral hexoses per 100 mg biuret protein survived without treatment.

2. The interval 1.60 to 1.80 was assigned as the "guarded" prognosis range. That is, entry into this range within the first 15 days postirradiation presaged impending deterioration, and, if treatment is to be instituted, it probably should be
started immediately. While only one animal of these groups was treated, and that minimal compared to more heroic measures (complete asepsis, bone marrow transplants, etc.) which could have been used, initiation of treatment before the dog's condition became irreversible was undoubtedly critical. Such a warning occurred in a number of the dogs as early as the 1st day postirradiation, and always appeared several days before the sharp terminal rise. More importantly, entry into the "guarded" prognosis range preceded appearance of overt symptoms.

3. Protein concentrations of neutral hexoses greater than 1.80 mg per 100 mg protein was evidence of poor prognosis, signaled the beginning of the terminal rise, and probably indicated that irreversible damage had occurred.

The above criteria were applied to nine dogs which were bled at intervals after receiving 240 rads of $^{60}$Co $\gamma$-irradiation for another experiment. One of the five survivors fluctuated between the good and "guarded" ranges (high 1.71, low 1.56 mg neutral hexoses per 100 mg protein). The remaining four survivors maintained protein concentrations of neutral hexoses well below the 1.60 level. The four diers all gave early warning by excursion above 1.60 and later exceeded 1.80 (to go as high as 3.74) in the terminal phase. Entry into the "guarded" prognosis range occurred from 8 days prior to death in two dogs which died on the 17th day postirradiation to 29 days prior to one animal's death on the 35th day. Entry into the poor prognosis range in these dogs was 3 and 19 days before death, respectively.

These boundaries are obviously applicable only to dogs. Differences among mammalian species in "normal" levels of protein concentration of neutral hexoses will require that appropriate ranges be established for each.
Establishment of criteria for objective assessment of radiation injury to the human presents a complicated problem in experimental design. Thus, practically all the cases available for study are patients receiving therapeutic irradiation, and its effects must be separated from the damage inflicted by underlying disease. Preliminary data suggest that such a separation can be made on the basis of preirradiation studies on different tumor types.

Combined with careful in-hospital clinical management, these tests may prove of value in determining the tolerance limit of the individual to radiotherapy.
REFERENCES


# DISTRIBUTION LIST

## AIR FORCE

Executive Officer, Director of Professional Services, Office of the Surgeon General, Hq. USAF (AFMSPA) T-8, Washington, D. C. 20333 (1)  
Headquarters, U. S. Air Force (AFMSPAB), Washington, D. C. 20333 (1)  
Chief, Weapons and Weapons Effects Division, Hq. RTD (RTTW), Boiling AFB, Washington, D. C. 20332 (1)  
Office of the Command Surgeon (ADCSG), Hq. ADC, USAF, Ent AFB, Colorado 80912 (1)  
Commander, 6571st Aeromedical Research Laboratory, Holloman AFB, New Mexico 88330 (2)  
Air Force Weapons Laboratory, ATTN: WLIL (1), ATTN: WLRB-2 (1), Kirtland AFB, New Mexico 87117 (2)  
Chief, Nuclear Medicine Department, P. O. Box 5088, USAF Hospital, Wright-Patterson AFB, Ohio 45433 (1)  
USAFSAM (SMBR), ATTN: Chief, Radiobiology Branch, Brooks AFB, Texas 78235 (1)

## ARMY

The Surgeon General, U. S. Department of the Army, Washington, D. C. 20315 (1)  
USACDC CSSG, Doctrine Division, Fort Lee, Virginia 23801 (1)  
Commanding Officer, USACDC CBR Agency, Fort McClellan, Alabama 36201 (1)  
Commanding Officer, U. S. Army Combat Developments Command, Institute of Nuclear Studies, Fort Bliss, Texas 79916 (1)  
CG, USCONARC, ATTN: ATUTR-TNG (NBC), Fort Monroe, Virginia 23651 (1)  
Commanding Officer, U. S. Army Medical Research Laboratory, Fort Knox, Kentucky 40121 (1)  
Commanding Officer, USA Nuclear Medical Research Detachment, Europe, APO New York, N. Y. 09180 (2)  
Chief of Research and Development, ATTN: Nuclear, Chemical and Biological Division, U. S. Department of the Army, Washington, D. C. 20310 (1)  
Army Research Office, ATTN: Chief, Scientific Analysis Branch, Life Sciences Division, 3045 Columbia Pike, Arlington, Virginia 22204 (1)  
Division of Nuclear Medicine, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D. C. 20012 (5)  
Commanding Officer, U. S. Army Environmental Hygiene Agency, ATTN: USAEHA-RP, Edgewood Arsenal, Maryland 21010 (1)  
Commandant, U. S. Army Medical Field Service School, ATTN: MEDEW-ZNW, Fort Sam Houston, Texas 78234 (1)

## NAVY

Chief, Bureau of Medicine and Surgery, U. S. Navy Department, Washington, D. C. 20390 (1)  
Commanding Officer, Naval Aerospace Medical Institute, Naval Aviation Medical Center, ATTN: Director of Research, Pensacola, Florida 32512 (3)  
Commanding Officer, Nuclear Weapons Training Center, Atlantic, Nuclear Warfare Department, Norfolk, Virginia 23511 (1)  
Commanding Officer, Nuclear Weapons Training Center, Pacific, U. S. Naval Air Station, North Island, San Diego, California 92135 (1)  
Director, Biological Sciences Division, Office of Naval Research, Washington, D. C. 20360 (1)  
Commanding Officer, U. S. Naval Hospital, ATTN: Director, REEL, National Naval Medical Center, Bethesda, Maryland 20014 (1)  
Head, Animal Behavioral Sciences Branch, Naval Aerospace Medical Institute, Naval Aerospace Medical Center, ATTN: Dr. John S. Thach, Jr., Pensacola, Florida 32512 (1)  
Commanding Officer, Naval Submarine Medical Center, Naval Submarine Base, NL, ATTN: Medical Library, Groton, Connecticut 06340 (1)  
Commanding Officer, Naval Submarine Medical Center, Naval Submarine Base, NL, ATTN: Code 53, Nuclear Medicine Training Division, Groton, Connecticut 06340 (1)

## D. O. D.

Director, Defense Atomic Support Agency, Washington, D. C. 20305 (1)  
Director, Defense Atomic Support Agency, ATTN: DDST, Washington, D. C. 20305 (1)  
Director, Defense Atomic Support Agency, ATTN: Chief, Medical Directorate, Washington, D. C. 20305 (4)  
Director, Defense Atomic Support Agency, ATTN: Chief, Radiobiology Branch, Brooks AFB, Texas 78235 (1)
D. O. D. (continued)

Commanding Officer, Harry Diamond Laboratories, ATTN: Nuclear Vulnerability Branch, Washington, D. C. 20438 (1)
Commander, Field Command, Defense Atomic Support Agency, ATTN: FC Technical Library, Sandia Base, Albuquerque, New Mexico 87115 (1)
Commander, Headquarters Field Command, Defense Atomic Support Agency, ATTN: FCTG8, Sandia Base, Albuquerque, New Mexico 87115 (2)
Director, Armed Forces Institute of Pathology, Washington, D. C. 20305 (1)
Administrator, Defense Documentation Center, Cameron Station, Bldg. 3, Alexandria, Virginia 22314 (20)

OTHER GOVERNMENT

U. S. Atomic Energy Commission, Headquarters Library, Reports Section, Mail Station G-17, Washington, D. C. 20545 (1)
U. S. Atomic Energy Commission, Division of Biology and Medicine, Washington, D. C. 20545 (1)
U. S. Atomic Energy Commission, Bethesda Technical Library, 7920 Norfolk Avenue, Bethesda, Maryland 20014 (1)
National Aeronautics and Space Administration, ATTN: Lt. Col. Charles M. Barnes, USAF, DB-3, MSC, Houston, Texas 77058 (1)
National Aeronautics and Space Administration, Manned Spacecraft Center, ATTN: Dr. B. D. Newsom, Mail Code DA, Houston, Texas 77058 (1)
National Bureau of Standards, ATTN: Chief, Radiation Physics Division, Washington, D. C. 20234 (1)
U. S. Public Health Service, Bureau of Radiological Health, Division of Biological Effects, 12720 Twinbrook Parkway, Rockville, Maryland 20852 (1)
U. S. Public Health Service, Bureau of Radiological Health, Library, 12720 Twinbrook Parkway, Rockville, Maryland 20852 (1)
U. S. Public Health Service, Northeastern Radiological Health Laboratory, 169 Holton Street, Winchester, Massachusetts 01890 (1)
U. S. Public Health Service, Southeastern Radiological Health Laboratory, P. O. Box 61, Montgomery, Alabama 36101 (1)
U. S. Public Health Service, Southwestern Radiological Health Laboratory, P. O. Box 15027, Las Vegas, Nevada 89114 (1)

OTHER

Argonne National Laboratory, Library Services Department, Report Section Bldg. 203, RM-CE-125, 9700 South Cass Avenue, Argonne, Illinois 60440 (1)
Dr. Donald G. Baker, Radiobiology Department, Zellerbach Saroni Tumor Institute, 1600 Divisadero Street, San Francisco, California 94115 (1)
Dr. J. T. Brennan, Radiology Department, University of Pennsylvania, 2400 Spruce Street, Philadelphia, Pennsylvania 19104 (1)
Brookhaven National Laboratory, Information Division, ATTN: Research Library, Upton, Long Island, New York 11973 (2)
Dr. J. S. Burkle, Director of Nuclear Medicine, York Hospital, York, Pennsylvania 17403 (1)
S. C. Bushong, Department of Radiology, Baylor University College of Medicine, Houston, Texas 77024 (1)
University of California, Lawrence Radiation Laboratory, Library, Bldg. 50, Room 134, Berkeley, California 94720 (1)
Director, Radiobiology Laboratory, University of California, Davis, California 95616 (1)
University of California, Lawrence Radiation Laboratory, Technical Information Division Library L-3, P. O. Box 808, Livermore, California 94551 (2)
University of California, Laboratory of Nuclear Medicine and Radiobiology, Library, 900 Veteran Avenue, Los Angeles, California 90024 (1)
Dr. C. Jelleff Carr, Director, Life Sciences Research Office, Federation of American Societies for Experimental Biology, 9560 Rockville Pike, Bethesda, Maryland 20014 (1)
Cdr. William H. Chapman, USN (Ret.), Bio-Medical Division L-523, Lawrence Radiation Laboratory, University of California, P. O. Box 808, Livermore, California 94551 (1)
Director, Collaborative Radiological Health Laboratory, Colorado State University, Fort Collins, Colorado 80521 (1)
Dr. L. W. Davis, Radiology Department, University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104 (1)
Professor Merril Eisenbud, New York University, Tuxedo, New York 10987 (1)
Dr. T. C. Evans, Radiation Research Laboratory, College of Medicine, University of Iowa, Iowa City, Iowa 52240 (1)
OTHER (continued)

Dr. Arnold Feldman, Institute of Radiology, School of Medicine, Washington University, 510 South Kingshighway, St. Louis, Missouri 63110 (1)
Mr. Orin Gelderloos, Division of Literature, University of Michigan, Dearborn Campus, Dearborn, Michigan 48124 (1)
General Dynamics/Fort Worth, ATTN: Librarian, P. O. Box 748, Fort Worth, Texas 76101 (1)
Gulf General Atomic Incorporated, ATTN: Library, P. O. Box 608, San Diego, California 92112 (1)
Dr. James E. Huff, Department of Pharmacology and Toxicology, School of Medicine and Dentistry, University of Rochester, 260 Crittenden Blvd., Rochester, New York 14620 (1)
IIT Research Institute, ATTN: Document Library, 10 West 55th Street, Chicago, Illinois 60616 (1)
Johns Hopkins University, Applied Physics Laboratory, ATTN: Document Library, 8621 Georgia Avenue, Silver Spring, Maryland 20910 (1)
Dr. R. F. Kallman, Department of Radiology, Stanford University, Palo Alto, California 94305 (1)
Dr. L. S. Kelly, Donner Laboratory, University of California at Berkeley, Berkeley, California 94720 (1)
Dr. Robert Landolt, Bionucleonics Department, Purdue University, Lafayette, Indiana 47907 (1)
Los Alamos Scientific Laboratory, ATTN: Report Librarian, P. O. Box 1663, Los Alamos, New Mexico 87544 (1)
Director, Nuclear Science Center, Louisiana State University, Baton Rouge, Louisiana 70803 (2)
Lovelace Foundation for Medical Education and Research, Document Library, 5200 Gibson Blvd., S. E., Albuquerque, New Mexico 87108 (1)
Dr. Ross A. McFarland, Guggenheim Professor of Aerospace Health and Safety, Harvard School of Public Health, 665 Huntington Avenue, Boston, Massachusetts 02115 (1)
Dr. J. I. Marcum, Rand Corporation, 1700 Main Street, Santa Monica, California 90401 (1)
Massachusetts Institute of Technology, M.I.T. Libraries, Technical Reports, Room 14 E-210, Cambridge, Massachusetts 02139 (1)
Dr. Charles W. Mays, Physics Group Leader, Radiobiology Division, University of Utah, Salt Lake City, Utah 84112 (1)
Ohio State University, Nuclear Reactor Laboratory, 1298 Kinnear Road, Columbus, Ohio 43212 (1)
Dr. Harvey M. Patt, Laboratory of Radiobiology, University of California, San Francisco Medical Center, San Francisco, California 94122 (1)
Purdue University, Nuclear Engineering Library, Lafayette, Indiana 47907 (1)
Dr. S. M. Reichard, Director, Division of Radiobiology, Medical College of Georgia, Augusta, Georgia 30902 (1)
Dr. H. H. Rossi, 630 West 168th Street, New York, N. Y. 10032 (1)
Dr. Eugene L. Saenger, Director, Radiisotope Laboratory, Cincinnati General Hospital, Cincinnati, Ohio 45229 (1)
Sandia Corporation Library, P. O. Box 5800, Albuquerque, New Mexico 87115 (1)
Scientific Committee on the Effects of Atomic Radiation, ATTN: Library, United Nations Room 3267, United Nations Plaza, New York, N. Y. 10017 (1)
Scope Publications, Franklin Station, P. O. Box 7407, Washington, D. C. 20004 (1)
Dr. Arthur R. Tamplin, Biophysicist, Information Integration Group, University of California, Lawrence Radiation Laboratory, L-612, Livermore, California 94550 (1)
Texas A and M University, Radiation Biology Laboratory, Texas Engineering Experiment Station, College Station, Texas 77840 (2)
Texas Nuclear Corporation, ATTN: Director of Research, Box 9267 Allandale Station, Austin, Texas 78756 (1)
University of Rochester, Atomic Energy Project Library, P. O. Box 287, Station 3, Rochester, New York 14620 (1)
University of Southern California, Nuclear Physics Laboratory, University Park, Los Angeles, California 90007 (1)
Western Reserve University, Department of Radiology, Division of Radiation Biology, Cleveland, Ohio 44106 (1)
Mr. Lionel Zamore, 601 Brightwater Court, Brooklyn, New York 11235 (1)

FOREIGN

International Atomic Energy Agency, Kärntnerring 11, Vienna I. 1010, Austria (1)
European Atomic Energy Community, C. E. E. A., Library, 51 rue Belliard, Brussels 4, Belgium (1)
Dr. L. G. Lajtha, Paterson Laboratories, Christie Hospital and Holt Radium Institute, Manchester, England (1)
Dr. L. F. Lamerton, Biophysics Department, Institute of Cancer Research, Surrey Branch, Belmont, Sutton, Surrey, England (1)
National Lending Library for Science and Technology, Boston Spa, Yorkshire, England (1)
Directorate of Medical and Health Services, FAF (Federal Armed Forces), Bonn, Ermekeilstrasse 27, West Germany (1)
Abteilung für Strahlenbiologie im Institut für Biophysik der Universität Bonn, 53 Bonn-Venusberg, Annabager Weg 15, Federal Republic of Germany (2)
Prof. Dr. H. Langendorff, Direktor des Radiologischen Instituts der Universität, 78 Freiburg im Breisgau, Albertstrasse 23, Germany (1)
FOREIGN (continued)

Priv.-Doz. Dr. O. Messerschmidt, Radiologisches Institut der Universität, 78 Freiburg im Breisgau, Albert-
strasse 23, Germany (1)

Dr. Helmut Mitschrich, Akademie des Sanitäts- und Gesundheitswesens der Bundeswehr, Spezialstab ATV,
8 München, Schwere Reiterstrasse 4, Germany (2)

Prof. Dr. F. Wachsmann, Gesellschaft für Strahlenforschung m.b. H., 8042 Neuherberg bei München, Institut für
Strahlenschutz, Ingolstädter Landstrasse 1, München, Germany (1)

Dr. M. Feidman, Section of Cell Biology, The Weizmann Institute of Science, Rehovoth, Israel (1)

Dr. G. W. Barendsen, Radiobiological Institute TNO, Rijswijk, Netherlands (1)

Dr. L. M. van Putten, Radiobiological Institute TNO, 151 Lance Kleiweg, Rijswijk 2 H, Netherlands (1)

Puerto Rico Nuclear Center, ATTN: Reading Room, College Station, Mayaguez, Puerto Rico 00708 (2)

Dr. H. Cottier, Pathological Institut der Universität, Bern, Switzerland (1)
Three groups of eight dogs each were given doses of 225, 230, and 400 rads of mixed gamma-neutron radiation, respectively. The doses were delivered at a rate of approximately 20 rads/minute from the AFRRI-TRIGA reactor. In animals with poor prognosis, the serum protein concentrations (milligrams carbohydrate per 100 mg biuret protein) of neutral hexoses, hexosamines, and sialic acid started to rise at varying times postirradiation, continued upward, and remained high until the death of the animal. Moderate to marked fluctuations in the protein concentrations were seen in the time course of all these carbohydrates, especially in the two lower dose groups. The protein concentration of the neutral hexoses gave the clearest warning of unfavorable prognosis in the animals which died and exhibited the greatest stability in those which survived. No significant changes in the concentration of protein-bound fucose were seen in any of the 24 dogs. Serum protein-bound neutral hexose concentrations offer promise for development of a relatively simple, objective prognostic test to supplement clinical observation in cases of radiation injury. Thus, numerical ranges of protein concentrations of neutral hexoses are proposed to indicate good, guarded, and poor prognoses for this species. These tentative ranges were tested in nine additional dogs and were found to be effective for prediction.