BIOLOGICAL EFFECTS
OF NONIONIZING ELECTROMAGNETIC RADIATION

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Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Research Center, Science Information Services Organization, under contract to the National Telecommunications and Information Administration (NTIA); funding provided by the U.S. Navy under interagency agreement with NTIA.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and other radio frequency radiation) are compiled, condensed, and disseminated on a regular basis. Biological Effects of Nonionizing Electromagnetic Radiation is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of the service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Nonionizing Electromagnetic Radiation is published quarterly. The issues of Volume IV, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.
ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)
Å - angstrom(s)
BRH - Bureau of Radiological Health
C - centigrade
cm - centimeter(s)
cps - cycles per second
dB - decibel(s)
EPA - Environmental Protection Agency
FDA - Food and Drug Administration
g - gram(s)
G - Gauss
GHz - gigahertz
HEW - Health, Education, and Welfare
hr - hour
Hz - hertz
IEEE - Institute of Electronic and Electrical Engineers
IMPI - International Microwave Power Institute
IU - international unit(s)
J - joule(s)
k - kilo-
l - liter(s)
m - meter(s)
m - milli-
M - mega-
mho - unit of measurement of conductivity
min - minute(s)
mo - month(s)
n - nano-
NBS - National Bureau of Standard
NIH - National Institutes of Health
NSF - National Science Foundation
NIOSH - National Institute for Occupational Safety and Health
NTIA - National Telecommunications and Information Administration
NTIS - National Technical Information Service
OE - oersted(s)
OSHA - Occupational Safety and Health Administration
OTP - Office of Telecommunications Policy
PHS - Public Health Service
rad - radiation absorbed dose
R - roentgen(s)
 rpm - revolutions per minute
sec - second(s)
USAFSAM - U.S. Air Force School of Aerospace Medicine
USDA - U.S. Department of Agriculture
UV - ultraviolet
V - volt(s)
VA - Veterans Administration
W - watt(s)
Wb - Weber(s)
WHO - World Health Organization
wk - week(s)
wt - weight
yr - year(s)

μ - micro-
SCIENTIST DISPUTES USE OF SAR IN THE DEVELOPMENT OF THE C65 SAFETY STANDARD REVISION

Allan H. Frey of Randomline, Incorporated of Huntingdon Valley, PA, in a recent letter appearing in the Bioelectromagnetics Society Newsletter, disputed the use of the specific absorption rate (SAR) concept as a fundamental assumption underlying the development of the proposed revision of the C65 safety standard. Mr. Frey explained that the SAR concept assumes that the only mechanism whereby microwaves and other radio frequency energies can effect biologic systems is by the volume heating of a homogenous mass of tissue, and since the concept is nothing more than a calculated absorption rate in a tissue mass, it is doubtful whether the SAR has any relevance to the biologic organism at incident power densities <10 mW/cm². Mr. Frey also disagrees with a secondary assumption that 70 MHz, the frequency for maximum energy absorption, is also the frequency for maximum sensitivity. He suggested that the biologic effects of low intensity energy observed at much higher frequencies would not necessarily have occurred at lower power densities at the 70-MHz region of the spectrum. Lastly, Mr. Frey considered that the use of the SAR concept in the proposed revision would ignore the effects of modulation and peak power. He added that some of his observations were supported by the results of a working group study, which met in February 1979. Mr. Frey concluded that "the assumption underlying the SAR concept renders it of little relevance to biological effects of low intensity or modulated energy which we are studying now. The application of the SAR concept in such studies is grossly misleading for both biologists and Regulators."


BIOELECTROMAGNETICS SOCIETY ANNOUNCES FIRST CALL FOR PAPERS FOR THE 1980 SECOND ANNUAL MEETING

The Bioelectromagnetics Society (BEMS) has announced the first call for papers for the 1980 BEMS Second Annual Meeting to be held September 14-18, 1980 in San Antonio, TX. Original papers are solicited for presentation in English (via platform or a poster session) on the interaction of electromagnetic energy (from 0 Hz through visible light frequencies) and acoustic energy with biologic systems. Areas of interest include: behavioral, physiologic, neurologic, endocrine, developmental, cellular and ultrastructural, and genetic effects; dielectric properties of biologic materials; electric field effects; exposure systems; dosimetry; diagnostic and therapeutic applications; interactive mechanisms; instrumentation; hyperthermia; and field perturbations. Authors wishing to submit papers should request an abstract submission form from the Bioelectromagnetics Society, P.O. Box 3651, Arlington, VA 22203. Abstracts submitted by non-members must be sponsored by at least one BEMS member. May 1, 1980 is the deadline for submission of abstracts.


NEW YORK AGENCIES TO INVESTIGATE HARMFUL EFFECTS OF A POWER LINE ON RESIDENTS

Two New York state agencies have agreed to conduct a detailed study of the possible hazards that residents of northern New York face from a nearby 765-kV power line, which has been in operation for about 1.5 yr carrying Canadian electric power to New York. The agreement, between the New York State Public Service Commission (PSC) and the New York State Power Authority (PA), calls for the PA to spend as much as $50,000 on a preliminary study to outline the full-scale research effort. The New York State Department of Health will assist with this study. Following the preliminary study and outline, research will be conducted to determine the possible harmful effects on humans and animals living near the line, which runs from near Massena on the U.S.-Quebec border to Utica, NY. The upper cost limit of the study will be about $5 million, which is approximately 2% of the line's construction cost. Francis Rivett, a spokesman for the PSC, explained that the agreement provides funds for a laboratory study, with no experimental work on humans. Mr. Rivett added that the commission is interested in finding out "what, if any" effects are produced by the electric and magnetic fields generated by the line.


ANNUAL EUROPEAN MICROWAVE CONFERENCE—A CONTINUED SUCCESS

Since the first European Microwave Conference took place in London in 1969, the venture has enjoyed an expanded scope and prosperity beyond what its organizers might have anticipated. The 1973 conference, organized by Microwave Exhibitions and Publishers Limited, under the direction of Roger C. Marriott, was attended by 720 delegates; in addition, 320 separately registered delegates attended a workshop. The conference consisted of a full week of activities running from the 17th to the 21st of September. The program included a 4-day session of formal technical paper presentation, generally requiring parallel sessions, followed by a 1-day workshop. A trade show ran coincident with the 4-day technical presentation, with approxi-
The latest BRH Publications Subject Index (HEW Publication [FDA] 80-8070) has been issued by the BRH. This publication supersedes HEW Publication (FDA) 79-8070. The Subject Index, an abbreviated version of the BRH Publications Index, is revised and published several times per year and distributed annually. The Subject Index identifies publications by broad subject areas providing titles and FDA publication series access numbers as part of a BRH national program to control unnecessary human exposure to potential hazardous ionizing and non-ionizing radiation. To obtain information on the current availability of the BRH Publications Subject Index contact the BRH Technical Information Staff (HFZ-28), 5600 Fishers Lane, Rockville, MD 20857 or (301) 443-3532.

BMR Publication (FDA) 80-8070, October 1979.

NINTH SUPPLEMENT TO THE BIBLIOGRAPHY OF MICROWAVE AND RF BIOLOGIC EFFECTS IS AVAILABLE FROM NTIS

The Ninth Supplement to the Bibliography of Microwave and RF Biologic Effects (DHHEW [NIOSH] Publication No. 78-126), which lists approximately 575 additional references that were published up to September 1977, brings the total number of references of the world’s literature concerning the biologic responses to microwaves (MW) and other radio frequencies (RF) to more than 4,600. In this Bibliography, particular attention is paid to the effects of MW and other RF on humans. The scope was broadened slightly from previous editions to include references to biologic studies of pure electric or magnetic fields, extremely low frequency fields, and ultrasound. Other entries cite biomedical studies involving electromagnetic pulse radiation, high voltage photography, biologic dosimetry, the effects of electromagnetic radiation (EMR) on cardiac pacemakers, EMR therapeutic applications, MW exposure regulations and standards, tissue fixation, insect control, and electroanesthesia. The citations are arranged alphabetically by author with sufficient information to retrieve the original document. Relevant presentations at technical meetings and anonymous reports are also cited, but in separate sections in the Supplement. The Bibliography of Reported Biological Phenomena (Effectal) and Clinical Manifestations Attributed to Microwave and Radio-Frequency Radiation: Ninth Supplement to Bibliography of Microwave and RF Biologic Effects is an up-dated listing of the Naval Medical Institute Research Report No. 2, which was completed under Research Work Unit MF12 524, 15-00048, October 1971. The Bibliography is available from the National Technical Information Service, Springfield, VA 22151.

DHHEW (NIOSH) Publication 78-126.
The FDA has issued for public comment two proposed regulations that classify both microwave (MW, 915-2,450 MHz) and shortwave (pulsed or continuous electromagnetic energy from 13 to 27.12 MHz) diathermy devices into class II (performance standards) for use in applying therapeutic deep heat and into class III (premarket approval) for all other uses. The Physical Medical Device Classification Panel has recommended that both MW and shortwave diathermy devices be classified into class II. Class II provides for the future development of one or more performance standards to assure the safety and effectiveness of the device, while class III provides for each manufacturer to submit to FDA a premarket approval application at a date to be set in a future regulation. The Agency believes that performance standards for MW and shortwave diathermy devices are necessary because general controls are insufficient to prevent the risks to health presented by these devices. Performance standards would provide reasonable assurance of the safety and effectiveness of these devices. The FDA believes that sufficient information is available to establish performance standards for both devices, and will issue a final regulation for classifying these devices after considering public comments.

ITEMS FROM THE COMMERCE BUSINESS DAILY

A CRITICAL APPRAISAL OF THE BIOLOGIC EFFECTS OF EXPOSURE TO MICROWAVE AND OTHER RADIO FREQUENCIES.

The Environmental Protection Agency, Headquarters Procurement Operations, Procurement Section C (PM-214-C), Crystall Hall #2, Room 1022A, Washington, DC 20460 is negotiating with the National Academy of Sciences, 2101 Constitution Avenue, Washington, DC 20418 for this study on the critical appraisal of the biologic effects due to exposure to radio frequency waves including microwaves. (October 19, 1979)
MEETINGS AND CONFERENCES

INTERNATIONAL RADIATION PROTECTION ASSOCIATION FIFTH CONGRESS

Date: March 9-14, 1980
Place: Jerusalem, Israel: Jerusalem Convention Center
Sponsor: Israel Health Physics Society, International Radiation Protection Association (IRPA)
Requests for Information: Israel Health Physics Society, c/o Soreq Nuclear Research Center, Yavne 70600, Israel
Content: Sessions will cover all aspects of protection against ionizing and nonionizing radiation

15th ANNUAL MICROWAVE POWER SYMPOSIUM

Date: May 6-9, 1980
Place: Ames, IA: University Iowa
Sponsor: International Microwave Power Institute (IMPI)
Requests for Information: Dr. Glen Fanslow, Department of Electrical Engineering, Iowa State University, Ames, IA 50010
Content: Technical sessions and short courses will be presented. Topics will include new technical contributions in noncommunication areas of radio frequency and microwave power such as biomedical applications; biologic effects on humans, animals, and microbiologic systems; chemical and plasma process; combination thermal and microwave food cooking systems; radio frequency and microwaves in the food industry; consumer microwave oven usage patterns; and industrial radio frequency and microwave systems and applications

1980 IEEE/MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM

Date: May 28-30, 1980
Place: Washington, DC: Shoreham-Americana Hotel
Sponsor: Institute of Electrical and Electronics Engineers (IEEE)--Microwave Theory & Techniques
Requests for Information: B. Shelag, Arrangements Chairman, Naval Research Laboratory, Code 5251, Washington, DC 20375
Content: Topics will cover the expected growth in microwave technology in the 1980s and will include microwave and millimeter wave devices, microwave acoustics, communication systems, field and network theory, and bioeffects.

THIRD INTERNATIONAL SYMPOSIUM ON CANCER THERAPY BY HYPERTHERMIA, DRUGS, AND RADIATION

Date: June 22-26, 1980
Place: Fort Collins, CO: Colorado State University
Sponsor: National Cancer Institute, Colorado American Cancer Society, Journal National Cancer Institute, University of Utah, Colorado State University
Requests for Information: Office of Conferences & Institutes, Rockwell Hall, Colorado State University, Fort Collins, CO 80523
Selected Bibliography of Papers to be Presented:

HYPERTHERMIA AND ELECTRON AFFINIC COMPOUNDS.
G. E. Adams

HEAT TRANSFER MECHANISMS AND THERMAL DOSIMETRY.
H. F. Bowman

APPLICATIONS OF MICROWAVE, ULTRASOUND AND RADIO-FREQUENCY HEATING IN VIVO.
J. Hunt

PHYSIOLOGICAL CONSIDERATIONS.
C. W. Song

CLINICAL LOCAL HEATING--RF.
J. H. Kim

CLINICAL LOCAL HEATING--RF.
K. Storm

CLINICAL LOCAL HEATING--MICROWAVES.
R. M. Scott

CLINICAL LOCAL HEATING--RF--INTERSTITIAL.
M. L. M. Boone, M. Manning

CLINICAL TECHNIQUES AND RESULTS FOR WHOLE BODY HYPERTHERMIA.
T. Herman, L. Parks, W. Levin, H. Reinhold

INTERNATIONAL SYMPOSIUM ON THE BIOLOGIC EFFECTS OF ELECTROMAGNETIC WAVES

Date: June 30-July 4, 1980
Place: Near Paris, France: Centre Superieur d'Enseignement des Affaires (CESA), Near Paris, France
Sponsor: International Union of Radio Science (URSI), Comite National Francais de Radioelectricite Scientifique (CNFRS), International Protection Agency, Bio-electromagnetics Society
Requests for Information: M. A. J. Bertrand, CNRS, 2, rue Henri Dunant, 94320 Thiais, France
Content: Topics will include the interactions of electromagnetic fields with biologic systems; the industrial and domestic uses of electromagnetic radiations; dielectric properties of living matter; dosimetry; molecular and cellular effects; physiologic, physiopathologic, and genetic effects; behavioral effects; and medical applications, such as hyperthermia and microwave thermography
MEETINGS AND CONFERENCES

BIOELECTROMAGNETICS SOCIETY SECOND ANNUAL MEETING

Date: September 14-18, 1980
Place: San Antonio, TX: El Tropicano Hotel
Sponsor: Bioelectromagnetics Society
Requests for Information: Bioelectromagnetics Society, P.O. Box 3651, Arlington, VA 22203
Content: Sessions will cover the interaction of electromagnetic energy and acoustic energy with biologic systems, including behavioral, physiologic, neurologic, endocrine, developmental, genetic, and cellular and ultrastructural effects. Also included are the dielectric properties of biologic materials, electric field effects, exposure systems, dosimetry, diagnostic and therapeutic applications, interactive mechanisms, instrumentation, hyperthermia, and field perturbations

FIFTH INTERNATIONAL WROCLAW SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Date: September 17-19, 1980
Place: Wroclaw, Poland: Wroclaw Technical Univ.
Requests for Information: W. Moron, Symposium Secretary General, EMC Symposium, 51-645 Wroclaw 12, Poland.
Content: All aspects of electromagnetic compatibility will be covered. Specific topics will include immunity and susceptibility; national and international cooperation in establishing regulations, limits, standards, and specifications; harmful effects of radio frequency energy; and shielding and filtering

FIFTH INTERNATIONAL CONFERENCE ON INFRARED AND MILLIMETER WAVES

Date: December 8-12, 1980
Place: Wurzburg, West Germany
Sponsor: Institute of Electrical and Electronics Engineers (IEEE)-Microwave Theory & Techniques Society
Requests for Information: K. J. Button, MIT National Magnetic Laboratory, Cambridge, MA 02139

TENTH L. H. GRAY CONFERENCE

Date: July 13-16, 1981
Place: Oxford, England
Sponsor: Institute of Cancer Research
Requests for Information: Dr. R. C. Hill, Institute of Cancer Research, Royal Marsden Hospital, Sutton, Surrey, England
Content: The biology and biophysics of radio frequency, microwave, and ultrasonic radiation will be reviewed, particularly with respect to their potential therapeutic value

FOURTH INTERNATIONAL ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM

Date: March 10-12, 1981
Place: Zurich, Switzerland: Federal Institute of Technology
Sponsor: Association of Swiss Electrotechnicians
Requests for Information: Dr. T. Dvorak, ETH Zen-trum-KT, 8092 Zurich, Switzerland
Content: Topics will cover the protection of the electromagnetic environment and will include the social and economical impact of electromagnetic compatibility (EMC); electromagnetic pollution, control, and enforcement; national and international cooperation in EMC; immunity of electronic systems; EMC of communications, electric power, and automation; EMC hazards to vital safety systems; compatibility of medical electronics; biologic effects of radio frequency energy; and shielding and absorptive materials

20th GENERAL ASSEMBLY OF THE URSI

Date: August 10-19, 1981
Place: Washington, DC: Hyatt Regency Hotel
Sponsor: International Union of Radio Science (URSI)
Requests for Information: Executive Secretary, R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418 or (202) 389-6470
CURRENT RESEARCH


Research is being conducted to explore the mechanisms that cause responses to low-level microwaves in neural substrates and to study the interactive mechanisms that are operative when electromagnetic fields (EMF) come in contact with critical nerve substrates. The first part of the study will be concerned with nerve terminal stimulation and transmitter release. Synaptosomes (pinched-off presynaptic terminals of neurons) will be isolated from whole rat brain. Horseradish peroxidase will be used as a tracer to determine if the EMF causes damage. The second part of the study will involve the effects of EMF on receptor binding molecules for several neural transmitters. (funding period n/a)


This project is part of a broader program to study adverse health effects (from acute to chronic) from environmental factors, such as microwaves. The general objectives of the research are to define the nature and extent of such effects with the aim of instituting appropriate preventive or control procedures. The research includes: laboratory studies on the biochemical mode of action of environmental toxicants, exploratory studies aimed at improving the reliability and efficiency of predictive toxicologic tests, improvement of diagnostic procedures for diseases possibly related to environmental factors, epidemiologic investigations, and field studies on the distribution of pollutants. (funding period 1/77-12/79).

Supporting Agency: HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences


The effects of electromagnetic (EM) fields on the immune response in mammals will be investigated and quantitative relationships between threshold and suprathreshold exposure parameters and observed immunologic alterations will be determined. Young adult hamsters (8-10 wk old) will be infected intraperitoneally with vaccinia virus. The infected animals will either be exposed to EM fields, sham exposed, or will serve as neutral controls. Serum from infected animals will be collected by cardiac puncture at 7- to 10-day intervals after the injection. The serum will be analyzed to determine antivaccinia antibodies by vaccinia neutralization, antibody-dependent cell-mediated immune responses (using spleen lymphocytes), macrophage immunity, and lymphocyte killer cell immune mechanisms. (funding period 07/79-n/a)


0556 RADIO FREQUENCY/MICROWAVE TERATOGENIC EFFECTS STUDY. Conover, D. (Div. Biomedical and Behavioral Science, HEW, PHS, Center for Disease Control, NIOSH, 4676 Columbia Pkwy., Cincinnati, OH 45226).

A follow-up study will be initiated to determine the thermal threshold for production of teratogenic effects in rats. Groups of pregnant rats will receive continuous high-intensity whole-body 27.12-MHz radio frequency (RF) radiation on the gestation day when maximal teratogenic effects are induced, and exposures will be discontinued as the animals reach a preselected temperature of 39, 40, 41, 42, or 43 C. In a second study, pregnant rats will be irradiated on the same gestation day for longer periods of time at lower power levels to assess the influence of irradiation time on the acute thermal threshold level. A total power absorption analyzer is being developed that will be used in conjunction with the NIOSH RF Near-Field Synthesizer to perform bioeffects research from 10 to 100 MHz. The analyzer will be used to noninvasively determine the absorbed RF power to aid in extrapolating the results of animal bioeffects studies to humans. Extrapolation of the results of animal bioeffects studies to humans will be useful in setting maximum permissible personnel RF/microwave exposure levels. (funding period 10/76-9/80)

Supporting Agency: HEW, PHS, Center Disease Control, NIOSH


Methods of optimizing the absorption of microwave energy by malignant tissue to achieve differential heating are being devised. Thus, the project involves both the development of methods of launching microwaves into a tumor and the measurement of the dielectric properties of normal and malignant tissue to determine a frequency region where microwave radiation is absorbed differentially by malignant cells at the expense of normal cells. The microwaves will be propagated into the tissue using a probe or appli-
CURRENT RESEARCH

The effects of both acute and chronic exposure of microwave frequencies common for Navy equipment on the central nervous system of Chinese hamsters and other small rodents will be investigated. The animals will be exposed to low power density microwave fields for 1 hr-60 days, and the histopathologic effects and alteration of the blood-brain barrier will be emphasized. Special neurocytologic stains for determining degenerating axons, terminal boutons, dendritic spines, myelin, general cytoplasmic appearance, and gliosis will be used to study the results. In addition, the subcellular aspects of neurons and glia will be examined by electron microscopy, and labeled amino acids, ions, and protein transport across the blood-brain barrier will be studied by autoradiography. Thresholds for observed effects will be determined in terms of both exposure intensity and exposure duration. (funding period 5/78-7/80)


See Current Research 0473 for description of this research. (funding period 8/72-7/73)

Supporting Agency: NIMH, NCI

0562 COLLABORATION ON AN IMPLANTABLE RF STIMULATOR. Ko, W. H. (Case Western Reserve Univ., Case Inst. Technology, 2040 Adelbert Rd., Cleveland, OH 44106).

An implantable radio frequency stimulator will be developed. This project is part of a broader program to develop a Biomedical Electronics Resource Center to service the national community in microelectronics and instrumentation. The Resource Center, located in the Engineering Design Center of
Case Western Reserve University, provides additional equipment to update the existing research facilities in microelectronics and integrated circuits, medical instrumentation, and mechanical design to provide service, training, and research in biomedical electronics. The major groups in the Resource are: a Microelectronics Technology Laboratory for implant instruments, medical transducers, and solid state electronics technology; a Medical Instrumentation Laboratory for research prototype design and development of practical health care instruments, a Package and Quality Assurance Laboratory to establish and operate facilities for packaging medical instruments and perform final testing of devices and instruments; and an Education and Training Group to interface with associated medical research groups to disseminate the information to other research institutions and industrial organizations. The research results, design service, and training opportunities will be provided by the Resource to the local and national biomedical community. (funding period 12/77-11/79)

Supporting Agency:HEW, PHS, NH, Div. Res. Resources


Research to examine and delineate physiologic regulations (neuroendocrine function) and tissue injuries (serum enzymes) in microwave exposed rats free of nonspecific stresses will be conducted. The quantitative relation among power densities, body temperatures, and neuroendocrine functions or tissue injuries will be assessed. Specific attention will be paid to the interrelation of hypothalamic-hypophysial/thyroid/adrenal somatotrophic axes in microwave exposed animals. The interaction of previous exposure on responses or injuries of rats to subsequent exposure will also be investigated. Recovery or manifestation of acute neuroendocrine perturbances or tissue injuries by microwave exposure will be attempted. Rats will be acclimated to experimental procedures; a 3-hr equilibrium period will be given before each microwave exposure. The proposed project will extend from single to repeated (60 times, 4 hr/day) exposure to 2,450 MHz continuous wave microwaves in the far-field at 0.1-40 mW/cm² or the equivalent specific absorption rate. The absorption rate will be determined for an interspecies and interlaboratory rate. The exposure techniques (single- versus multi-body) will be compared. (funding period 8/79-7/80)

Supporting Agency:HEW, PHS, NH, Natl. Inst. Environmental Health Sciences


To further develop and stimulate biomedical research and training among faculty members at the University of Puerto Rico, five new projects are proposed. One of the projects will involve the study of microwave exposure spectroscopy of effects on microorganisms, comparison of normal and abnormal tissue, and study of cell membrane features. (funding period 9/77-2/80)

Supporting Agency:HEW, PHS, NH, Div. Res. Resources


The effects of environmental pollutants, such as high-voltage electric fields, on the daily (diel) cycles of energy metabolism, motor activity, and body temperature will be studied in small rodents. The initial phase of work with pollutants will be focused on radiation variables including both ionizing and nonionizing; the nonionizing radiation will include 60-Hz electric fields and 2,450-MHz microwaves (as produced by the proposed Solar Power Satellite system). The effects of each pollutant will be characterized and then analyzed to determine whether subsequent health effects can be predicted. Diel cycles of metabolism, activity, and temperature will be logged continuously and automatically for several mice simultaneously for periods up to 2 weeks. The search for indicator variables has been limited to energy expenditure variables; thus far, three variables have been identified that predict the length of life, i.e., resting metabolic rate (negative correlation), ratio of average to resting metabolic rate (positive correlation), and change of metabolic rate from youth to old age (negative correlation). The search will now be extended to the activity and temperature variables, which have become functional only recently. (funding period 07/79-na)


As part of a research program to investigate human responses to the thermal environment, the thermal and nonthermal effects of microwaves will be studied in nonhuman primates using a combination of physiologic and behavior techniques. Objectives of this program include a better understanding of the effects of the thermal environment, identification of vulnerable segments of the population,
and the development of strategies for effective protection of such vulnerable individuals and for evaluation of public health consequences of energy conservation strategies. (funding period 6/77-5/80)

Supporting Agency: HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

Data collected to date from a 3-yr study of longevity of mice that were exposed in utero to near-lethal doses of 2,450-MHz microwave radiation demonstrated an increased mortality among control and radiated animals. Spontaneous tumors appeared in two controls (n = 81) but not in irradiated mice (n = 83). The acute studies focused on distributions of thermalized energy in the brain and lower body of anesthetized rats, guinea pigs, and rabbits during brief, but near-lethal, exposures in a 2,450-MHz multipath field. Pre-exposure temperatures within an animal differed anatomically by 0.5-1 K (e.g., colon versus superficial cortex); radiation-induced whole-body ATs of 4.5-12 K were associated with altered distributions that differ both anatomically and among species. Continuing studies of escape behavior by rats in intense 918-MHz multipath fields confirmed that irradiation per se, even at levels that proved lethal within minutes, lacked the sensory salience to promote escape learning; however, pairing of photic (and to a lesser extent, acoustic) stimuli as sensory cues with irradiation can reinforce successful escape. Twelve pilot studies have been completed to determine optimal conditions for adjuvant treatment by microwave hyperthermia of experimentally induced glioblastoma in rats. Formal studies will begin this year. Complementing the work on glioblastoma is recent pilot work on the role of fever in transfer of circulating antibody across the cerebrospinal-fluid (CSF) barrier. There is no evidence in rats that subconvulsive, microwave-induced fevers of short duration (<30 min) provide access to CSF (i.e., to the brain) by experimentally induced antibody. The peak titer of serum antibody (in response to pneumococcal antigen) is variably suppressed or augmented by the febrile treatments, but the evidence is not statistically significant. (funding period 9/77-8/80)

Supporting Agency: HEW, PHS, FDA, ORH

The absorption of several duplex deoxyribonucleic acid homopolymers in the microwave frequency region will be calculated. The calculations will be rigidion calculations based on calculated eigenvectors, and will be made for various helix lengths and for kinked or bent helices. (funding period 9/78-8/80)

Supporting Agency: HEW, PHS, FDA

The theoretical effect of electromagnetic fields on the dynamic properties of small drops will be investigated. Rayleigh's theory of small drops oscillations will be extended to include the effect of electromagnetic fields on the dynamic properties of dielectric and charged conducting spheres. (funding period 3/73-10/n/a)

5. Orientation in the total intensity of the earth’s magnetic field thereby creating a zero field, resulted in complete disorientation of both adult and juvenile hornets. The maximum current in the solenoid’s coil was 37.2 mA (inverted natural field). The degree of misalignment for orientation was demonstrated that these animals may be disoriented inside a shielded space or in an artificial magnetic field. In the absence of other timers, the disturbance of this field by any object having an electric conductivity different from that of water is perceived by specific receptors. These receptors are sensitive to changes in potential of as little as 0.03 μV/cm.

Birds, insects, and bees are sensitive to changes in the earth’s magnetic field and can use its variation for orientation. Other studies have demonstrated that these animals may be disoriented in shielded space or in an artificial magnetic field. In the honey bee, the direction of the axis of the waggle dance, communicating the direction in which the food is located, is consistently misdirected with respect to the earth’s magnetic field. The degree of misalignment correlates highly with the daily variation in the total intensity of the earth’s magnetic field. In the absence of other timers, the daily variations in the magnetic field are used by the honey bee as an external clock.


Evidence is presented to show that the ability of pigeons to sense magnetic fields may be associated with a small, unilateral structure between the brain and the skull that contains magnetite in what appears to be single domains (tiny unit magnets). Tests for stable and superparamagnetic domains in pigeons were performed with a SQUID magnetometer after about 24 hours, previously frozen, or perfused pigeon heads and necks were dissected. Permanently magnetic material was found in one of the pigeon specimens tested. The material was unilateral and was located either in a small (1 x 2 mm) piece of tissue between the dura and the skull or was too closely associated with the skull to be separated from it conveniently. About 40% of the pigeons had a natural remanence (a net field due to a preferential direction of alignment among the many individual magnets) that ranged from 10^-7 to 10^-9 electromagnetic units. All pigeons had an inductive remanence (a measure of the total amount of magnetic material) of 10^-6 to 10^-8 electromagnetic units. The relatively weaker natural remanence and other observations suggest that the alignment among the single-domain magnets is only locally regular. Few, if any, superparamagnetic domains were found. Light and electron microscopy of the naturally magnetic tissue revealed that it is richly supplied with clusters of electrone- opaque structures approximately 0.08-0.15 μm long and with an approximate length-to-width ratio of 4:1. Electron probe analysis revealed that these particles are rich in iron. Additional microscopic observations and measurements of Curie temperature led to the conclusion that the primary magnetic component is magnetite.


To investigate the influence of the earth’s magnetic field on comb-building orientation, hornet workers (vespa orientalis) maintained in artificial breeding boxes in groups of 10-20 individuals were placed both inside a solenoid and at some distance from it in the same room. Experiments were conducted with adult worker hornets more than 1-day-old and with juvenile hornets. The maximum current in the solenoid’s coil was 37.2 mA (inverted natural field). The introduction of a magnetic field that counteracted the vertical component of the earth’s field, thereby creating a zero field, resulted in complete disorientation of both adult and juvenile hornets. The mortality rates for adults and juveniles in this zero field were 25% and 70-90%, respectively. Adult hornets built combs or even small comblets in which they deposited eggs, whereas juvenile hornets showed almost no building activity. Neither adult nor juvenile hornets placed in pulsed fields (0.5 sec pulse duration) averaged to zero showed any building activity; however, the mortality of adults and juveniles in this zero pulsed field was only 10-15%. Hornets placed inside an inverted magnetic field needed 2-3 days to adapt but then proceeded to develop and build in a normal manner. Hornets placed in pulsed fields (0.5 sec pulse duration) averaged to 50% of the natural field built regular combs, albeit with cells almost twice the natural size, but their mortality rate was relatively high (20-65%). During zero field conditions, only two combs were observed; one attached to the ceiling with two uncompleted cells and one attached to a wall with two cells oriented at 40-50 degrees from vertical. Both pedicles had an elliptical cross-section with the larger axis oriented in the north-south direction, as opposed to the circular cross-section of normal pedicles. The following additional phenomena were observed in two breeding boxes placed at both ends of the solenoid where the axial field of the solenoid was not uniform: simultaneous building of combs on the ceiling and on the side walls; combs with cells of different sizes; and cell walls containing considerably more strips of cellulose than the cell walls in control boxes. The above results suggest that the terrestrial magnetic field is the main guideline for vespian building orientation.

6391 MICROWAVES CAN KILL INSECT PESTS. (Prep.) Hurlock, E. T. (Agricultural Science...
Microwave dose however, only a 29% mortality for T. castaneum adults and 96% mortality for E. cautella larvae. In a third test with cocoa beans (68% moisture), a microwave dose of 599 kW-sec resulted in 90% mortality for T. castaneum adults and 96% mortality for E. cautella larvae but only a 29% mortality for T. castaneum adults. However, when this test was repeated using hot dry air (85°C) in addition to microwave irradiation, a microwave dose of 780 kW-sec resulted in 100% mortalities for both these pests.


The Bell System's microwave radiation facilities are discussed in relation to growing public concern about the possible hazards of exposure to microwave radiation. The Bell System has nearly 5,000 microwave radio installations in the United States; these carry nearly 70% of all long distance phone calls as well as network television programs and data communications. Based on the opinions of experts in this field, Bell officials do not consider exposure levels associated with their equipment to be hazardous either to their employees or to the public. Measured microwave levels around Bell towers in areas to which the public has access indicate that even the stringent Soviet standards for public exposure are met. In terms of occupational exposure, microwave levels, e.g., directly in front of an antenna, are almost always below the 10 mW/cm² occupational exposure standard in the United States. It is also pointed out that natural microwave radiation emission from the human body is greater than the exposure resulting from the operation of a microwave relay tower.

6393 MICROWAVE: BASIC BACKGROUND AND TERMINOLOGY. (Eng.) Anonymous. (No affiliation given). Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

A review of microwave technology and its reported effects on humans is presented, with particular reference to the Bell Telephone System's use of this technology in its intercommunications network. There is substantial scientific evidence that microwave levels above 100 mW/cm² can harm the human organism as a result of the tissue heating effect; however, levels below 10 mW/cm² are not harmful. Some Eastern European countries and the Soviet Union have reported non-heating effects (e.g., headaches, insomnia, fatigue, depression, memory loss) at levels between 10 and 100 mW/cm²; however, it has not been clearly established whether these effects were caused by microwave radiation.

6394 INTERNATIONAL COLLABORATION ON THE HEALTH EFFECTS OF NONIONIZING RADIATION. (Eng.) Suess, M. J. (WHO Regional Office for Europe B, Scherfisgvej, 2100 Copenhagen, Denmark). J Microwave Power 14(2): 93-94; 1979. (0 refs)

The development of international collaboration on the health effects of nonionizing radiation (NIR) is reviewed. The convening of a working group on NIR by the WHO Regional Office for Europe at the Hague in November 1971 can be considered as the beginning of international activities on NIR protection. This working group developed a sectoral program on NIR protection designed to facilitate relevant investigations, data evaluation and exchange, establishment of biologic criteria for damage, promotion of protective legislation, and training of national surveillance personnel. WHO, together with the United States Department of HEW and the Polish Scientific Council to the Minister of Health and Social Welfare, subsequently sponsored an international symposium on the Biologic Effects and Health Hazards from Microwave Radiation. The proceedings included presentations on thermal and biologic effects, influences on the nervous system and behavior, effects at the cellular and molecular level, measurements of radiation, and occupational exposure and public health aspects. Working groups were established to critically review and evaluate documents on the health aspects of NIR. Their results, consolidated in a manual for future publication, cover the electromagnetic spectrum of NIR from UV through visible light, infrared, microwave and radio frequency radiation to magnetic and electric fields at power frequencies. Ultrasound radiation is also included in the manual because of its similar applications in medicine, science, and technology. Regulation and enforcement procedures, two directories on national legislation and institutes concerned with NIR, and a glossary of terms are included in the manual.

6395 SOVIET-AMERICAN COOPERATION IN ENVIRONMENTAL HEALTH SCIENCE. (Eng.) Schambra, P. E. (Natl. Inst. Environmental Health Sciences, P.O. Box 12233, Research Triangle Park, NC 27709); Kell, D. P.; Sidorenko, G. I.; Pinigin, M. A.; Lit-
vinov, N. W. Environ Health Perspect 30: 1-7; 1979. (40 refs)

The first 5 yr of experience with a Soviet-American collaborative program in the environmental health sciences is reviewed. Beginning in 1975, 3 yr after its initiation, the program was expanded to include studies on the biologic effects of physical factors in the environment. These studies have focused on the biologic effects of nonionizing radiation, particularly the effects of microwave radiation and static and low frequency electromagnetic fields. Joint efforts have been initially aimed at revealing the potential health hazards associated with long-term exposures to low doses of microwaves. During the 1st yr of the program, the Soviet side reported effects on rabbits and rats due to microwave exposure at power densities of 10-500 \(\mu\)W/cm\(^2\) and exposure durations of 7 hr/day, 5 days/week for 3 mo. Changes in the electroencephalograms of rabbits were measured along with alterations in behavior and immunologic and cytotoxic parameters in the blood of rats. The American studies, which have been performed at higher exposure levels, have generally shown no effects unless the microwave levels were high enough to produce heating of the specimens. However, exceptions to these findings include increased calcium efflux from brain tissue at microwave fields modulated near brain wave frequencies, suppression of immunologic responses in rabbits exposed to 10 mW/cm\(^2\) for a 6-mo period, and decreased performance in rats following exposure to exposures of 15 mW/cm\(^2\) and above. Collaboration on studying the effects of static and low frequency electromagnetic fields is in the early stages of development. An exchange of reviews of national scientific literature on this topic has taken place, and a joint workshop has been convened to propose joint work on outstanding problems. The first edition of a bilingual glossary of specialized scientific terms used by both countries in the area of environmental health was completed in 1975.


The effects of nonionizing electromagnetic radiation on the central nervous system, behavior, and blood are reviewed in light of recent research conducted in the United States as part of a collaborative effort with the Soviet Union. Results of investigations studying the effects of microwaves on isolated nerves, synaptic function, transmission of neural impulses, electroencephalographic (EEG) recordings, behavior, and the chemical, cytotoxic, and immunologic properties of the blood are reported. Increased calcium efflux from isolated forebrains was observed when neonatal chick brains were exposed to 6-Hz amplitude-modulated 147-MHz fields at power densities of 1-2 mW/cm\(^2\). Cats have also been exposed to 147-MHz fields amplitude-modulated at brain wave frequencies (power density, 1 mW/cm\(^2\)), and such fields had a strong influence on spontaneous and conditioned EEG patterns. Evidence that microwave irradiation may weakly enhance synaptic transmission in the spinal cord was obtained when the spinal cords of cats were directly exposed to 2,450-MHz continuous wave radiation for 30 min. Experiments in which adult rats were exposed to 2,450-MHz radiation over a wide power density range indicated that such exposure can produce alterations in learning behavior of animals; decreased performance occurred in direct relation to increases in the power density of exposure. Experiments designed to determine the pathologic, hematologic, and immunologic effects of chronic microwave exposure (2,450 MHz, 10 mW/cm\(^2\), 23 hr/day for 6 mo) in rabbits revealed abnormal myeloid/erythroid ratios in the bone marrow of exposed animals compared with controls. This exposure also appeared to slightly suppress immune competence as shown by tests in which pokeweed mitogen was used to stimulate lymphoid cells from the spleens of exposed animals.


A public health approach to setting standards for exposure to microwave (MW) and radiofrequency (RF) radiations in the 30-kHz to 300-GHz frequency range is presented based on a review of experimental, clinical, and epidemiologic studies. Biological effects of MW and RF observed in animals include the following: chromosomal anomalies in Chinese hamster and fruit flies (5-40 MHz pulsed, power density not reported); mutagenesis in Swiss male mice (17 GHz at 50 mW/cm\(^2\)); changes in cell structure and density of bacteria (50-90 GHz at 10-50 mW/cm\(^2\)); teratogenesis in mealworms (9-10 GHz at total power of 20-80 mW) and in mice (2,450 MHz, energy absorption of 3-8 calories/g); behavioral impairment in rats (1.3-1.5 GHz pulsed at 0.4-2.8 mW/cm\(^2\)); neuroendocrine and hormonal alterations in rats and dogs (2,450 MHz at 20-60 mW/cm\(^2\) for 30-60 min); prenatal impairment of body and brain weight in rats (2,450 MHz at 10 mW/cm\(^2\) for 5 hr/day over 17-day gestation period); blood-brain barrier alterations in hamsters (2,450 MHz at 10 mW/cm\(^2\)); central nervous system influence in chicks (147 MHz at 1-2 mW/cm\(^2\)); and mortality in rats, rabbits, and dogs (40 mW/cm\(^2\) for minutes to hours, 2,800 MHz pulsed, various wavelengths between 1 mm and 10 cm). Biological effects of MW and RF observed in humans (exposure parameters not reported in most cases) include cataractogenesis and other ocular effects, central nervous system influences, speculative oncogenesis (epidemiologic suggestion of carcinogenesis in North Karelia region of Finland but no direct clinical evidence), biochemical imbalances, subjective psychologic complaints (0.01-10 mW/cm\(^2\)), and hematologic changes. Based on the available evidence, it is concluded
that a permissible occupational exposure level to MW and RF radiation of 500 μW/cm² is indicated, less by a factor of 20 than the current OSHA guidelines of 10 mW/cm² for working areas. With an additional safety factor of 10 for a public environmental standard, an exposure level of 50 μW/cm² is recommended. These proposed regulations apply to MW and RF stationary transmitters. However, similar biologic considerations apply to MW and RF radiation from mobile units (e.g., citizen band radios); hazards associated with these types of units are incompletely evaluated and merit careful public health surveillance.

6398 CAN HIGH VOLTAGE CAUSE ENVIRONMENTAL HAZARDS? (Nor.) Anonymous. (No affiliation given). Teknik Teknik 126(35): 16; 1979. (3 refs)

The environmental hazards of high-voltage power transmission lines are discussed. The electric field intensity can reach up to 10,000 V/cm directly under a 765,000 V-line, to about 50 V/cm at a 30-m distance, and to 5 V/cm at a 60-m distance. Some of the most sensitive pacemakers can be affected by the electric field around high-voltage power lines. A study conducted among 250 workers of 500- and 750-kV transformer stations in the USSR demonstrated such common symptoms as headache, weakness, and malaise. Reduced growth of rats and mice; stress and increased pulse rate and blood pressure in dogs; and behavior and physiologic changes in fish, birds, rabbits, monkeys, and bees were seen after exposure to electric field intensities that occur in the vicinity of high-voltage power transmission lines.

6399 BIOLOGIC EFFECTS OF MAGNETIC FIELDS. (Cze.) Jerabek, J. (Centrum hygieny prace a nemoci z povolani, Institut hygieny a epidemiologie, Srobarova 48, 100 42 Prague 10, Czechoslovakia). Prac Lek 31(3): 98-106; 1979. (68 refs)

Studies on the biologic effects of magnetic fields are reviewed. Colonies of Micrococcus prodigiosus demonstrated such common symptoms as headache, weakness, and malaise. Reduced growth of rats and mice; stress and increased pulse rate and blood pressure in dogs; and behavior and physiologic changes in fish, birds, rabbits, monkeys, and bees were seen after exposure to magnetic fields intensities that occur in the vicinity of high-voltage power transmission lines.

6400 BIOLOGIC EFFECTS OF ELECTROMAGNETIC FIELDS. (Ger.) Bernhardt, U. (Institut fur Radiologie, Krankenhausstr. 12, D-5220 Erlangen, W. Germany). Z Naturforach C7) 34(7): 616-627; 1979. (89 refs)

The biologic effects of electromagnetic fields on humans are reviewed with special emphasis on the thermal effects. The maximum permissible energy density for low-frequency exposure is set at 10 mW/cm² in western countries, which corresponds to a heat production of about 1 mW/cm² of tissue. Microwave radiation energies of 100-1,000 mW/cm² are used therapeutically. The formation of cataracts has been observed at energy densities exceeding 100 mW/cm². For frequencies below about 30 kHz, excitation processes cannot be excluded in exceptional cases. Between 30 and 100 kHz, thermal effects are predominant before excitation can appear. Artificially generated currents and intensities of the same orders of magnitude of those of the electroencephalogram currents may affect the central nervous system, but they are not hazardous. At frequencies around 10 kHz and a current intensity of 10 μA/cm², interactions with physiologic processes taking place on the cell membrane at a time constant of 0.1 msec are possible.


Epidemiologic data on 53 substation workers with more than 5 yr of exposure to electric fields of 400 kV were compared with data for a matched reference group of 53 nonexposed workers at the same power stations in Sweden to investigate the possibility of chronic health effects resulting from high-voltage exposure. The investigation included effects on the nervous system, the cardiovascular system, the blood, and fertility. The results showed no significant differences between the exposed and reference groups as a result of long-term electric field exposure. The exposed group did consistently better on psychologic performance tests, but this was attributed to the higher education of the exposed group relative to the reference group. Members of the exposed group also had fewer children, especially boys, than did members of the reference group. However, this difference appeared to be related to factors other than exposure since it existed 10-15 yr prior to employment at the substations. These results offer no evidence for the development of chronic health effects in high-voltage substation workers as a consequence of electric field exposure.


Reducing public exposure to alternating current
(AC) transmission line fields is discussed in relation to the uncertainty concerning the possible health effects of such exposure. Available experimental evidence on human health effects due to electromagnetic field exposures from high-voltage transmission lines is limited and inconclusive. The primary basis for public concern is a series of experiments conducted in the Soviet Union that revealed adverse effects such as headaches, sluggishness, fatigue, irritability, poor sleep, and reduced sexual potency in male switchyard workers exposed to electromagnetic fields generated by 400- to 500-kV potentials. Results from a study in Spain appear to support the Soviet findings. However, virtually all research in North America and Western Europe has yielded negative results; to date, slight changes in reaction times and small changes in blood chemistry are the only effects in humans that these investigators have observed. Clinical studies of American linemen and Canadian substation workers as well as a French study of linemen and their families have all failed to uncover any of the effects claimed by the Soviet studies. In the face of this uncertainty concerning possible health effects, it is not possible to perform an analysis that trades an evaluation of known health effects against the costs of controlling exposure to AC transmission lines in a way that will allow for selection of an optimal level of control. A review of various possible control strategies indicates that wider right-of-ways and/or the use of grounded shield wires may warrant serious consideration depending on the specific parameters of the line involved and on subjective opinions about threshold exposure and level of possible undetected per capita health impact.

6403 EFFECTS OF ELECTROMAGNETIC RADIATION ON HUMANS. (Eng.) Lockey, M. W. (No affiliation given). J Miss State Med Assoc 20(10): 237; 1979. (0 refs)

A brief editorial on the thermal and nonthermal effects of nonionizing electromagnetic radiation (EMR) is presented. To date, only thermal effects of EMR have been adequately documented. The amount of heat produced in a tissue exposed to EMR is proportional to the level of EMR energy generated by the instrument, time of exposure, and source-to-subject distance. Microwave cataracts are a well documented form of EMR damage in persons cooking with microwave energy and in persons cooking with faulty microwave ovens. Persons with any metallic implant, such as a rod, plate, or other types of medical implants should avoid close exposure to EMR energy sources since the metal heats more rapidly and produces surrounding tissue damage. The effects of EMR on cardiac pacemakers are also well known, and such patients should avoid exposure. Nonthermal effects of EMR that have been reported but not documented include behavioral changes, malaise, restlessness, sterilization, fetal damage, and central nervous system changes. These effects are currently being critically evaluated, especially by the Russian electronic industry. A common nonthermal complaint associated with EMR has been the occurrence of headaches and mood changes in persons living very close to high-tension power lines that produce EMR.


Fifteen cases of acquired capsular cataract in commercial air traffic controllers and airline pilots (ages at onset, 33-55 yr) are reported. In all of these cases, it was confirmed that capsular cataract was acquired following prolonged employment in avionic environments containing spurious nonionizing radiations emitted by radar, radio, navigational devices, cathode ray tubes, video display units, etc. The significance of the capsular type of cataract acquired during adult life in the absence of signs or symptoms of prior intraocular inflammatory disease relates to the differential diagnosis. All of the other ordinarily encountered cataracts such as congenital, familial, metabolic, drug, or senile cataracts initially become evident within the lens substance itself instead of at the site of its capsule. All but 1 of the 15 patients with capsular cataract were otherwise healthy and were referred in order to pass a relatively stringent annual Federal Aviation Agency (FAA) physical examinations; each patient had passed until developing the cataracts and therefore failing the visual acuity test. In accordance with the classification of nonionizing radiation cataracts developed in 1973, all of the cases reported here can be identified as "delayed" hertian radiation cataracts, as differentiated clinically from "acute" or "subacute" types. Delayed hertian radiation cataracts usually form insidiously over a 5- to 30-yr period. It is during the critical interval, while the cataract is evolving and before significant visual loss has occurred, that it is important to arrive at a correct diagnosis. Not infrequently, during the early months or years, one lens can exhibit opacities while the other lens may still be completely transparent. Regardless of whether the cataracts are bilateral, unilateral, or at markedly different stages in the two eyes, removing the patient from further continuing exposure may result in either a slowing down of the rate of cataractogenesis or a total arrest of the process in a form fruste stage.


The difficulties in the certification of microwave diseases are discussed and three case reports demonstrating this problem are presented. Microwave diseases are difficult to recognize as occupational diseases because the exposure parameters and clinical pictures have not yet been sufficiently identified. A 41-yr-old induction furnace operator (fur-
nace output of 2,000 kHz, 60 kW) developed photo-
genic epilepsy, a sensation of warmth in his legs, and other disorders after 17 yr on the job. His condition was recognized as a microwave disease. A second case is that of a 56-yr-old man who worked as a maintenance mechanic at a radio broadcasting station for 8 yr. Sixteen years later, he de-
veloped a psycho-organic syndrome; his condition was not recognized on diagnosis as an occupation-related disease. A 37-yr-old ship radio officer developed headache, malaise, and visual and psychic distur-
bances 8 days after he was accidentally exposed to microwaves while repairing radar equipment. His condition was diagnosed as an occupational disease.

Clinical techniques used for electrostimulation of bone healing are described along with some results in patients with nonunions. Stimulation with electric currents may be completely invasive (electrodes are surgically implanted) or semi-invasive (insertion of percutaneous electrodes). The small currents involved allow for the use of light weight power packs so that the patient can be ambulatory. The existence of metallic inclusions (screws, plates, etc.) does not preclude the use of this method. Electrostatic stimulation using electret films has been used in only a small number of patients; thus, a proper evaluation of the technique is difficult. This method requires no power supply, but it is doubly invasive. Magnetic field stimulation with air-cored coils is a completely noninvasive system and is potentially fully portable with the use of rechargeable nickel-cadmium batteries. However, it is doubtful that it can be used in the presence of metallic inclusions except in some carefully defined cases. Magnetic field stimulation with iron-cored electromagnets is also completely noninvasive but requires a mains-operated power pack and a magnet heavy enough to preclude ambulation. However, the field is closely defined so that the technique may be used where metallic inclusions are sufficiently remote. There is no evidence illustrating the relative efficacy of the fast rising but brief field pulses of air-cored coils versus the slower rising more protracted fields of iron-core magnets. Results from a long-term clinical trial where patients with various types of acquired nonunion were treated with an orthopedic stimulator electromagnet are reviewed. The stimulator was run continuously for a treatment period of 8-8 wk; total treatment time/day was about 22 hr. An analysis of the first eight patients in this trial revealed that six experienced sound bony union.

Electric stimulation of bone growth and repair (abstract). (Gen.) Burny, F.; Herbst, E.; Hinsekap, M.; eds. (New York: Spring-

See Current Literature 6362, 6473, and 6474 for description of this article.

Studies on electrical stimulation of bone healing are reviewed. In one study using small electrical currents, a multicathode apparatus was used to treat 57 cases of nonunion. The device used a 7.5-V bat-
tery along with a field effect transistor (FET) cur-
cent source to deliver 10 mA (or 20 mA for large bones) to each of four cathode wires. A stainless steel grid anode was used on the skin surface. Of 57 patients who exhibited nonunion after fracture, 39 (68%) achieved clinical and radiological union after electrical current stimulation. Several of the failures involved mechanical faults such as cathode displacement. Studies of the effects of electric and magnetic fields on bone stimulation are relatively few in comparison to those dealing with electrical currents. However, two animal studies have demonstrated that both static and pulsing electric fields modify bone growth pro-
cesses. Moreover, one research group has success-
fully treated at least one patient using an elec-
trot method. A crossed pair of electret strips were placed on the periosteum over the fracture line of a patient with a delayed union of the tibia; 15 wk later, x-ray examination revealed callus for-
mation and bone union. The effects of applying pulsed magnetic fields across fibular osteotomies have been investigated in dogs. Pairs of air-cored coils were strapped to each side of the leg so that the axis of their magnetic field crossed the frac-
ture site laterally. When a pulse frequency of 65 pulses/sec and a pulse duration of 0.15 msec were used, subsequent mechanical testing indicated that significant improvement in resistance to bending was present in the stimulated fibulae of 10/13 dogs. Magnetic fields have also been used to treat both acquired and congenital pseudarthroses in humans. Air-cored coils were used for treating patients for whom treatment such as bone grafting had failed. Initially, a single 0-shaped coil was used, pulsed at 75 pulses/sec by an electronic module that provided a fast-rising 0.3-msec pulse. Using a search coil (consisting of 50 turns of 30 gauge wire with a 5-mm inside diameter), an in-
duced voltage pulse of about 80 mV was observed at the face of the treatment coil. Progression to union following this treatment was observed in 10/13 patients with acquired pseudarthroses and in 9/11 patients with congenital pseudarthroses. Although electrical stimulation appears to be of value in the treatment of nonunions, the fundamental processes occurring as a result of stimulation are not understood fully.
I. TN as many cancers as the latter with about the same Two orthogonal linear arrays consisting of discrete alternative to x-ray examination, as it can detect extremely similar. However, among the TP of comparison of 5.9 GHz detects more cancers that at each value of corresponding detection thresholds were varied. mammography detection and are discussed, with particular reference to a study of a 80-pound dog. The distance between the two ap-sides of the left gluteus major of an anesthetized wave Power MA

105-115; 1979. (21 refs)

Medical applications of microwave thermography (MT) are discussed, with particular reference to a study of breast cancer detection at microwave frequencies of 1.3 and 3.3 GHz. True positive (TP) and true negative (TN) rates for about 1,000 normal patients and 29 breast cancer patients were analyzed for detection by MT, infrared thermography (IRT), xero-mammography (X), and several combinations as the corresponding detection thresholds were varied. With regard to the frequency of MT, the TP rate at each value of TN for 1.3-GHz MT exceeded the TP rate for 3.3-GHz MT by about 102; i.e., MT at 1.3 GHz detects more cancers than at 3.3 GHz. A comparison of 1.3-GHz MT results with IRT results shows that at a TN of 0.65, both methods have a TP of 0.75; thus their statistical performance is extremely similar. However, among the 29 cancer cases examined, the MT and IRT methods disagreed in their diagnoses in 12 cases (41%). This is a higher rate of disagreement than that of the MT and X methods (24%) or of the IRT and X methods (28%). This lack of correlation is evident when the MT and IRT criteria are combined; the TP rate is thereby increased by about 10% over that of either method alone. The combination of MT and IRT in breast cancer detection offers a potential alternative to x-ray examination, as it can detect as many cancers as the latter with about the same TN rate but without the hazards of x-ray exposure.

6411 THERAPEUTIC POTENTIAL OF CONFORMAL APPLICATORS FOR INDUCTION OF HYPERTHERMIA. (Eng.) Mendecki, J. (Dept. Radiotherapy, Montefiore Hosp. and Medical Center, Bronx, NY 10467); Friedenthal, E.; Bottstein, C.; Sterzer, F.; Pag-lione, R. J Microwave Power 14(2): 139-144; 1979. (8 refs)

Preliminary measurements of heat distribution in volumes of tissues placed between two conformal applicators energized at 2.45 GHz are presented. The conformal applicators consist of a printed-circuit antenna array comprising a multiplicity of dipoles, typically a 4 x 4 dipole array. The anten-nna board with its printed array of dipoles and its backing metal cavity, designed for operation at about 10 GHz, is filled with a powder of high relative dielectric constant so that its actual operating frequency is reduced to the treatment frequency of 2.45 GHz. In addition, a flexible plastic bag filled with the same powder is attached to the rim of the metal box in front of the printed antenna board to form a bean-bag type of applicator to match the system and minimize reflected power. Uniform temperature distribution was obtained with this system in a 5-cm thick piece of meat, while a distinct temperature peak appeared at the center of a 3-cm piece and a concave heat distribution pattern was obtained when a 7-cm thick slab of meat was used. In vivo experiments were performed in which the two applicators were positioned on two sides of the left gluteus major of an anesthetized 80-pound dog. The distance between the two ap-plicators was approximately 5 cm. An approximately uniform temperature of 42.5 °C was obtained across the thickness of the muscle mass. The conformal microwave applicators are eventually intended for use in the hyperthermic treatment of breast tumors.
terial is placed opposite the two image arrays. The amplitude and phase of excitation of each radiator are adjusted to produce a suitable focal spot region within the body to be heated, which is assumed to be a homogeneous attenuating region immersed in a matching lossless dielectric medium. Although the focal region of a focused linear array has a depth several times greater than its width, superposition of two orthogonal focal regions can produce a region with a depth/width ratio equal to unity if required. Thus, the required shape of the focal region can be synthesized by controlling the array-illumination function. An example of the microwave-intensity distribution attainable with realistic system parameters indicates that the focused microwave array system should be able to sustain a raised temperature in the focal region of several degrees above that of the surrounding attenuating tissue. This approach offers flexibility in choice of position, shape, and temperature gradient in the tumor for given temperature limits elsewhere. The heating system is adaptable to microcomputer control with television display. Tumor distribution could be determined from x-ray computerized tomography scanner images, and microwave acquisition could be furthered by locking onto a small implanted scatterer.


The physical principles of microwave radiometric measurement of temperature and the biomedical applications of this method are described. Microwave radiometers operating in the Ghz range are able to sense minute temperature differences, e.g., 0.1°C. Thus, microwave radiometers are of great value potentially in diagnostics, e.g., in the diagnosis of cancer of the lungs and breast, due to their ability to detect minor temperature differences between normal and malignant tissues. Compared with infrared temperature measurement, the microwave radiometers are better suited for the determination of subcutaneous temperatures.

**6414 NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY AND TEMPERATURE DISTRIBUTION IN A MICROWAVE IRRADIATED BREAST CARCINOMA: PRELIMINARY RESULTS.** (Eng.) Zimmer, R. (Laboratoire d'Electroradiologie, Faculté de Medecine, 11, rue Humann, 67085 Strasbourg, Cedex, France); Gros, C. M. J Nucl Med 14(2): 155-158; 1979. (4 refs)

A numerical calculation of the temperature distribution in a breast tumor model irradiated by microwaves is presented. The model is considered in two parts: an electromagnetic (EM) part used to calculate the energy distribution resulting from microwave irradiation and a thermal part showing the temperature pattern resulting from the calculated energy distribution. In the EM part, an ellipsoidal model is used to approximate the breast tumor irradiated by a plane wave. The inside and outside fields are calculated by a computer and are depicted in three-dimensional and densitographic formats. The computations, done by an analytical method, are performed for different frequencies, conductivities, and tumor shapes. It is assumed that the conductivity of the outside media is equal to zero, but the relative permittivities of both outside and inside media are different from that of the free space. For the thermal part, the model consists of an ellipsoidal tumor surrounded by an ellipsoidal capillary system. The boundary of the model (i.e., skin of the breast) is also ellipsoidal. Certain assumptions are made regarding heat transfer, thermal conductivity variations, and heat source distribution as calculated from the EM model. The calculations are done in 400 points by a method derived from the Crank-Nicholson method with a time increment of 30 sec. Combining the two models, thermal patterns versus time are calculated after 10 min of heating and at 5 and 10 min following the heating period. These preliminary results show that it is not easy to obtain a uniform thermal distribution due to very low values of thermal conductivity and nonuniform microwave energy distribution. The computation provides evidence of a strong interdependence between frequency, conductivity, shape, and EM energy distribution (i.e., thermal source distribution).


Clinical applications of centimeter-wave and millimeter-wave (MMW) thermography are reviewed. Contacting thermography at long centimeter wavelengths has been used to examine confirmed breast cancer cases. When 70 women were examined with 3.3-GHz thermography and 25 with 1.3-GHz thermography, a cancer detection rate of about 70% and a false alarm rate of about 30% were found. These values are similar to the corresponding rates for infrared (IR) thermography. Remote sensing thermography using focused apertures has been studied for imaging purposes at short centimeter and long millimeter wavelengths. Limited clinical trials have been performed for over 1yr and are now being expanded to clinical screening of large populations of women with suspected breast pathology. A comparison of 68-GHz MMW thermography with IR thermography in a patient with a cancerous lesion of the right breast (confirmed by xeromammogram) revealed several differences. The MMW thermograms were smoother and less spotty than the IR. Temperature variations in the diseased breast were larger for MMW (±4°C) than for IR (±2°C). The average temperature of the entire right diseased breast was about equal to the temperature of the entire left normal breast at MMW; however, averaging only over the hottest area of the left and right side showed that the right side was hotter by about 2°C according to MMW. At IR wavelengths,
both averages yielded a lower temperature on the left side. Finally, the cancer lesion, as located by mammography, was characterized by an extended hot spot with MW thermography, whereas the IR picture exhibited a generally cool area. Other abnormalities that have been localized by MMW thermography include arthritic joints, abnormalities in the spine, and tumors of the thyroid gland and brain. The use of multifrequency scanners (9, 30, and 68 GHz) for three-dimensional probing of subcutaneous hot spots is currently being studied.


Millimeter-wave (MMW) thermographic studies of 14 breast cancer patients were performed at frequencies of either 30 GHz (6 patients) or 68 GHz (8 patients), and the results were compared with those from infrared (IR) thermograms. Both IR and MMW thermographic examinations were performed under thermally controlled conditions in a room with adequate electromagnetic shielding and thermal uniformity. Significant discrepancies were observed between IR and MMW thermography. In three cases, two of which corresponded to nonpalpable carcinomas in situ, IR thermography was negative while MMW thermography clearly showed hyperthermia. In three patients with 2T1 and 1T2 carcinomas (1, U.S.C. nomenclature) with superficial tumor depths of less than 2.5 cm, local hyperthermia corresponding to the tumor was observed with MMW thermography while intense vascular hyperthermia with anachronic patterns over wide regions was observed on IR thermograms. In five patients with relatively deep (3-5.5 cm) tumors corresponding to 1T1, 3T2, and 1T3 carcinomas of the scirrhous type, no anomaly appeared on the MMW thermogram, whereas IR thermography was positive with intense vascular hyperthermia up to 4°C in two cases. In three patients who had received radiotherapy (RT) for 1T3 and 1T4 tumors, both techniques were positive; however, the hyperthermia characteristics were local or diffuse on the MMW thermogram and of the vascular type on the IR thermogram. In two patients where skin reactions induced by RT were clinically noticeable, diffuse hyperthermia of the whole treated breast was seen on the IR thermogram, whereas no relevant anomaly was seen on the MMW thermogram. In general, it seems that MMW thermography, especially at 30 GHz, is able to provide information on subcutaneous thermal conditions and can be positive in cases of carcinoma in situ that generally are false negatives on IR thermograms. Also, MMW thermograms do not exhibit curvilinear hyperthermia similar to that often observed on IR thermograms as a result of very superficial veins.

6417 PROSPECTS OF USING LOCAL UHF HYPERTERMIA COMBINED WITH RADIATION THERAPY OF MALIG-

NANT TUMORS. (Rus.) Lopatin, V. F. (Res. Inst. Medical Radiology, USSR Acad. Medical Sciences, Obninsk, USSR); Dedenkov, A. N. Med Radiol (Mosk) 24(9): 9-13; 1979. (13 refs)

The effects of ultra-high frequency (UHF) hyperthermia (41-42.5°C, 40-60 min) combined with gamma radiation (900-2,200 rads) on the growth of sarcomas 180 in 98 outbred mice and on the growth of the R-1 tumor in 56 Wag rats were studied. UHF hyperthermia alone caused only an insignificant and temporary tumor-inhibiting effect, but it significantly enhanced the tumor inhibiting effect of gamma radiation, especially when given immediately before irradiation; 100% tumor inhibition was observed after irradiation with 2,200 rads and UHF hyperthermia 20 days after treatment. UHF fields causing only moderate hyperthermia (41-41.5°C) prevented the radiation injury of the tissues.

6418 UHF RADIATION EFFECT ON SARCOMA 180 GROWTH. (Rus.) Lopatin, V. F. (Res. Inst. Medical Radiology, USSR Acad. Medical Sciences, Obninsk, USSR); Dedenkov, A. N. Med Radiol (Mosk) 25(8): 75-77; 1979. (8 refs)

The tumor growth-inhibiting effect of low-intensity ultra-high frequency (UHF) irradiation (15 W) was studied in mice with subcutaneously transplanted sarcoma 180. The rectal temperature of the animals was maintained at 36-37°C during the irradiation. In one series, the animals were irradiated for 0.15-2 hr/day for 10 consecutive days, beginning on day 7 after tumor transplantation. The animals were sacrificed on day 20. The tumor growth inhibition was 31% for 0.15 hr/day, 62% for 0.5 hr/day, 47% for 1 hr/day, and 56% for 2 hr/day, averaging 49% for the entire series (i.e., the average tumor weight was 49% lower than in the nonirradiated controls; p<0.05). The tumor growth inhibition was 60% in another series in which the animals were irradiated for 0.5 hr/day for 10 consecutive days, beginning on day 10; there was a 56% inhibition after irradiation at 0.5 hr/day for 5 consecutive days. A single 0.5-hr irradiation had no effect on the tumor growth. The average survival time of the tumor-bearing animals increased by a factor of 1.5 as a result of the irradiation.


Radio frequency hyperthermia (433.92 MHz) and γ-ray radiotherapy were used to treat 52 patients with relatively radioresistant tumors. Most of the tumors were either squamous cell carcinomas (21 patients) or soft tissue sarcomas (10 patients). Tumors were preheated with 433.92-MHz hyperthermia for 5-7 min, with the tumor temperature after 5 min
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being 40-42°C. After hyperthermia, y-ray therapy was delivered at a daily dose of 170-200 rads, 5 times/wk to a maximum total tumor dose of 6,000-6,500 rads in most cases. Among 42 patients evaluated for response, 29 achieved a 100% tumor response; 9, a 75% response; and 4, a 50% response. There were only two local recurrences, and distant metastases were seen in only four patients. Normal tissue exhibited excellent tolerance to this therapy. It is concluded that this combined treatment is superior to megavoltage radiotherapy alone in radioresistant tumors.

6420 CANCER THERAPY WITH LOCALIZED HYPERTERMIA USING AN INVASIVE MICROWAVE SYSTEM. (Eng.) Douple, E. B. (Dartmouth Hitchcock Medical Center, Hanover, NH 03755); Stroehbehn, J. W.; Bow- ers, E. D.; Walsh, J. E. J Microwave Power 14(2): 181-186; 1979. (10 refs)

An invasive needle microwave antenna for producing local hyperthermia in small animal tumors was used to treat mammary adenocarcinomas (MTG-B) implanted in the thighs of C3H mice. A sweep oscillator, crystal detector, oscilloscope, and double-stub tuner matching network were used to maximize radiated power to a 50-ohm load for antennas inserted into tumors. For tumor heating the sweep oscillator was replaced by a 3-W, 1-GHz oscillator and a power supply. The antenna was inserted until approximately 1-2 mm of the outer conductor was inside the tumor, a condition that was important for achieving an electrical match in the tissue. The temperature at the antenna was maintained at 46°C by manually regulating the voltage supply to the oscillator. The thermal distributions produced were characteristic in MTG-B tumors, and the results suggested that this system is capable of heating a tumor as large as 1 cm in diameter to therapeutic hyperthermia levels of 42-46°C. For therapy trials, 21 mice were divided into three groups of 7 animals each. Mice in the treatment group were placed in the system with an antenna inserted approximately 1 mm from the center of the tumor and were treated for 50 min with the temperature at the antenna being 46°C. Animals in a sham-treatment group were subjected to the identical regimen but without power supplied to the antenna. Control animals were given anesthesia only. On the 3rd day after treatment a trend was established, with the heat-treated tumor sizes being significantly smaller at the 95% probability level than those of either control or sham-treated tumors. Tumor growth was inhibited for only a short time following treatment (not specified); after the initial post-treatment period, the growth rate of heat-treated tumors was the same as that for both sham-treated and control tumors. The mean survival time of microwave-treated mice was 14.3 days after treatment compared with 11.7 days for sham-treated mice and 11.3 days for controls. These differences were not statistically significant at the 0.05 confidence level. The development of the antenna for incorporation into a percutaneous probe or a catheter could render this system a useful tool for clinical applications such as the heating of deep-seated, well-defined tumor volumes.


The possible relationship between tumor type and ability to induce localized radio frequency hyperthermia was investigated in 48 patients with histologically proved cancer that continued to progress despite standard therapy. A total of 52 solid tumors (18 melanomas, 3 teratocarcinomas, 2 epidermoid carcinomas, and 7 other less common tumors) were treated with 13.56-MHz radio frequency waves at 50-1,000 W of absorbed power for periods up to 1 hr. Superficial tumors and those with less than 1 cm of overlying normal tissue were treated with experimental surface contact electrodes, with or without surface cooling. Deep subcutaneous and internal tumors were treated by a Magnetron employing circumferential noncontact electrodes to provide uniform deep heat without preferential surface tissue heating. Intratumor temperatures of 42°C or greater in 42 tumors and of 45°C or greater in 23 tumors appeared to be independent of histologic type. In 29/52 tumors, temperatures of 45°C or greater could not be achieved without injury to normal tissues. However, no correlation with tumor type could be established. Hyperthermia was generally well tolerated with virtually no injury to normal tissue in mildly sedated, conscious patients. These findings suggest that potentially tumoricidal hyperthermia may be achieved for treatment of solid human tumors regardless of histologic type.


A radiation balance microwave thermograph for simultaneous and independent temperature and emissivity measurements is described that overcomes the problem of variable mismatch between the test object and the receiving antenna. Measurement error due to the above problem is eliminated by making the temperature of the receiver equal to that of the object. This effect is accomplished by employing the receiver to measure the difference between the incoming and outgoing radiation flux, which equals the production of emissivity and the temperature difference between the receiver and the test object. An integrating servo amplifier controls a variable noise source that adds excess thermal radiation to the receiver's outgoing radiation flux such that the receiver temperature and the
test object's temperature are in balance. The system works as long as the emissivity is not zero. The front-end components of the radiometer can be regarded as a broadband reflectometer completed to form an emissivity measurement bridge by including the direct signal path to the noise source. This property can be simultaneously exploited by modulation of the noise source and detection of the modulated signal fraction after the first synchronous detector. This self-balancing radiometer permits greater measurement accuracy than that of conventional radiometers in situations where contributions from sources other than the test object can be minimized by direct or at least close application of the antenna. Errors due to undefined source mismatch are eliminated. The automatic error compensation of the radiation balance thermograph was compared with the performance of a conventional radiometer by making a manual scan across the surface of a piece of bacon that consisted of interleaved layers of fat and lean. Prior to the measurement, the meat had been heated homogeneously in a waterbath. While the compensated measurement reveals just a slight decline of the temperature along the scan path, the uncompensated measurement is totally misleading due to variable mismatch. The radiation balance thermograph was also used to measure the emissivity of different regions of the human body relative to several experimental antennas. From this experiment, it was concluded that emissivity values between 70 and 100% are well within the practical range for optimum antennas but may be lower than 50% in cases of improper application. The radiation balance thermograph is insensitive to mismatch and mishandling, whereas any conventional radiometer directly responds with considerable error.


A method for combining local microwave heating of subcutaneous living tissue with microwave radiometry in the same system is described that overcomes the problem of intermodulation between the microwave generator circuit and the radiometer circuit. A microwave generator supplies microwave power to the tissue through a probe-applicator (circuit 1) and heats a tissue volume (test volume) that depends on the applicator, the generator frequency, and the dielectric properties of the tissue. The test volume emits thermal radiation that is collected by the applicator. This signal, which is proportional to the temperature in the test volume, can be detected by a radiometer (circuit 2) operating in a bandwidth around a certain frequency. To avoid direct coupling between the two circuits, these circuits are operated at different frequencies chosen to prevent intermodulation.

In a preliminary experiment where the applicator was a miniature coaxial line dipped in water or in a chunk of beef, the microwave power generator was operated at a frequency of 4.6 GHz, and a filter was used to attenuate harmonics and noise. The radiometer was operated at a frequency of 9.6 GHz with a bandwidth of 60 MHz. Intermodulation between the two circuits was avoided, and fair agreement was obtained between radiometric and thermocouple temperature measurements. During one experiment, irradiation of a beef sample with 5 W of power resulted in a temperature increase of 8 °C in 10 min. The above method has potential application in both the detection and local hyperthermic treatment of diseases like cancer in which the permittivity of the diseased tissue differs from that of the normal tissue.


A microwave heating system for improving temperature uniformity in heated tissue is described. The system uses parallel-opposed waveguide applicators, operating in the TEM0 mode at 2,450 MHz. The tissue to be heated (exterolateral mouse intestine) is immersed in a liquid bolus (dextran in physiologic salt solution) that is both biologically compatible with and dielectrically similar to the tissue. The liquid bolus improves microwave coupling and avoids the shape- and size-dependent absorption characteristics of irregularly shaped tissue. By maintaining the liquid bolus at a temperature close to the target tissue temperature, thermal losses and hence temperature gradients in the tissue are reduced compared with heating in hot liquid alone. This was demonstrated by subjecting a typical transverse section of intestine to microwave heating (30 W) while it was immersed in liquid bolus (43 °C) for 30 min. The thermal damage can be contrasted with that which results from immersion in bolus alone. Protection near the mesentery vessels is reduced with the microwave heating system, and the gradients of thermal damage are minimized. This result is confirmed by quantitative results of surviving crypts around the jejunal circumference. The biologically compatible liquid bolus could also be used in direct contact with the skin of patients receiving microwave heating treatments for superficial lesions.


Macroscopic and microscopic changes in the prostate
and surrounding tissues were investigated in 15 sexually mature male mongrel dogs subjected to local microwave hyperthermia (933 MHz). The prostate was irradiated for 15-20 min using a rectally insertable applicator consisting of a cylindrical slot antenna with a water-cooled covering. A flexible thermistor probe for temperature measurement was inserted into the prostate via the urethra, and two additional thermistor probes were located surgically on the dorsal and ventral side of the prostate. Four experiments are described in detail because of the variability of experimental parameters. The thermistor probe temperatures ranged from 43.5 to 48 °C, and the microwave power used to irradiate the prostate varied from 36 to 90 W during the course of the experiments. In one dog, a slight redness of the rectal mucosa and hyperemia of the rectum near part of the ventral prostate were observed. Histologic examination of the rectum revealed no significant changes. The tissue between the rectum and prostate was gelatinous, and hemorrhage as well as granulocytic infiltration into the capsule and interstitium of the prostate were observed. In another dog, no macroscopic or histologic changes of the prostate were observed. However, the rectum showed hyperemia, hemorrhagia, and coagulations of the mucosal membrane. In a third dog, an edematous swelling of the rectal mucosal membrane was observed. Gelatinous tissue was found between the rectum and prostate. The dorsal part of the prostate was hyperemic and exhibited a reddish-blue coloring. Histologic examination revealed necrosis of the tunica muscularis; necrosis in the parenchyma as well as in the interstitium of the prostate was also seen. In a fourth dog the rectum was edematously thickened, but the prostate was without findings. Histologic changes were similar to those observed in the third dog but were less marked because of the lower treatment temperature in this case (43.5 vs. 44 °C). Overall, the results show that local heating of the dog prostate is possible. The undesired hyperthermia of the rectum, as manifested by the above changes, was caused by inadequate contact of the rectum with the cooled antenna covering. The gelatinous tissue between the rectum and prostate may have resulted from hyperthermic edema or surgical manipulation. The pathologic and micromorphologic changes of the prostate were mainly due to hyperthermia. Local hemorrhage in the capsule was partly caused by fixation of the thermistor probes with sutures.

Three typical cases that illustrate the potential application of millimeter-wave thermography (MWT) in the diagnosis of thyroidal, orbital, and intracranial pathologies are presented. In the first case, the results of cervical anterior scintigraphy of a patient with hyperthyroidism due to an autonomously nodule in the right thyroid lobe were presented along with the results obtained by infrared (IR) photography and 68-GHz MWT. Despite the coarser resolution of MWT compared with IR, the former appeared to have more structure and better localization capabilities than the latter technique. In another patient with exophthalmos and an infected mucocoele of the left frontal sinus, a bone scintigram showed a distinct hyperactivity in the upper part of the orbit. In contrast, an IR thermogram was perfectly normal. However, 68-GHz MWT revealed a substantial hyperthermy on the left side. The third case involved a patient with an extensive vertebral osteoma on both sides of the midline that was easily recognizable from the right lateral view of a scintigram. In addition, there was an underlying meningioma that did not cross the median line, as shown on an anterior brain scintigram. For this case, IR thermography could not be used because of the opacity of hair and bone. However, these tissues are relatively transparent to MWT, and a 30-GHz thermogram of the vertex showed a hot left hemisflexion in contrast with the colder right side. It is concluded that the meningioma is responsible for the hyperthermia, while the osteoma probably results from little hyperthermia. Overall, it appears that MWT yields more diagnostic information about subcutaneous and intracranial thermal abnormalities than conventional IR thermography, which is limited to cutaneous temperature measurements.
surrounding normal tissue and dropped to 10% only at distances of 1.6 cm.


A theoretical model is developed to simulate the temperature distribution in a three-layer tissue consisting of skin, fat, and muscle heated by short-wave (27.12 MHz) or microwave (915 MHz and 2,456 MHz) radiation. The results under the fixed core temperature condition were in good agreement with in vivo data measured at the anterior thigh of human subjects. Short-wave diathermy was superior in producing a broader and more uniform temperature distribution in the musculature, but compared with microwave diathermy, it was a less attractive method of muscle heating, producing a slow rise in the muscular temperature and requiring a higher power density. Microwave diathermy application with a low frequency spectrum produced a temperature distribution with peak values in the musculature near the fat/muscle interface. The temperature profile rose with its peak shifting toward the skin/muscle interface, and the minimum temperature in the fat layer became more distinct as the frequency and/or power intensity increased. An exposure to high frequency microwave heat at 2,456 MHz produced a temperature distribution with a peak value in the superficial skin tissue, a minimum in the fat layer, and a second peak (lower than the first peak) value in the musculature near the fat/muscle interface. Heating with 915 MHz microwave radiation produced a pronounced temperature rise, with the highest peak being in the musculature. Thus, microwave diathermy at a frequency of 915 MHz is recommended for deep tissue heating.

6429 EMPLOYMENT OF MAGNETOTHERAPY IN THE COMPLEX TREATMENT OF PATIENTS WITH ULCERS. (Rus.) Guseva, N. G. (Dept. Physiotherapy, Voroshilovgrad Oblast Clinical Hosp., Voroshilovgrad, USSR); Shelygina, N. M. Vrach Delo (7): 5-8; 1979. (7 refs)

The therapeutic effectiveness of magnetotherapy with alternating magnetic fields (20 sessions, 15-20 min/session, intensity 350 or 230 G) was studied in 137 patients with uncomplicated peptic ulcer (92 men and 45 women, aged 17-50 yr). The duration of the disease was 1-5 yr in 70 cases, 5-10 yr in 32, and over 10 yr in 27. Eighty-nine patients received magnetotherapy in addition to the conventional drug treatment; the other 48 patients received drugs only. The radiologic examinations showed the complete disappearance of the ulcerative niche in 86/89 irradiated patients and in 38/48 controls. The time necessary for the niche to disappear and for clinical cure was 2-4 days less in the irradiated patients. The pain syndrome was also controlled more rapidly. The gastric motor function improved, and the length of hospitalization decreased compared with the controls. The magnetotherapy had no adverse side-effects.

6430 A PILOT STUDY TO INVESTIGATE SKIN AND TUMOR THERMAL ENHANCEMENT RATIOS OF 41.5-42.0 C HYPERTHERMIA WITH RADIATION. (Eng.) Johnson, R. J. (Dept. Radiobiology, Univ. Texas, Austin, TX 78712); Ono, H.; Sones, S. Y.; Bicher, H. I. J. Radiat Oncol Biol Phys 5(7): 947-953; 1979. (16 refs)

Normal tissue and tumor responses resulting from radiotherapy (RT) followed immediately (usually 5 min or less) by 1.5-2.0 hr of 915-MHz microwave-induced hyperthermia (41.5-42.0 C) were measured in 10 patients with multiple metastatic melanomas. The response of normal skin to treatment was measured by evaluating the degree of erythema using a numerical scoring system. Tumor response to treatment was assessed by measuring tumor diameter at follow-up visits. One, three, or four fractions of RT were used with a minimum 72-hr interval between each fraction. The RT dose/fraction was 500, 600, 650, 700, 800, or 900 rads. In some cases, single fractions of 1,000, 1,100, 1,200, or 1,300 rads were used. Two or more control lesions were treated with RT but without heat. Heat was applied using direct skin contact Roswell Park Memorial Institute applicators. Skin cooling was required to obtain equal skin and tumor temperatures. A minimum circular area of 5 cm in diameter was heated to a 41.5 C target temperature. Thermocouple measurements were recorded every 10 min with the power on and 5 sec after the power was turned off for the next 10 sec to allow for the dissipation of any local heating resulting from thermocouple positioning and field interference. Thermometry was performed with a fiber optic probe for surface measurement over the normal skin. In addition, 29-gauge thermocouples were inserted into the tumor center and in its deepest aspect. Thermocouples were inserted at right angles to the field of the microwave waveguide in the TEO1 mode to minimize local heating effects. Results are presented for patients with at least 1 mo of follow-up. Normal skin reactions to RT and microwave hyperthermia generally ranged from slight to severe erythema. Although good data were difficult to obtain because of frequent short or incomplete follow-ups, some tumors demonstrated 100% regression in response to therapy. The study did demonstrate that superficial tumors up to 4 cm in diameter and 2 cm in depth can be heated with an accuracy of ±0.5 C. It was also found that normal skin and subcutaneous tissue can be heated to 41-42 C for periods up to 2 hr after RT without any evidence of thermal damage. It is suggested that skin surface temperature measurements may be underestimated when the thermocouple needle is placed directly on the skin surface, where the tip is exposed to air and the applicator end temperatures may be up to 15 C cooler than the skin surface. A more reliable measurement is made if the thermocouple tip is inserted within the first millimeter of the skin tissue. The thermocouple readings should be checked every 10
Data on daily admissions for acute myocardial infarction to hospitals in the West Midlands region of the United Kingdom for the years 1969-70 were analyzed for their possible relationship to geomagnetic activity during the same period. The geomagnetic data consisted of the daily sums of the 3-hr Kp-values obtained from catalogues of recordings taken in the U.K. There were 6,298 hospital admissions over a 720-day period, a mean of 8.75/day. The Kp-sums averaged 15.73/day. Analy ses were performed with both raw data and logarithmic transformations. Same-day correlation coefficients were calculated between the two values within each of 24 successive 30-day periods. Serial correlations were calculated separately for geomagnetic activity and for heart attack admissions between pairs of readings separated by 1, 2, ..., 31 days. Finally, over the full 720-day period, correlations were calculated between geomagnetic readings on day 0 and hospital admissions on days -15, -14, ..., +14, +15 days. The results were qualitatively similar for the raw and the log-transformed data. Serial correlations of the admission data gave significant values at 7 days ($r = 0.15$), 14 days ($r = 0.16$), and 21 days ($r = 0.12$). A complex day-of-week variation over the full period, mainly characterized by a deficiency of admissions on Sundays, confirmed the validity and demonstrated the origins of the findings. Serial correlations of the geomagnetic data gave significant positive results at 1/2 days ($r = 0.50$ at 1 day), 16/17/18/19 days (0.17 at 17 days), and 25/26/27/28 days (0.21 at 27 days). The 27-day cycle represents the sun's rotation period. None of the 720-day-period correlations with intervals of -15, ..., 0, ..., +15 days showed significant positive or negative correlations; the greatest absolute value was $r = 0.06$. None of the intra-30-day-period same-day correlations between medical and magnetic data gave a significant value, either positive or negative. Despite the fact that the above statistical analysis was sensitive enough to detect serial correlations within each of the individual data sets, it was not possible to confirm Indian observations of a remarkable correlation between daily variations in the geomagnetic field strength and daily admissions to the cardio-thoracic wards of hospitals.

The effect of a pulsating magnetic field on reducing resorption of the alveolar ridge of 1-year-old female beagle dogs following extraction of the third and fourth premolars on both sides of the mouth was investigated. One group of six dogs had a bridge containing a magnetic coil that was applied to one side of the mouth and a second bridge without a coil that was applied to the other side of the mouth in the extraction wound area. Another group of four dogs had bridges without magnetic coils. The magnetic coil specifications were as follows: dimensions, 12 by 18 by 3 mm; number of turns, 100; resistance, 3.4 ohms; and self-inductance, 230 microhenry. The signal to drive the coil consisted of a pulsating magnetic field with a frequency of 10 Hz and a pulse length of 2 msec. The magnetic field strength ranged from 6,000 A/m at the middle of the stimulated half of the mandible to only 70 A/m at the middle of the control half of the mandible. A quantitative measurement of the resorption was made with the aid of a reproducible standardized x-ray technique. Resorption of the alveolar ridge following tooth extraction was reduced by 70% for stimulated wounds and by 50% for nonstimulated wounds in dogs receiving the pulsating magnetic field treatment. The reduction in resorption for nonstimulated wounds in stimulated dogs can be explained either by assuming a central mechanism of effect or an effect of the very low field present at the opposite side of the stimulated alveolar ridge.
Enzymatic and ultrastructural changes in cultured C6 glioma cells irradiated with 2.4-GHz microwaves are reported. Cultured cells were irradiated for 10-15 min at an frequency ranging from 48 to 56.3 C. Measurements of plasminogen activator activity after microwave irradiation showed that cells kept at 48 C for 10 min or 49 C for 15 min were relatively unchanged with respect to control cells maintained at 28 C. However, an increase in the temperature and time of irradiation (51.6 C for 13 min or 56.3 C for 15 min) resulted in a dramatic loss of plasminogen activator activity compared with controls. Electron microscopic studies of irradiated cells showed that the surface morphology of C6 glioma cells remained relatively unchanged up to a cell culture medium temperature of 49 C for 15 min. However, when cells were irradiated such that the cell culture medium temperature rose to 51.6 C for 13 min or 56.3 C for 15 min, the following morphologic changes were observed: holes within the cell membrane, a decrease in microvilli, and destruction of zelotic blebs. These changes in surface morphology were most rationally attributed to alterations of membrane proteins.

A radiotracer method was used to determine if 2,450-MHz continuous wave microwave energy increases blood-brain barrier (BBB) permeability in the rat to [14C]-labeled mannitol, which is normally excluded from entering the brain. Anesthetized adult rats were irradiated singly for 30 min in the quiet zone of an anechoic chamber at average power densities ranging from 0.1 to 30 mW/cm². After irradiation, a carotid bolus injection of [14C]-mannitol/[3H]-water mixture and was decapitated 15 sec later. Uptake of [14C]-mannitol relative to the highly permeable [3H]-water was calculated as the brain uptake index (BUI) for four brain regions. Differences between mean BUI values for brain regions removed from microwave-irradiated rats compared to sham-irradiated rats were not significant at the 5% level, and a microwave influence on BBB permeability was not evident. Mean BUI levels for cortex and diencephalon remained close to the 2% level across treatment groups. However, mean BUI values for cerebellum (4.24 ± 0.52 to 7.76 ± 2.06%) and medulla (8.05 ± 0.97 to 16.84 ± 4.50%) were much higher than those for diencephalon and cortex, and there was much more variability both within and among treatment groups. The generally higher BUI values in cerebellum and medulla compared with other brain regions were related to the fact that both of these tissues contained more [14C]-mannitol and less [3H]-water than diencephalon or cortex. Medulla absorbed or retained the least [3H]-water of all four tissues, and thus BUI values were highest for this tissue.

The effect of a super-high frequency (SHF) electromagnetic field (wavelength 12.6 cm, energy density 13, 23, or 35 mW/cm²) on the inactivation of diploid, triploid, tetraploid, and hexaploid strains of Saccharomyces cerevisiae (strains 211, 301, 400, and 600) was studied, and the results were compared with those obtained by a probability model of the action of electromagnetic irradiation on cells. The model is based on the hypothesis that the probability of successful cell division is determined by the degree of cell damage. The temperature of the cell suspensions was 50-55 C during the irradiation. The effect was assessed by a stimulation of antibody production to sheep red blood cells and then by determining the 20-day survival rate following vaccination with ribosomes and membrane fractions of Klanselia pneumoniae. Highly significant stimulation of antibody production was seen in animals irradiated for 15 min or more at energy densities greater than 5 mW/cm².
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4 hr/day on 4 consecutive days. Irradiation for 1-3 hr/day on 4 consecutive days had no protective effect against challenge, and there was no significant difference in the survival rate compared with nonirradiated controls. However, a statistically significant increase in the survival rate was seen in animals irradiated for 4 hr/day for 4 days.

6438 FURTHER PROGRESS WITH ONCOLYSIS DUE TO LOCAL HIGH FREQUENCY HYPERTHERMIA, LOCAL X-IRRADIATION AND APATHOGENIC CLOSTRIDIA. (Eng.) Gerlcke, D. (Hoechst AG, 6230 Frankfurt/Main 80, W. Germany); Dietzel, F.; Ruster, L. J Microwave Power 14(2): 163-166, 1979. (11 refs)

The oncolytic effect of local x-irradiation, local high-frequency hyperthermia (HHF), and treatment with apathogenic Clostridia is reported. Fifty NMRI mice received a subcutaneous transplant in the neck of a Harding-Passay melanoma. When the tumor diameter reached at least 8 mm, the mice received x-irradiation (2,000 rads), followed immediately by 461-MHz HFN (40-41°C for 3 min), and followed 12 hr later by an injection into the tail vein of 10^8 spores of Clostridium ongleyticum s. butyricum. After one cycle of this treatment, only 10% of the mice were free of tumor relapse; however, this percent rose to more than 30% after two cycles of treatment and to more than 60% after six treatment cycles. Oncolysis occurred after each repeated spore application, and treatment was well tolerated.

6439 EFFECT OF CONTROLLED ELECTROMAGNETIC RADIATION ON THE GROWTH OF CELLS IN TISSUE CULTURE. (Eng.) Peters, W. J. (Suite 1-120, Univ. Wing, Toronto General Hosp., 101 College St., Toronto, Ontario M5G 1L7, Canada); Jackson, R. W.; Iwano, K. J Surg Res 27(1): 8-13; 1979. (24 refs)

Various mammalian and bacterial cell lines were exposed for 1 min or multiples of 1 min to microwave (MW) radiation at a wavelength of 12 cm, a frequency of 2.45 GHz, and a current of 120 mA under strictly controlled temperature conditions to assess the effect of this exposure on their growth in tissue culture. When L-929 cells were exposed to five 1-min doses of MW energy, subsequent growth was significantly decreased. The maximum temperature reached during irradiation was 34-35°C. When these cells were alternately cooled in an ice bath (0°C) and placed in a water bath (34-35°C) for five 1-min exposures, their subsequent growth was not affected. The sensitivity of suspension cultures of asynchronous L6OT cells to MW radiation was similar to that of L-929 cells, and alternate cooling and heating again had no effect on their growth. In experiments where L6OT cells were synchronized and subsequently exposed to five 1-min doses of MW energy as the cells progressed through the cell cycle, it was found that cells in the S and G2 phases of the cell cycle were resistant to MW radiation. However, 12% of the cells in the M phase failed to proliferate following MW exposure, and about 45% of those in the GI phase failed to form colonies after MW treatment. The susceptibility of L6OT cells during the GI phase suggested that if an asynchronous population were treated at four successive 4-hr intervals, growth would be inhibited to a greater extent than if the population were treated at four successive 1-hr intervals; this was indeed found to be the case. Preliminary experiments indicated that the growth of Vx2 and RT cells (two cell lines derived from neoplastic tissue) was more sensitive to MW energy than the growth of L cells at comparable energy levels. Intermittent exposure of these cell lines to a water bath (35°C) and an ice bath (0°C) for five 1-min exposure periods had no effect on their subsequent growth. Bacterial cultures of Staphylococcus aureus, Streptococcus pyogenes and viridans, Bacillus subtilis, Escherichia coli, and Pseudomonas aeruginosa were totally resistant to MW irradiation unless the exposure temperature was elevated to destructive levels.


Neurologic, behavioral, and immunologic reactions of rabbits and rats exposed to far-field irradiation at a frequency of 2,375 ± 50 MHz are reported. In one experiment, 24 rabbits were exposed to continuous wave radiation at power densities of 10, 50, and 500 µW/cm² for 7 hr/day over a 3-mo period. Power densities of 10 and 50 µW/cm² stimulated brain bioelectric activity, as indicated by an increase in the regularity of the basic theta-rhythm and the degree of similarity of the form of oscillation with a parallel increase in its amplitude in the thalamus-anterior hypothalamic. In the cortex regions, the increase in activity was associated with raised excitability of the brain. A power density of 500 µW/cm² suppressed brain bioelectric activity, as evidenced by an increase in slow delta waves of high amplitude that occurred after 2 wk of irradiation in the cortex. A gradual increase in slow high amplitude activity was also seen after 1 mo of irradiation at a power density of 50 µW/cm². In another experiment, rats exposed to 500 µW/cm² of radiation for 7 hr/day over a 1-mo period exhibited decreases in work capacity, levels of unconditioned feeding stimulus, investigating activity, and electronic irradiation threshold. This power density also caused a sudden and statistically significant disturbance of the immunologic system; this was manifested by substantial suppression of phagocytic capability of neutrophils and by a reduction of the functional activity of immunocompetent cells responsible for cellular and humoral protection reactions.

6441 ERYTHROCYTE DAMAGE CAUSED BY THE MAEMO- THERM® MICROWAVE BLOOD WARMER. (Eng.)
Erythrocyte damage to blood units in Fenval blood bags was examined after water bath warming and after warming by a Haemotherm microwave blood warmer operating at a frequency of 2,450 MHz. Extracellular hemoglobin and potassium, hematocrit, osmotic fragility, and mean cellular volume were measured as indicators of red blood cell damage. Warming in the water bath caused no erythrocyte damage at temperatures of about 46°C. At temperatures above this, progressive hemolysis, swelling, and finally erythrocyte fragmentation were observed. Units of red blood cells in saline warmed to temperatures above 46.3°C with the Haemotherm showed intense hemolysis and changes in all of the parameters used to assess red blood cell damage; below this temperature no erythrocyte damage occurred. When the amount of blood warmed was less than 300 g or when the hematocrit exceeded 0.70, the blood mixing mechanism became insufficient, leading to local overheating and hemolysis. The mean plasma hemoglobin increase of 10 whole blood units warmed by the Haemotherm® to 36.0-36.8°C was 125 mg/l. The above results indicate that microwaves per se are not harmful to erythrocytes but that penetration of microwaves together with insufficient blood mixing during warming are the critical factors leading to hemolysis.

**6442 HOLOGRAPHIC ASSESSMENT OF A HYPOTHESIZED MICROWAVE HEARING MECHANISM.** (Eng.) Frey, A. H. (Randomline, Inc., Huntingdon Valley, PA 19006); Coren, E. Science 206(4415): 232-234; 1979. (21 refs)

Dynamic time-averaged interferometric holography was used to measure predicted motion in the skull or soft tissue of the heads of rats and guinea pigs exposed to pulsed microwaves to determine if the thermoacoustic expansion-bone conduction hypothesis accounts for sound perception of microwaves in mammals. In one experiment with 10 Sprague-Dawley rats, the microwave energy carrier frequency was 1.275 GHz; the pulse width, 25 usec; the pulse repetition rate, 50 pulses/sec; and the incident peak power, 1,700 mW/cm². In five of the animals, an additional set of holograms was made at 100 pulses/sec as each layer of head tissue was removed, starting with the holograms of the muscle tissue. In a second experiment, 16 adult male guinea pigs were used, half of them being tested at a frequency of 1.1 GHz and the others at 1.2 GHz in a 2 x 2 x 2 factor design. The factors were peak power density at 1,250 and 8,500 mW/cm², pulse width at 10 and 20 usec, and pulse repetition rate at 25 and 50 pulses/sec. A treatment-by-subject design was used in which each animal was its own control. The experiments showed that the predicted motion of head tissue did not occur. Based on this finding and evidence reported elsewhere, it is suggested that the locus of radio frequency hearing is in the cochlea, where possible thermoacoustic expansion could account for the auditory perception of microwaves.

**6443 AN ELECTROMAGNETIC ENERGY COUPLER FOR MEDICAL APPLICATIONS.** (Eng.) Iskander, M. F. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durning, C. H. Proc IEEE 67(10): 1463-1465; 1979. (12 refs)

An applicator for coupling electromagnetic (EM) energy into a dielectric material such as tissue with minimum leakage radiation is described. The applicator is a printed-circuit 50-ohm surface strip transmission line (coplanar waveguide) that is fed by a small coaxial line and is terminated by a thick-film 50-ohm chip resistor; the ground plane is placed on both sides of the center strip conductor. This geometry allows the spread of EM fields around the transmission line rather than confining them between the conductors. The coupling characteristics of the EM applicator were determined by mapping the fields coupled through a layer of wet sponge, which simulated the tissue, and placing the sponge on top of the applicator. The peak field intensity coupled to the sponge occurred at the contact region with the applicator, and the signal amplitude rapidly decreased as the distance from the contact region increased. The feasibility of using the EM applicator in medical diagnostics was examined by inducing pulmonary edema in the lungs of dogs and using the EM applicator to monitor changes in the microwave (915 MHz)-transmitted signal in vivo. Changes in the phase of the microwave-transmitted signal agreed very well with changes in the pulmonary edema, as indicated by changes in the mean pulmonary arterial pressure. The results obtained from both the phantom and animal experiments illustrate the high coupling efficiency of the applicator with minimum leakage radiation around the body.


A method for imaging biosystems using microwave radiation is described and illustrated using a phantom brain target and an isolated canine kidney. The images are two-dimensional arrays of microwave transmission coefficients (magnitude and phase) of the complex power transmission coefficient \( \sigma_2 \) that depict the relative insertion loss and relative phase shift of a 3.9-GHz signal as it propagates through the specimen. The image is a square array containing a total of 4,096 pixels. At each point in the image, the magnitude and phase of \( \sigma_2 \) is measured and recorded. The data collection system, consisting of an electromechanical scanner subsystem, a control and recording subsystem, and a microwave stimulus-response measurement subsystem, provides \( \sigma_2 \) microwave images that can then
be related to known organization within the canine kidney. Specifically, the regions thinly populated with glomeruli in the cortex corticis are distinguishable from deeper cortical regions containing large numbers of glomeruli with some suggestion of lobulation. Likewise, the medullary outer zone where the thick loops of Henle are found in greatest proportion is easily distinguished both from deeper cortical layers and the renal pelvis. Thus, regions corresponding to filtration appear to be separable from regions corresponding to osmotic concentration, and these are easily separable from the pelvis. These maps of #21 also allow inferences concerning regions within the kidney that may be more liable to injury with sufficiently high power microwave fields. To the extent that the interrogation frequency is well removed from the relaxation frequency of water, so that temperature effects on complex permittivity are minimized, the #22 image will represent regions of increased propagation loss (i.e., energy dissipation) for high power fields of the same frequency. It can therefore be inferred that the corticomedullary junction and medullary outer zone are especially liable to microwave injury, and that when sufficient interior fields are induced, the thick regions of the loops of Henle are at special risk. Thus, the hazard can be expected to be expressed as a defect in osmotic concentration rather than, for example, as defects in ultrafiltration.

6445 MICROWAVE INTERFERENCE WITH THE FUNCTION OF AN IMPLANTED CARDIAC PACEMAKER. (Eng.) Neelakantaswamy, P. S. (Sch. Applied Science, Univ. Science Malaysia, Minden, Penang, Malaysia); Ramanan, K. P. IEEE Trans Electromagn Compat 21 (3): 274-276; 1979. (8 refs)

A theoretical model is proposed to explain the occurrence of a syncopeal episode in a patient with an implanted ventricular sensing cardiac pacemaker who was exposed to 2,450-MHz radiation from a microwave oven. A subsequent clinical study with a similar microwave environment showed a high frequency artifact on recorded electrocardiogram (ECG) tracings, demonstrating effective blocking of the implanted pacing activity. It is theorized that the absorbed microwave energy by the biomedium containing the implanted pacemaker represents a volume of heat source that sets up thermoelastic waves in the biomedium. These acoustic waves induce in the pacemaker circuit noisy microphonic oscillations that correspond to the high frequency artifacts on the ECG tracings. It is suggested that calculation of the amplitude and frequency of the vibration causing the high frequency noise in the pacemaker output would enable the proper design of a pacemaker oscillator circuit with quenched microphonics.


The health status of 100 workers exposed occupationally to electromagnetic fields (20-60 uW/cm², occasionally 100 uW/cm², electric component 20-100 V/m, magnetic component up to 3 A/m) was analyzed as a function of the length of exposure. Ninety workers were less than 45 yr of age. The length of employment involving exposure was 1-5 yr in 42 cases (group 1), 5-9 yr in 24 (group 2), and greater than 10 yr in 34 (group 3). Group 1 workers had practically no complaints, while two workers in group 2 complained about headaches, epicardiac pains, weakness, and somnolence; workers in group 3 also had similar complaints. In group 4, three workers had chronic gastritis and cholecystitis, five had recurrent coryza, four each had angina and radiculitis, and seven had other diseases. Electrocardiogram (ECG) changes (left shift of the axis, sinus tachycardia, disorders in intraventricular conduction, and signs of myocardial hypoxia) were seen in some workers 1 yr after to 3.5-yr exposure. The incidence of these ECG changes was higher in groups 2 and 3. Focal opacification of the crystalline lens, arteriosclerosis, and dilatation of the veins of the fundus of the eye were found in 3 workers in group 1, in 9 workers in group 2, and in 16 workers in group 3. Vegetative dystonia, asthenoneurotic syndrome, neurovascular dystonia, and neurasthenic syndrome were found in six workers in group 3, and autonomic vascular dystonia was found in two workers in group 2.


The high school and university students are exposed to electromagnetic fields in laboratory practice. The energy can be as high as 1,000-1,000,000 W and the current intensity can reach 1,000 A. The frequency is usually in the range of 10,000 Hz to several GHz. Despite the possible harmful physiologic and mutagenic effects of magnetic fields, no maximum allowable levels have yet been established for students. According to the recommendation of the Stanford Linear Accelerator Center (SLAC), the maximum dose should not exceed 2 Tesla for the arms and legs, and 0.2 Tesla for the whole body.
Electromagnetic fields and tractor-trailer vehicles. These measurements were made with all common combinations of mobile transmitters and antennas. The radio frequency transmitting sources used the maximum legal output power (110 kW) at nominal frequencies of 40, 162, and 416 MHz and nominal 100-W power levels in the high-frequency band (3-30 MHz). Illegal power levels (100 W) of citizens’ band transmissions at 27 MHz were used through special authorization by the Interagency Radio Advisory Committee. Fields in and around vehicles with on-board transmitters ranged mostly from 10 to 300 V/m. Field strengths in and around vehicles adjacent to vehicles with transmitters ranged mostly from 5 to 100 V/m. The results of electric field strength measurements in the near-field regions of fixed, high-power transmitters are also reported. These sites included amplitude-modulated (AM), frequency-modulated, and television broadcast stations and high-power military and Federal Aviation Agency fixed transmitters. The electric field strengths in the near-field region of the AM broadcast stations in the frequency range of 550 kHz to 1.6 MHz were much higher than those at other fixed, high-power transmitters, particularly for AM transmitters with 5/8 wavelength towers. Unperturbed fields of over 800 V/m were measured 3 m from the base of a 50-kW, 5/8-wavelength transmitting tower for an AM transmitter operating in the frequency range of 550 kHz to 1.6 MHz. Service vehicles may come within 3 m of a transmitter tower, but at AM frequencies there should be no resonances (since even a tractor-trailer is short compared to wavelengths in the AM frequency range). Based on the measured results, it is concluded that these phenomena are present.

(1) Each data curve shows a resonant peak in the 20- to 40-MHz frequency range. Vehicle dimensions (approximately 5 m) are such that a half-wavelength resonance can be expected. There may be other resonances at higher frequencies that were not observed due to the wide frequency separation in the higher test frequencies (above 40 MHz). (2) The field strength levels decrease inversely with the square root of frequency except for the resonant peaks. This follows a skin-effect loss. The metallic vehicle has losses that increase proportionally to the square root of frequency. The more energy that is dissipated in skin-effect losses, the less available for nondissipative electromagnetic fields. (3) The larger the vehicle, the lower the field strength levels in and around it for equal levels of excitation power. The vehicle is an antenna, but the larger the volume for constant excitation power, the lower the energy density (and hence field strength levels) for this larger volume. All of the measurement results are tabulated in terms of type of vehicle, type of ground surface, frequency, type of field, number of measurements, and five percentile values (100, 95, 90, 75, and 50). Units of measurement for electric fields are V/m, and those for magnetic fields are A/m (far-field V/m equivalent in parenthesis). Although it is recognized that converting A/m to V/m is not valid under near-field conditions, this conversion permits ready comparison of the magnitudes of the magnetic field results with the electric field results on an energy density basis. The magnetic field strength levels were measured with a magnetic field probe and were not obtained by converting from electric field results. It should be noted that many of the field strength levels measured were obtained for personnel exposure. The implications for people who use, manufacture, and regulate these systems could be serious.

6449 ELECTRIC FIELD EFFECT ON THE HELIX-COIL TRANSITION OF POLY(L-α,γ-DIAMINOBUTYRIC ACID HYDROCHLORIDE) IN METHANOL/WATER MIXTURES.

Electric field effects on the helix-coil transition of poly(L-α,γ-diaminobutyric acid hydrochloride) in methanol/water mixtures were studied by transient electric birefringence. The electric field was applied to the solution in a Kerr cell in the form of single rectangular pulses. The pulse duration was about 500 usec, and the highest voltage was 7 kV. Anomalous birefringence transients were observed above a certain threshold field strength, and the field strength dependence of the electric birefringence of the solution resembled the behavior of a permanent dipole momentum orientation over a limited range of field strengths. The anomalous transients can be interpreted as being due to a conformational change from the charged helix to the charged coil induced by the electric field. A certain fraction of counterions will be bound to the charged helix, but they will be mobile in the axial direction. Application of the electric field displaces such counterions along the helix, giving rise to an induced dipole moment. The helices are then preferentially oriented by the electric field. As the applied field is enhanced, the average degree of orientation becomes larger, causing the component of the field along the helix to increase still more. When the counterions are shifted towards one end of the helix and the increased repulsion between the ionized groups at the other end overcomes the attraction due to the hydrogen bond and other nonbonding interactions, unwinding of the helix will start at that end and propagate along the helix. This process will occur above a critical field on the verge of the transition region. The mechanism involved is analogous to that proposed for field-induced conformational changes in molecules such as deoxyribonucleic acid.

6450 SOME CURRENT RESEARCH TRENDS ON THE BIOLOGIC EFFECTS OF ELECTROMAGNETIC WAVES.

Current research trends on the biologic effects of electromagnetic waves are reviewed in the light of recent conferences and publications on nonionizing radiation. Current research is focused on the action of electromagnetic waves at the cellular,
subcellular, and molecular levels; on the effects on the nervous system; on immunologic and hemato-
logic effects; as well as on the possible applica-
tions of microwaves for cancer therapy. The ability
of microwaves to destroy the blood-brain barrier
is also being studied.

Work published since 1974 on the physiology of
the peripheral electroreceptive system of fish is reviewed.
The following general topics are covered: species
and individual specific stimulus-frequency filter-
ing by tuberous electroreceptors; the role of tuber-
ous electroreceptors in object detection; the sen-
sitivity of ampullary receptors to electric and
magnetic fields; and the role of calcium ions in
the maintenance of electroreceptor function. Amp-
ullary receptors, which as a class are the most
sensitive electroreceptor type, are found in all
electric fish and in nonelectric Siluroids, Chon-
drosteans, and Elasmobranchs. In Teleosts the
threshold for an afferent response is about 1 uV/cm;
behavioral thresholds are 10-100 times lower. Am-
pullary receptors are most sensitive to low stimu-
lus frequencies, lower than about 50 Hz and as low
as 5 Hz or less. The ongoing activity of the af-
ferent neurons postsynaptic to the ampullary re-
ceptor cells is a train of action potential spikes for
the maintenance of electroreceptor function. Am-
pullary afferents postsynaptic to the ampullary re-
ceptor cells are a train of action potential spikes
occuring regularly at a rate of 30-80/sec. This
afferent activity is modulated by the receptor cells,
and the amount of modulation depends on the fre-
quency and intensity of the electric field stimulus.
For sinusoidal electric field stimulus, the modula-
tion frequency and the modulation depth is propor-
tional to the stimulus intensity; thus, response
frequency is the neural code for stimulus intensity.
Concomitant with the ability of electroreceptors
to detect electric fields is their ability to de-
tect magnetically induced electric fields. During
investigations of the magnetic sensitivity of amp-
pullary electroreceptors in two species of skate
(Frygon pastinara and Raja clara), the activity
of ampullary afferents was recorded during stimu-
lation with nearly uniform, vertically-oriented
magnetic fields. The afferents responded to mag-
netic fields that were varied at rates of 0.8-20
G/sec but did not respond to static fields. This
is consistent with the predicted electric, as op-
posed to ferromagnetic, detection of magnetic
fields. The relationship between the afferent
discharge frequency and the rate of change of mag-
netic induction was approximately linear. Also,
the response threshold was proportional to both
the length of the ampullary canal and the electric
field threshold of the receptor. On the animal's
left side, receptors with canals opening rostrally
were excited by increasing south (dorso-ventral)
directed magnetic fields, while receptors with ca-
als opening caudally were inhibited by these
fields. On the animal's right, the rostrally
opening receptors were excited by increasing
north directed fields; the caudally opening
receptors were inhibited by these fields. Thus
an ampullary afferent can be either excited or
inhibited depending on the sign of the change
in the magnetic field. It has been proposed
that the response difference between rostrally and
caudally directed receptors is a result of a rostro-
caudal induced current loop, with the current flow-
ing from one ampullary group into the other; thus
one group is excited while the other is inhibited.
The left-right difference may be explained
by the induced current patterns that may be a
function of the stimulus apparatus. Even with-
out increased sensitivity by central integrative
processes, these receptors are sensitive enough to
respond when a skate is moving through the earth's
magnetic field (0.5 G) at a velocity of 30 cm/sec.

The effect of an ultra-high frequency electro-
magnetic field (50 uW/cm², frequency not specified,
7 hr/day for 10-30 consecutive days) on slow de-
layed contact allergy induced by dinitrochloroben-
ze (DNB) was studied in 78 guinea pigs. DNB
(1% in acetone) was applied topically to the skin
for 7 consecutive days; the challenge dose was
applied 24 hr after the last treatment. Compared
with the nonirradiated animals, the intensity of
the dermatitis was significantly reduced in the
animals irradiated for 10 days, and even more in
those irradiated for 20 or 30 days. The blast
transformation of peripheral blood lymphocytes by
phytohemagglutinin was also reduced significant-
ly in the irradiated animals (16.6-22.1% versus
31.7-35.4% in the controls). The findings indi-
cate that low-intensity electromagnetic fields of
ultra-high frequency induce immune deficiency in
thymus-dependent lymphocytes.

A new type of Gaussian-beam launcher for producing
a focused microwave exposure field in biologic
experiments for selective partial-body irradiation
is proposed. The launcher is formed by placing a
dielectric hemisphere (instead of a full sphere)
at the aperture end of a corrugated circular wave-
guide (scalar horn) that supports a balanced hybrid
(HE₁₁) mode. This enables a reduction in the path
length of the ray in the lens-medium, and hence
the spherical aberration effects are relatively
minimized. Also, by using a hemisphere instead of

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6451 PERIPHERAL ELECTROSENSE PHYSIOLOGY: A
REVIEW OF RECENT FINDINGS. (Eng.) Vian-
cour, T. A. (Dept. Biology, Rice Univ., Houston,
(44 refs)

6452 EFFECT OF A LOW-INTENSITY ELECTROMAGNETIC
FIELD OF ULTRA-HIGH FREQUENCY RANGE ON THE
COURSE OF LOW ALLERGIC REACTIONS. (Rus.) Ving-
gradov, G. I. (Biologic Hygienic Res. Lab., A. N.
Marzev Kiev Scientific Res. Inst. General and Com-
munal Hygiene, Kiev, USSR); Vinarskaya, E. I. Vraч
Delo (6): 101-103; 1979. (6 refs)

6453 DIELECTRIC HEMISPHERE-LOADED SCALAR HORN
AS A GAUSSIAN-BEAM LAUNCHER FOR MICROWAVE
EXPOSURE STUDIES. (Eng.) Meelakantaswamy, P. S.
(Electronics Section, Sch. Applied Sciences, Univ.
Science Malaysia, Minden, Penang, Malaysia); Hong,
F. C. IEEE Trans Microwave Theory Tech 27(9):
797-799; 1979. (14 refs)
a full sphere, the launcher structure become lighter and smaller. An X-band launcher was designed and fabricated based on the theoretical results for an aperture edge taper of 25 dB at a frequency of 9.5 GHz. The desired spot size at a distance of 6 cm along the optical axis from the lens was taken as 28 degrees, corresponding to a spot diameter of 5 cm at a distance of 6 cm from the lens along the optical axis. The sphere radius was calculated to be about 4.25 cm. The dielectric hemisphere was made with paraffin wax and was supported at the horn aperture by polystyrene foam. The spherical aberration function calculated for this lens is presented as a function of the equivalent aperture radius normalized with respect to the free-space wavelength. For comparison, the aberration function resulting from the use of a full sphere is also illustrated graphically. A considerable reduction in the aberration effects when the dielectric hemisphere is used as the lens is evident from these results. Near-field measurements were performed at a frequency of 9.487 GHz, and measured and calculated beam parameters at a distance of 6 cm along the optical axis from the lens are given. The results indicate that the test launcher produces a near-circular Gaussian beam in the proximity of the focusing lens. A simple design procedure can be used to calculate launcher dimensions for prescribed constraints (e.g., spot size) on the Gaussian beam.


The biologic and physical effects of various types of nonionizing electromagnetic radiation (e.g., UV, visible light, infrared [IR], microwave, and radio frequency radiation) are reviewed. For nonionizing electromagnetic radiation, the principal effect of nonionizing electromagnetic radiation on man is general or localized heating. The detail of tissue damage varies with the different types of radiation. Microwaves and other radio frequency radiations generate heat at deeper tissue levels than IR; thus tissues that are not usually heated are damaged, as in the case of lens cataracts. Over the range from 30 to 30,000 MHz, the percent of incident energy absorbed in tissue increases from 10 to 60% while the depth of penetration, which is defined as the depth at which the energy is reduced to about one-third of its original intensity, decreases from 3 cm to 1 mm. Taking these two factors into consideration, the least favorable exposure frequency for living tissue is around 3,000 MHz, where 50% of the incident energy is absorbed and the depth of penetration is about 1 cm.

6455 AN EMPIRICAL FORMULA FOR BROAD-BAND SAR CALCULATIONS OF PROLATE SPHEROIDAL MODELS OF HUMANS AND ANIMALS. (Eng.) Durney, C. H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Iskander, M. F.; Massoudi, H.; Johnson, C. IEEE Trans Microwave Theory Tech MTT-27(8): 758-763; 1979. (7 refs)

An empirical relation for calculating approximate values of the average specific absorption rate (SAR) over a broad frequency range for any prolate spheroidal model is derived for E-polarized incident plane waves by using a combination of antenna theory, circuit theory, and curve-fitting. This formula provides a simple and inexpensive method for calculating the SAR for various spheroidal sizes between those of rats and humans. The formula satisfies the f^2 SAR behavior at lower frequencies, the resonance characteristic at intermediate frequencies, the 1/f behavior past resonance, and the dependence on the dielectric constant at the geometric optics limits. An expression for the resonance frequency (f_0) in terms of the dimensions of the model is also derived, with the unknown expansion coefficients being determined by curve-fitting all of the data available in the second edition of the Radiofrequency Dosimetry Handbook. A comparison between values of f_0 obtained from the formula with those obtained using the extended boundary convolution method illustrates that the formula provides a quick and easy method for calculating the f_0 with approximately a 5% error at most.


Sensitivity to microwave-induced local tumor hyperthermia (43 C, 60 min) was investigated for eight different solid mouse tumors that were transplanted subcutaneously in the left flank of C3H/He, CD2F1 (BALB/c x DBA/2F1), or B6DF1 (C57BL/6 x DBA/2F1) mice. The local tumor hyperthermia (LTH) microwave source was a four-way power-dividing network and reflected power monitor, a temperature-controlled microwave power regulator, and small direct-contact microwave applicators (3.2-cm in diameter). The applicators were coupled to the tumor by enclosing the tumor in a bolus of muscle-equivalent dielectric material. The temperature at the center of the heated tumor was regulated to within ±0.1 C, while the temperature uniformity within the tumor was ±0.5 C. The temperature distribution measured in these tumors was: top, 43.5 C; center, 43.0 C; and bottom and edges, 42.5 C. Tumor growth inhibition (TGI) and tumor growth delay (TGD, the extra number of days needed by treated mice relative to control mice to reach an average tumor size of 1 cm^3) were calculated. In general, LTH reduced the size and retarded the growth of treated tumors relative to controls for each of the tumors tested. Although slight increases in life-span were observed in several experiments, only 5/188 treated mice were cured. Of the eight tumors tested, colon carcinoma 26 and Lewis lung carcinoma were the least responsive, with TGIS of less than 35% and TGDs of about 1-2 days. Most of the tumors were moderately responsive to LTH; TGIS of 37-75% were observed following a single LTH treatment of B16 melanoma, mam-
Current Literature

The effects of open-space microwave (MW) irradiation in the millimeter (73 GHz) and centimeter (17 GHz) range were examined in Drosophila melanogaster. Both the wild type strain Paris and the strain delta carrying melanitic tumors in the 3rd larval stage, in pupae, and in adults were used. Cooked baker's yeast was used as nutrient medium, and growth was monitored in an incubator. The microwave apparatus included either a Klystron of the Varian frequency modulating apparatus and a preamplifier, an FM modulator, a centimeter only the electrode bias is measured. When the other 17-GHz is closed and only the electrode bias is measured. When the one valve is opened, both the electrode bias and the voltage gradient are measured. The electrode signals are fed to a differential DC preamplifier and to an alternating current (AC) amplifier. The (low frequency) signals are matched for recording on magnetic tape by means of a frequency modulating device. In the laboratory, the signals can be demodulated and displayed on an oscillograph; however, this device has its limitations. It measures only in one direction and gives only indirect information about the direction of the electric field. A three dimensional version of this system, the GEM III, was also constructed. In this module, one measuring electrode is situated in a PVC tube and is in connection with the surrounding seawater; the other electrode is placed in a central compartment. A valve system provides electric contact between this electrode and one of the other tubes. During a measuring cycle (6 sec), the valves open in a predetermined order so that with only one valve open the electrode bias is measured. When another valve is opened, both the electrode bias and the voltage gradient are measured. The signals are successively fed to a preamplifier, an FM modulator, a demodulator, and an 11-channel recorder. This GEM III device can be used in water to a depth of 200 m. The results of the pilot study performed in the Schelde estuary and in the Waddensea were obtained with GEM II and GEM I (a unit with measuring electrodes that rotate around a vertical axis) devices. Local electric fields (up to 150 μV/m) caused
by bottom structures and regional electric fields (up to 60 μV/m) due to electromagnetic processes were measured. Most of the recorded fields fell within the perceptive range of sharks (10 μV/m) and rays (1 μV/m).


A generator, known as the Priore Machine, which produces a biologically active combination of modulated magnetic and microwave fields is described. It is claimed that the generator produces radiation that causes certain implanted animal tissues to regress and cures trypanosomiasis in certain laboratory animals. A review of the literature describing the generator and its biologic effects reveals that the biologic data are presented in careful detail while information on the generator is sparse and often contradictory. A review of the patent for the generator discloses that the active radiation emerges from a tube containing a rotating deflector upon which impinge, from several different sources, a stream of positive ions accelerated in a cyclotron, a beam of centimeter waves generated by a magnetron, and a magnetic field. Any or all of these may be chopped or modulated according to various patterns.


A thermoelastic theory of acoustic wave generation in spherical models of the mammalian head exposed to rectangular pulses of microwave energy is presented. It was shown that the distribution of absorbed energy inside the head is approximately spherically symmetric for many combinations of size and microwave frequency. By taking advantage of the symmetry of the absorption pattern and assuming that heat conduction does not occur within the short periods of time under consideration, it was possible to solve the thermoelastic equation of motion for the acoustic waves in the spherical head without shear stress under both stress-free and constrained-surface boundary conditions using boundary-value technique and Duhamel's principle. It was found that the fundamental frequency of sound generated inside the spherical head is independent of the frequency of the impinging microwave and the pattern of absorbed microwave energy distribution and is strongly a function of the size of the spherical head and the acoustic property of the tissue involved (velocity of sound). In addition to giving pressure and displacement amplitudes, the theory shows that there is an optimum pulse width for the efficient conversion of microwave to acoustic energy. For instance, computations indicate that the peak pressure generated in a cat-sized (3-cm radius) sphere exposed to 2,450-MHz energy is maximum around 2 usec and that it falls off rapidly for shorter pulse widths. Its decrease for longer pulse widths is characterized by some oscillatory behavior. A comparison of the thermoelastic theory of microwave auditory effect with experimental measurements revealed good correlation in terms of width of impinging microwave pulses, independence from microwave frequency and specific absorption rate distribution, frequency of sound, and threshold of sensation. The advantage of a small direct contact applicator in experiments involving electrophysiologic recordings simultaneous with microwave exposure was also demonstrated. This exposure technique eliminates the need for specially designed sensing devices and processing instrumentation necessitated by conventional microwave exposure techniques. Not only does the small direct contact applicator permit placement at different areas on the head to establish desired differences in absorbed energy distribution, but it also substantially reduces interference due to direct pickup of microwave artifacts by the recording electrode.


A review of the present state of knowledge of the biologic effects of nonionizing electromagnetic radiation is presented along with recommendations for current research needs in this area. The review includes radio frequency radiation (RF) from 1 Hz to 300 GHz and electric and magnetic fields associated with both direct current and alternating current high voltage transmission lines (HVTLS). Research in the past 5 yr has indicated that some biologic systems exhibit responses to RFR at exposure intensities that were previously considered to be too low to produce detectable alterations (1-10 mW/cm²). The extent to which RFR-induced perturbations actually compromise living systems has not been determined, nor are the RFR conditions necessary to produce an observed alteration well defined. Although present evidence for the effects of RFR on the nervous system and on the reticuloendothelial system, including immunologic processes, is scanty, biologic alterations appear to be involved in many of the reported effects. Much less research has been done on the effects of HVTLS fields, and biologic systems have not been adequately tested to determine if deleterious interactions do occur. It is difficult at present to develop meaningful guidelines for exposures due to insufficient data covering exposure conditions such as frequency, waveform, and exposure duration. In conjunction with biologic effects research, it is essential to in-
corporate long-term, low-level studies, mechanisms of interaction studies, and to develop appropriate instrumentation and dosimetric techniques. Areas of biologic effects research that are considered highest priority based on current knowledge and recent research include the nervous system, reticuloendothelial system, membrane structure and function, and teratologic and developmental effects.


Electrical parameter values of some human tissues in the radio frequency range of 10 to 10,000 MHz are reported. Curves of conductivity and dielectric constant as a function of frequency are given for muscle, skin, dura, brain, blood, cerebrospinal fluid (CSF), and fat-bone-yellow bone marrow. Because of the scarcity of measured values (particularly at the high and low ends of the frequency range, where conductivity and dielectric constant vary rapidly), the curves for tissues of medium or high water content are drawn in proportion to the curves for muscle, for which relatively extensive data exist. Values extracted from these curves give reasonable estimates of the inter-relationships among various tissues over the frequency range of interest. Values of conductivity (at a frequency of 800 MHz and a temperature of 37°C) extracted from appropriate curves for brain, CSF, dura, bone, fat, skin, muscle, blood, and yellow bone marrow are 0.96, 1.74, 1.23, 0.096, 0.096, 1.23, 1.45, 1.60, and 0.096 ohm/m, respectively. The corresponding dielectric constants for these tissues are 33.76, 79.47, 45.64, 5.61, 5.61, 45.64, 51.27, 61.52, and 5.61, respectively.


Studies are cited covering the search period 1964 to January 1979 of U.S. government-funded research on the Navy's global communication system that employs extremely low frequency (ELF) radio waves. This system was previously called Sanguine, has been given the name Seafarer. The bibliography is divided into four parts. The first covers the biologic effects of ELF radiation on humans, animals, plants, and ecosystems. The second part presents research on equipment, performance, feasibility, design, and transmission. The last two sections cite surveys for the Sanguine antenna in Texas and Michigan. This updated bibliography contains 177 abstracts, 11 of which are new entries to the previous edition.


In order to confirm or reject previous findings suggesting an association between Down's syndrome and paternal radiation or possibly between this disease and paternal exposure to radar, a replication of the original study was performed on parents of a current series of 300 Caucasian Down's syndrome cases and controls (born in 1962-1968 and 1945, respectively). In addition, validation of military service and radar exposure through a search of government records on all original and current series fathers (involving 791 cases, controls, and new matches) was performed along with a chromosome study of 162 radar-exposed and unexposed fathers (159 with successful cultures) from both series. In contrast to the original findings, data for the current series showed no difference in medical radiation exposure between case and control mothers or fathers. Even when the original and current series were combined, no significant differences were observed between case and control mothers with respect to radar exposure or military service. While more chromosome aberrations were seen in radar-exposed than in unexposed fathers for the two series combined, excesses in the particular types of deviants observed (gaps and single chroma-tid breaks) can be attributed to technical error; thus, the cytogenetic findings may not be a reliable indicator of chromosome fragility associated with microwave exposure. More definitive, preferably longitudinal studies are required for confirmation or rejection of such a possible hazard.


Hematologic and immunologic effects of continuous wave (CW) and pulsed wave (PW) microwave radiation were studied in female Swiss Webster mice under well controlled and defined exposure conditions. For each study, 16 mice were randomly assigned to two groups: 8 for microwave exposures and 8 for sham exposures. In some experiments, mice were exposed in the far field of an anechoic chamber to 2,880-MHz PW microwaves (2.3-µsec pulses, 100/ sec) for 3-7.5 hr/day, with the total exposure time
ranging from 60 to 360 hr. Five studies were performed at average power densities of 5 mW/cm² and four at 10 mW/cm². The mean specific absorption rates were 2.25 mW/g at 5 mW/cm² and 4.50 mW/g at 10 mW/cm². An additional group of mice was exposed to 2,450-MHz CW microwaves at a power density of 5 mW/cm². In two of five studies with 5-mW/cm² CW microwaves, there was a significant (p<0.01) and (p<0.05) increase in bone marrow cellularity compared with sham-exposed groups. Significant differences were occasionally seen in erythrocyte, leukocyte, and platelet measurements from microwave-exposed groups, but these effects were not consistently observed. The only effect in mice exposed to 5-mW/cm² CW microwaves was a reduction in reticulocyte concentration (p<0.02). During one of four exposures to 10-mW/cm² CW microwaves, mean bone marrow cellularity was reduced (p<0.02). In the microwave-exposed mice; in another group the concentration of circulating lymphocytes was increased (p<0.05). During only one exposure (10 mW/cm² for 360 hr) any effect on serum proteins noted (reduction from 5.6 ± 0.36 g/diliter [d] in sham-exposed mice to 5.1 ± 0.29 g/dl in exposed mice). This was due to a decrease in alpha and beta-globulins, with no effect on albumin or gamma-globulin concentrations. No effect on bone marrow hematopoetic colony-forming units (CFU) was noted after exposure to 5-mW/cm² CW microwaves. However, after one of four exposures to 10-mW/cm² CW microwaves, there was a significant (p<0.05) increase in CFU-agar colonies. No significant effects of 10-mW/cm² microwave exposures were detected on assays of in vivo and in vitro cell-mediated immune functions. No exposure-related histopathologic lesions were found on examination of several tissues and organs.


A tensor integral equation method was developed to quantify the internal electromagnetic fields (EMF) induced in finite, heterogeneous biological bodies by nonuniform impressed EMF. An experimental study was also conducted to develop and study implantable EMF probes that can be used to measure the internal EMF induced in simulated biologic bodies. Additional studies were performed to investigate induced EMF inside the human body, EMF local heating for hyperthermic cancer therapy, and the interaction of near zone fields of an antenna with the human body. Using the tensor integral equation method to quantify the internal electric field and the specific absorption rate (SAR) of EMF induced inside human bodies exposed to EMF of up to 500 MHz, it was found that the induced SARs inside the body depended strongly on the body geometry and the frequency and polarization of the incident EMF. In many cases, hot spots were induced in narrow regions of the body such as the neck, legs, and arms. To verify the theoretical results, an experimental study was conducted to directly measure the induced electric field inside a phantom model of man with a noninterfering implantable electric field probe. The section of lead wires adjacent to the probe was constructed with two series of lumped resistors (3,000 ohms each) to minimize the current induced on the lead wires by a strong electric field that is perpendicular to an irradiated conducting body surface. The probe itself was made from a zero-bias microwave diode. Qualitative agreement was obtained between the theory and the experiment. The main cause of discrepancy between theory and experiment appeared to be due to numerical inaccuracy, which could only be improved by subdividing the body into many more subcells. A study investigating effective methods of inducing EMF hyperthermia in internal tumors in animals and humans is also described, with references provided for the published results.


The theories and experiments presented at the URSI symposium on millimeter wave biophysics that dealt with the construction of simple biologic systems for displaying the effects of weak nonionizing radiation are reviewed. Theories that were presented included: 1) supramolecular sensitive domains in biologic systems that can be raised by metabolic energy to a single coherent metastable vibrational state; 2) the resonance frequency of this domain may be in the range of 100-1,000 GHz; 3) the supply of microwave energy at the resonance frequency above a critical rate will generate the coherent state within the sensitive domain and thus modify the behavior of the system; 4) the microwave action spectrum is highly frequency-specific, having the character of one or more resonance curves, possibly damped by mode-softening occasioned by long-range dipole-dipole interactions; 5) the dose-response relation will tend to a step function at a critical level of absorbed energy; 6) the response to microwave stimulation is a highly specific property, indicating that sensitive test systems will be required; and 7) long-range coherent interactions involving more than one enzyme system may give rise to slow chemical and electric oscillations. Three presentations that offered new information on dielectric and microwave spectroscopic properties of cell constituents included: 1) experiments with microwave dispersion in the dog brain over 0.1-7.0 GHz, with the results analyzed in terms of free and bound water in a suspension of nonconducting spheres; 2) an extremely sensitive method for microwave spectroscopy of transparent materials in which a split laser beam is used to detect changes in the refractive index that are produced by microwave absorption; and 3) the scanning and computer processing of the data from various dense aqueous solutions and suspensions of biologic materials.
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at 0.5-GHz intervals over the range of 26.5-90.0 GHz. Experiments were also discussed that dealt with the use of lysogeny as a state possibly inducible by microwaves, the incorporation of a biologic temperature probe during irradiation of cells, and the simultaneous physicochemical and electrophysiologic study of the smallest available functioning domains of small or embryonic brains. Another presentation described an experiment in which ascites tumor cells were injected subcutaneously into mice after exposure for 20 min in vitro at controlled temperature to a 30-MHz field at 0, 5, or 10 V/cm. The effects, which were clearly distinguishable from the effects of heating, included a decreased percent of samples developing into tumors, an increased latent period, a progressive fall in the rate of volume increase, and an eventual regression. These changes were produced at the cellular level by low intensity irradiation; thus, this mouse assay provided an excellent method for biologic amplification. Although several worthwhile papers, theories, and experiments were presented at the URSI symposium on millimeter wave biophysics, little attempt was made to join theory with practice. An intensification of effort to detect microwave resonances and long-range interactions underlying some of the biologic phenomena is suggested.

Biological Effects of Nonionizing Electromagnetic Radiation [IV]. March 1980

Four studies to determine the health effects of microwave irradiation of employees at the American Embassy in Moscow between 1953 and 1977 are summarized. In 1965, the Medical Services Office of the State Department conducted an internal survey of the medical records of 130 employees and 268 dependents assigned to the Moscow Embassy. This internal survey plus a subsequent contract study, the "Moscow Viral Study," did not establish any genetic or other adverse biologic effects on employees and dependents that were attributable to microwave irradiation of the Embassy. However, the study was also unable to conclusively establish that no such an effect was present. Another study, the "Project Pandora," was initiated in 1965 to investigate possible behavioral and biologic effects on primate irradiated with microwave signals simulating the exposure of Embassy employees in Moscow. To a reasonable extent, the intensity of the microwave signal was set to the maximum useful capacity of the laboratory equipment then available, which yielded an exposure intensity of 4-5 mW/cm² compared with the average intensity of the Moscow signal that was 2-18 mW/cm². However, the Pandora primate study did not provide an acceptable answer to the above question because of experimental limitations and design flaws. In 1976 a study was undertaken to determine if higher than average lymphocyte counts in Moscow Embassy personnel could be attributed to microwave irradiation of the Embassy personnel. Blood counts from Embassy subjects showed mean lymphocyte counts approximately 41% higher than those of a control group of foreign service personnel. However, the changes in the average lymphocyte count in the Moscow population did not correlate either in time or space with the exposure of individuals within the population to microwave irradiation of the embassy. A Johns Hopkins Foreign Service Health Status Study was conducted between 1976 and 1978 to analyze mortality and morbidity of Embassy employees and dependents assigned there between 1953 and 1976. This study found no evidence that the Moscow group experienced a higher total mortality or a higher mortality for any specific causes of death than a comparison group of nonirradiated subjects. However, morbidity data indicated two differences between the Moscow group and the comparison group. The Moscow male employees had a threefold higher risk of acquiring protozoal infections between the time of arrival at the Embassy and the time of last observation than did the comparison employees. Also, both men and women in the Moscow group had slightly higher frequencies of some of the common kinds of health conditions reported. However, these conditions represented a very heterogeneous collection, and it is difficult to conclude that they could have been related to exposure to microwave radiation since no consistent pattern of increased frequency in the group exposed to other than background microwave radiation could be found. Overall, no convincing evidence has been discovered that would directly implicate microwave exposure of Moscow Embassy employees in the causation of any adverse health effects.


The theory and applications of a computer program (SCAT) for calculating the scattering and absorption of radio frequency and microwave radiation by spherical lossy dielectric bodies exposed to linearly polarized plane wave fields are described. The irradiated body may be a homogeneous sphere or multilayered, spherical, or arbitrary regions of arbitrary radii. Each region can be made to simulate biologic tissue by assigning the appropriate dielectric properties. Induced fields and observed power density within these regions may then be calculated for an external radiation frequencies. Several applications of the SCAT program are discussed, and associated computer plots of fields and absorbed power are presented. These include the distribution of absorbed power density in the major plane of a 6.0-cm-diameter homogeneous sphere exposed to a 3.0 GHz plane wave; the power absorption as a function of frequency in a 2.1-cm...
diameter multilayered model of the hamster head; and the field intensity in a 3.3-cm and 8.0-cm radius homogeneous sphere at 2,450 MHz and 915 MHz, respectively, for probe measurement evaluation. From these plots it is seen that inhomogeneous systems exhibit discontinuities in the induced field and in the power deposition at the boundaries separating biologic tissue of different dielectric properties. Furthermore, spherical systems exhibit resonant properties depending on body dimensions relative to wavelength; these spherical body resonances give rise to internal hot spots. Although limited to applications where isolated spherical geometry is appropriate, the results may nevertheless be used to obtain quantitative estimates of the effects of relative body size, frequency, and dielectric properties on the total power absorption and on the internal distribution of absorbed power.

6470 ELECTROMAGNETIC FIELDS AND RELATIVE SAR PATTERNS IN BILAYERED BIOLOGICAL TISSUE EXPOSED TO A CIRCULAR APERTURE APPLICATOR (ABSTRACT). (Eng.) Tsang, H. K. (Ph.D. dissertation, Univ. Washington, 1979); 184 pp. [available through Diss Abstr Int B, Order No. 7917654]. (0 refs)

The specific power absorption rate (SAR) was calculated for human tissues exposed to a direct- or indirect-contact microwave diathermy applicator having a circular aperture source with a TE11 mode field distribution. The dielectric simulated fat-muscle tissue was bilayered. A Fourier-Bessel integral representation technique and a Gauss-Legendre Quadrature integration technique were used in the theoretical study and numerical computations, respectively. Limited experimental results were in agreement with theoretical predictions within a reasonable limit. The effects of varying aperture size and frequency on the induced normalized SAR for biologic systems are limited to safety levels of electromagnetic radiation with respect to pertinent levels of thermal stress. The assessment of risk of exposure to low-intensity microwave and other RF fields is complicated by the limited amount of data on effects of long-term or chronic exposure of animals or man, the complex nature of microwave and other RF energy absorption in the body, the detection of biphasic intensity and pulse repetition rate responses, and the lack of interaction mechanisms to account for low-intensity exposure effects.


Assuming that the earth’s natural electromagnetic fields provide signals that not only enable avian navigation but also synchronize the mammal’s biological clocks, the coupling of artificially generated fields from power lines and from radio and television broadcasts could act as a source of biologic electromagnetic interference (EMI). It is pointed out that thoroughly defined and well documented instances of athermal, life-threatening EMI problems in man are essentially nonexistent, as are instances of life-threatening EMI problems in the area of medical electronic systems. Existing EMI standards for medical electronic systems are limited to the pacemaker standard developed by the Association for the Advancement of Medical Instrumentation (AAMI). Existing EMI standards for biologic systems are limited to safety levels of electromagnetic radiation with respect to personnel established by the American National Standards Institute (ANSI). Like the AAMI pacemaker standard, this standard was developed via a consensus procedure. Compliance is voluntary, and a 5-yr schedule for review, update, and/or withdrawal is used by ANSI. The acquisition and use of EMI environmental data was discussed. A complete description of the EMI environment would not be useful for establishing standards without full knowledge of radiation effects on the environment and systems. The Federal Communications Commission (FCC) rule-making policy, as it relates to consumer reaction and involvement, and the public’s understanding and view of the term radiation was also discussed. Consumer reactions should represent a true cross-section of the consumers and not just a vocal minority. Accurate information should be disseminated to the public by organizations, the press, manufacturers, and FCC meetings.

6473 A REVIEW OF DIFFERENT STIMULATION METHODS. (Eng.) Herbst, E. In: Electric Stimu-
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Various electrical stimulation methods used for experimental (animal) and clinical (human) bone growth and repair are briefly described. The following three techniques have been investigated in relation to electrically stimulated osteogenesis: direct current (DC) stimulation; stimulation with pulsed currents, pulsed voltages, and alternating currents; and electromagnetic field stimulation. In clinical studies, one investigator used stimulation with DC (10-20 μA) in 24 nonunions and 5 congenital pseudoarthroses (4 in the tibia and 1 of the clavicle). The cathode (stainless steel wire) was inserted into a small hole within the defect, and the anode consisted of a stainless steel skin electrode. In some cases, multiple cathodes were used. Complete union occurred in 15 nonunions and in 1 congenital pseudoarthrosis of the tibia. For patients with nonunion of the tibia and femur, further immobilization after completion of 12 wk of electric stimulation was required to obtain complete healing. Another investigator used a combination of pulsed voltage stimulation and treatment with a Hoffman apparatus (maintains good external fixation) to treat 24 cases of crural fractures. The stimulator was attached to the frame of the Hoffman apparatus, and the insulated bone screws served as electrodes. The average time required to gain a certain stability was 30% lower in stimulated patients than in control patients. Skin irritation around the anode was observed during stimulation. Other investigators have reported over 100 cases of pseudarthrosis and spontaneous fractures treated with electromagnetically induced alternating current. The method used was invasive and based on internal fixation. Kuntscher nails or screws insulated from the osteosynthesis plate served as electrodes in this system. The pulsed magnetic field induced was about 30 Oe, and this field induced an alternating voltage at the electrodes of 0.3-0.5 V and a current of 1-2 μA/mm². No statistical evaluation of the results was reported.


The effect of a magnetic field (MF) on the growth and regeneration of embryonic rat femurs was investigated. Embryos from SPF-albino rats in day 17 or 18 of gestation were cultured in vitro using a purely synthetic growth medium. All tests were performed with a field strength of 30 G and a frequency of 20 Hz applied during five equally spaced 60-min periods/day. In a first experiment, the femurs were oriented with their long axis parallel to the MF axis. The temperature of the culture medium was monitored daily with thermistors. In a second experiment, the cultures were protected against the heating effect of the MF coils, and the femurs were oriented with their long axis partly parallel and partly perpendicular to the MF axis. In a third experiment, the distal epiphyses were cut half way across perpendicular to the long axis of the femur, and the test femurs were oriented so that the MF axis lay along the epiphyses; regeneration characteristics were then tested. In the first experiment, the difference in wet weight between test and control femurs was approximately 20% and was significant. However, the temperature measured in the MF test cultures was 40.1 ± 0.2°C compared with a temperature of 37.6 ± 0.1°C in control cultures. In the second experiment, no differences between wet or dry weights were observed between test and control femurs when the test and control media were held at comparable temperatures. In the third experiment, no differences in regeneration were observed between test and control femurs when the test and control media temperatures were comparable. There were no significant histologic differences between the test and control femurs in any of the three experiments. Overall, it is concluded that the organ cultures showed neither a positive nor a negative MF influence on the growth and regeneration of embryonic rat femurs. The significant differences in the first experiment were in all likelihood attributable to temperature differences. These results provide no basis for the clinical application of just the MF component of the Kraus-Hecher method.


Biophysical considerations of thermal dosimetry when heterogeneous tissues are heated locally or regionally are discussed. To monitor temperatures within heated masses during localized hyperthermia trials, small thermometers must be used and biologic data suggest that thermal dose be recorded physi- cally in terms of time at specified absolute temperatures to within 0.1°C. This limit of accuracy is possible if individual thermometers are calibrated and if sources of error are recognized. It is shown that needle-mounted thermometer probes must be inserted at least 4 mm into an object to avoid errors greater than 0.1°C. Nine thermometer probes that are under development for use in strong electromagnetic fields are listed. Two of these use thermistor sensors, one with microminiature integrated circuitry and the other with carbon-loaded PTFE leads. Resistance is the physical parameter sensed. Another five devices sense light intensity. The sensor is a liquid crystal in two of these, a liquid meniscus variation in one, an optically birefringent crystal (LiTaO₃) in another, and a semiconductor optical absorption (GaAs) in the fifth. All use optical fibers as leads. Another probe with an optical etalon sensor and optical fibers for leads detects light wavelength changes. The ninth probe uses a fluid viscosity (orifice) sensor with dielectric tubing for leads to detect
fluid pressure difference. Noninvasive methods of determining temperature distributions in deep-seated heated regions are also being studied; these studies involve the use of the temperature dependence of the speed of sound in tissue as well as the use of a sensitive microwave radiometer to monitor the thermal radiation emitted at frequencies of about 1 GHz. Determination of the thermal dose implies knowledge of the temperature versus time profile throughout the volume of tissue being heated. Two or three probes implanted within the tissue may not provide sufficient information on thermal distributions. Thus, trials in phantom materials may be helpful in a semiquantitative manner for selecting heating configurations and for establishing how tissue characteristics (e.g., heterogenous electrical resistivities or circulation patterns) affect the thermal pattern. Small volumes (<10 cm³; e.g., mouse tumors) can be heated adequately by various methods and only a few watts of power are required to raise and maintain the tumor at hyperthermia temperatures. Thermal dosimetry and, in particular, thermometry are more troublesome for moderate volumes (10-100 cm³; e.g., human and large animal surface tumors) than for smaller ones. The required power level is on the order of 10-50 W, depending on the size of the mass and the mechanism of heat dissipation. Needle-mounted thermistors are routinely used to monitor temperatures in masses heated by 500-kHz current fields with little significant error. Large volumes and regional heating (greater than 100 cm³), which are applicable to many cases of clinical hyperthermia, are the most difficult problem in thermal dosimetry. Larger masses require more power (from 100 W to a few kW), enhancing the intensity of thermal gradients, especially if heat is conducted rapidly away from the region by massive blood flow. Tissue heterogeneities can cause thermal heterogeneities because of non-uniform power deposition or non-uniform cooling paths.


Studies concerning the interaction of local microwave hyperthermia (LH) on tumors and cell-mediated immunity (CMI) are reviewed. An initial series of experiments on the effect of microwave hyperthermia, applied alone or in combination with nonspecific immunostimulators, on transplantable tumors revealed that whole-body microwave hyperthermia inhibited virus multiplication and influenced the course of experimental acute infections with herpesvirus (HSV-1) and vaccinia virus. Daily whole-body microwave hyperthermia, applied immediately after inoculation and continued for 4, 8, or 12 days after infection, protected the animals from encephalitis development; the mortality rate was significantly lower in the hyperthermia-treated animals than in the untreated controls (20-35% versus 95%, respectively). Whole-body microwave hyperthermia (2,450 MHz) inhibited the growth of sarcoma 180 in mice and lowered the mortality by about 60%. Because hyperthermia combined with Streptolysin O resulted in a significantly higher inhibition of tumor growth, it was concluded that immunotherapy may enhance the tumor-inhibiting effect of microwave hyperthermia. This was confirmed in a series of experiments on the combined effects of microwave hyperthermia with Poly I-Poly C and/or mouse interferon on the growth of sarcoma 180. All three factors resulted in lowered mortality (by about 50%), tumor regression (16/24 tumors), and reduction of the tumor mass (from 1,361 to 575 mg). Since neither combination of LH with Streptolysin O or Poly I-Poly C and/or interferon led to total cure of sarcoma 180, rats bearing Guerin epithelioma, a poorly metastasizing tumor with high infiltration by macrophages, were treated with 2,450-Hz LH (43°C) in combination with known nonspecific immunostimulators purified Streptolysin O and Corynebacterium parvum. The results summarized to date indicate that LH applied three times for 1 hr on the 3rd and/or 5th wk after tumor implantation resulted in an increase in tumor temperature from about 30°C to 43°C over 6-7 min. The temperature of muscles below the tumor did not exceed 41°C, while rectal temperature and the temperature inside the abdominal cavity did not exceed 38°C. The best results were obtained when tumors were heated on both the 3rd and 5th wk, although no total tumor cures were observed. Immune system monitoring was performed 5 wk after tumor implantation. Inhibition of tumor growth by LH and immunopotentiators was accompanied by stimulation of CMI. Increased cytotoxicity of spleen cells and peritoneal macrophages from LH-treated rats to cultured Guerin tumor cells and high reactivity of lymphocytes to mitomycin-inhibited tumor cells indicated specific stimulation of the T lymphocyte systems by heat-suppressed tumor cells in vivo. It is suggested that the population of suppressed tumor cells that survives LH because of nonuniform heating of tumors may be a very important factor in the stimulation of immunologic systems and in the inhibition of both the primary tumor and its metastases. In view of the immunostimulation by intensive LH, great care should be taken in combining heat treatment with either X-rays or cytostatic immunodepressants. It is concluded that further study of the stimulation of the immunologic systems by LH and of hyperthermia as a simultaneous selective killer of cells and an immunopotentiator is needed.


The use of hyperthermia (HT), alone or in combination with radiation, for cancer therapy is reviewed. In addition to whole-body HT, water-bath...
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HT, and hyperthermic perfusions of the extremities or bladder, regional HT using radio frequency (RF) currents is possible. RF current HT may provide a good heat distribution for some tumors since the surface electrodes can be shaped to obtain the desired distribution. Limitations of this method include fall-off of heat with increasing depth and excessive surface heating. Localized current fields employing 500 kHz and either noninvasive external electrodes or implanted needle electrodes have been used in five patients with recurrent tumors. HT was applied without radiation therapy (RT), and tumor regression was reported using temperatures of 44°C. In another study, six patients were treated with RT at the end of a 45- to 60-min heating period. Heat was applied initially using hot air; later, microwaves were used. Skin temperatures of 42-48°C were measured during microwave heating. Good tumor regression with an increase in normal skin response was reported. In a pilot study, multiple cutaneous metastatic human tumors were treated with either high dose fractions of RT alone or with lower dose fractions of RT in combination with HT (41.5-42°C). Heat was applied using either 2,450- or 915-MHz microwaves. Either dielectric or air surface cooling was developed for use with 915 MHz to obtain an improved heat distribution at depth. The results suggested that a thermal enhancement ratio for the tumor of 1.2-1.3 could be obtained. Skin scoring data for the normal tissue thermal enhancement ratio was inadequate to obtain a therapeutic ratio; however, it was apparent that the normal skin response was increased by the addition of post-RT HT. A cooperative group protocol has been developed to establish a therapeutic ratio for post-RT heating of tumor and skin to 41.5-42°C using a heat period of 2 hr and three RT fractions (with 72 hr between each fraction to avoid the possibility of thermal tolerance). Opposing field pulsed microwave units are being developed that will be suitable for heating buccal lesions; one applicator is used inside the mouth and another large applicator is used externally. Frequencies from 433 to 915 MHz will be selected to achieve optimum thermal dosimetry. Radio frequency and microwave applicators may have specific tumor sites for optimum application, however, a considerable effort must be made to obtain accurate thermometry during heating periods and to obtain thermal dosimetry. The future of hyperthermia and/or radiation techniques for cancer therapy will depend on several factors: the development of hyperthermia techniques, the investigation of both normal and tumor tissue responses to hyperthermia, and the application of currently used techniques and available physiologic data in the design of new clinical protocols.

A new radio frequency procedure, the cancer multi-step therapy (CMT) selectotherm technique, is described that permits the supply of large heat quantities per volume unit into deep-seated, localized tumor tissues without causing thermal lesions in healthy tissues near or at the body surface. With the CMT technique, the supply of energy within the energized volume remains almost constant in the planes parallel to the body surface (x-y plane), and in the dual-system array (body section between two applicators), the energy supply on the z-axis normal to the body surface is reduced very slowly. The spatial homogeneity of the energy supply resulting from the CMT selectotherm technique is corroborated by measurements in a gelatin phantom. Similar phantom measurements demonstrated that the CMT technique creates a new physical situation with respect to the drop in energy supply versus growing penetration (AZ) into the body tissues. In one particular configuration, the drops in energy supply obtained in the center of the body for body layer thicknesses of 12, 16, 20, and 24 cm were 50, 33, 24, and 19%, respectively. With a single-system array and a thickness of 24 cm, the power supply would drop to 5%, and for a standard decawave apparatus with a coil section, the power supply would drop to 0.5%. In the case of the CMT selectotherm technique, the decrease in power supply obtained with growing depth into body tissues can be attributed to a reduced energy density in the superficial layers (by raster motion of the applicators) and to doubling the strength of the rotational magnetic field in the center of the body. Improved preconditions for achieving local hyperthermia in tumor tissues are created by building up local hyperthermia on the increased temperature level of a metabolism-induced whole-body hyperthermia (e.g., CMT spontaneous hyperthermy at 39.5°C) and by selectively increasing the thermal sensitivity of tumor tissue by creating a pH drop in tumor tissue and by decreasing the microcirculation (main step of the CMT concept). The main application of blood-stream and pH selective local hyperthermy is in treating late-stage primary tumors where the wide difference of blood streams and the pronounced pH difference between healthy tissue and tumor tissue contribute to the therapeutic selectivity. The application of pH-selective local hyperthermy alone is in treating early stage tumors and metastases. Compared with the host tissue, there is hardly any temperature increase in tumor tissue; however, the temperature of the host tissue itself becomes much increased. This is important in the case of metastases where it is often necessary to superheat a large portion of the body.


Methods of inducing hyperthermia for the treatment...
of cancer and other medical problems are briefly reviewed. Ultrasound (US) and electromagnetic radiation (EMR) have been introduced to overcome the problem of limited heat transfer through tissue, a difficulty associated with hot water, hyperthermia. US is capable of penetrating soft tissues to depths required for cancer treatment, and it has the advantage of producing sharply focused beams capable of delivering greater heating at depth than near the surface. This advantage is counterbalanced, however, by the much larger absorption of US in bone than in soft tissue. In addition, transmission of US through air spaces, such as the lung, is very small. The technology exists to direct focused US beams to a select target volume in uniform soft tissue and to produce reasonably uniform heating. However, there are major problems with heating uniformity near bones and air spaces of any magnitude. EMR at frequencies ranging from a few kHz to several MHz has been used to treat medical conditions that respond to mild heating. One of the classic techniques uses radio frequencies (20-30 MHz) and capacitive plates placed on either side of the part to be heated. At these lower frequencies it is possible to heat deeply enough, but there is excessive heating of fat and some difficulty in controlling field shape. Radiative fields in the microwave range have been introduced to overcome some of these problems. With microwaves, limited penetration in wet tissue rather than selective heating of fat poses a problem. The depth of penetration depends on frequency and is much greater in fat than in wet tissues (26, 18, and 11 cm of fat and 9, 3, and 2 cm of wet tissue for microwave frequencies of 433, 915, and 2,450 MHz, respectively). Microwaves can be reflected from the boundary between fat and muscle layers; this effect results in standing waves and complex heating patterns. In addition, when microwaves impinge on a curved surface equivalent in size to their wavelength, the amount and spatial distribution of energy deposited is size- and shape-dependent. Focusing of microwave energy in curved bodies can take place with an effective depth of penetration much deeper than predicted for simple plane objects.

DEVICES FOR MICROWAVE HYPERTHERMIA


Two types of microwave radiators that can be directly inserted into the target tissue for hyperthermic treatment are described. One, a microwave syringe for the direct injection of radio frequency and other microwave fields into deep tissues in vivo, consists of a subminiature rigid coaxial waveguide connecting to the generator at one end and terminating in a needle-like configuration that radiates the field at the other end. A coaxial guide is needed that has low frequency cutoff. The radiator is obtained by open-
Two types of direct-contact microwave applicators designed to operate at frequencies of 915 and 2,450 MHz are described. Each applicator is essentially a square cross-section waveguide closed at one end and open at the application end. The waveguide is excited in the TE01 mode, using a coaxial line to probe antenna. To couple all of the incident power into the guide, the radiation resistance of the probe antenna is made equal to the characteristic impedance of the coaxial line, and the contribution of the TE01 mode reactance to the total input reactance is adjusted to cancel the part of the input reactance contributed by all of the higher-order evanescent modes. One applicator, which is designed to operate at 2,450 MHz, can be used to deliver either microwaves alone or in conjunction with ionizing radiation. A prototype was designed, which was attached to a Picker 28-kv machine. The other applicator operates at 915 MHz, and its waveguide is loaded with low-loss dielectric material (dielectric constant = 6.0) to reduce the size of the waveguide (cross-section = 8-cm² side). The solid dielectric protrudes a few millimeters out of the conducting walls to avoid touching the skin. The applicator is further modified by attaching a plastic bag at the application end through which a dielectric liquid (2:1 mixture of ethylene glycol and kerosene) is circulated to cool the skin. Dosimetric measurements of the temperature distribution for each applicator were made in vivo on pigs using copper-constantan 30-gauge probes of either the bipolar or unipolar type, with the latter type, the electric current flows along the central axis of the conductor. For the bipolar type, the microwave (or ultra-high frequency) current flows in the tissue between the inner and outer conductors of the coaxial cable. The current density can be shaped with a tapered dielectric coating to achieve good uniformity of dissipated power along the probe. Depending on the frequency, the active length of the probe can be varied in muscle tissue from about 5 mm at 2 GHz to 35 mm at 100 MHz. An advantage of the bipolar probe over the unipolar probe is that it can be used alone. With the latter type, the electric current flows between the inner conductors of different probes placed at some distance from each other; the outer conductors act only as shields. By using several probes of either the bipolar or unipolar type, it is possible to shape the region to be heated and to achieve a good uniformity of the temperature increase within it. Since both the bipolar and unipolar probes are "cold" at temperature equilibrium with the surrounding medium, the temperature distribution obtained is much more uniform than the distribution that could be obtained with "hot" probes delivering the same power via heat conduction to the medium. In addition to the frequency of operation, the impedance and power output of the generator must also be considered. The impedance is a function of the probe diameter to the distance, length, and nature of the tissue to be heated. In muscle and similar tissue, probes 1 mm in diameter and 3 cm in length placed at a distance of about 1 cm from each other present an impedance of about 50 ohms for commercially available generators so that the matching of the probes (reduction of reflected power to zero) is straightforward. For a given configuration, the power necessary to reach the chosen increase in temperature is determined by the heat conductivity and blood flow through the volume to be heated. As a rough indication, 3 Ws is enough to achieve a 6°C increase inside a cylinder 2.5 cm in diameter and 4 cm in length in muscle tissue. In this case, the equilibrium temperature is practically reached within 8 min, a time duration that could be de-
creased somewhat by applying a higher power such as 5 W for a few minutes. In the case of high blood flow, the power should be increased, with a corresponding decrease in the time necessary to reach the temperature equilibrium. A power of 10 W per probe is more than enough for any situation. A significant advantage of the above interstitial heating method is that the same set of probes can be used either to heat the tissue or to measure the temperature near each individual probe or in some volume surrounding them. This can be achieved through radiometric measurements. Another advantage to heating with the coaxial probes is the production of good localization of the heated region, without any over-heating, even at the probe location. Once practical experimental equipment for temperature measurement has been designed, measurements can be made in human tumors, completing one more step to producing a simple and reliable technique for clinical use.


A technique that may permit the treatment of certain deep-seated tumors by the introduction of coaxial microwave applicators into body cavities such as the bladder, colon, cervix, esophagus, etc. is described. In an initial experiment, the shape of a body cavity such as the esophagus was simulated by a cylindrical styrofoam container. Equal volumes (1.5 cm³) of animal muscle were arranged symmetrically at four equidistant points around the radiating antenna of a coaxial applicator placed in the center of the container. Temperature rise as a function of power and time was mapped using a 2,450-MHz microwave source, as was the spatial heat distribution. The results indicated that it is possible to reach the 42.5°C threshold temperature of interest in tumor cell destruction and that a fairly uniform temperature distribution (maximum variation of 1.5°C) could be maintained at a given radius. Directivity of heating was obtained by geometric modifications of the applicators, and in a second experiment, a coaxial applicator equipped with a semicylindrical (180 degrees) aluminum reflector was used in a simulated body cavity and the procedure of the previous experiment was repeated. Tissue cubes placed opposite the directive reflector of the applicator could be heated to a temperature of 43°C in 3 min using 25 W of power and could be maintained at this level for 20 min with only 4 W of power. The temperature at other points to the rear of the reflector showed only a slight increase. In a third experiment, an inflated rubber sphere with a coaxial cable placed at its center was inserted through a midline incision into the abdominal cavity of a live anesthetized rat whose intestines had been removed. The right half of the abdominal wall was folded backward, increasing its thickness for the purpose of studying heat penetration. Application of 2,450 MHz resulted within 3 min to a temperature increase to 42°C, which was easily maintained. In contrast, the animal’s oral temperature remained unchanged. In a final experiment, heat distribution when solid (muscle) tissue is heated directly was measured by implanting a 0.8-mm thick coaxial applicator into the thigh of a live rat. The temperature rose to 43°C at the applicator site within 5 min (2.5 W), while the other thermocouples registered 1°C less for each 0.5 cm of distance. Similar results were obtained with coaxial applicators implanted into mouse mammary adenocarcinoma at a frequency of 2,450 MHz. Based on these experiments, a prototype of a coaxial applicator suitable for clinical use is proposed. This model would consist of a coaxial cable inserted into the center of an indwelling Foley catheter that could be inflated to conform to the anatomic space under treatment. Thermocouples affixed to the inflatable part of the catheter equidistant from the cable would permit monitoring the temperature at several points of the cavity wall, providing simultaneous readings within the heated malignant tumor and in the surrounding tissues.


A microwave hyperthermia facility for the simultaneous far-field irradiation of several mouse tumors is described. The tumors were transplants of spontaneous mammary carcinomas on the flanks of C3H mice. Initially, local tumor heating in the free field with 2,450-MHz microwaves was accomplished by shielding the mouse within a tubular metal sleeve with the mouse tumor projecting into the heating field through a slot aperture in the cylinder. However, these small (1-cm) tumors were difficult to heat at 12-cm wavelengths and required relatively high power levels because of poor coupling. A strategy was then developed in which the tumors were encapsulated within a larger spherical mass ("microwave bolus") of phantom material. The microwave facility designed for this purpose incorporated a 3-kW, phase modulated, 2,450-MHz source (Gersing-Moore #4003) that was wavelength-fed to a ceiling-mounted standard gain horn antenna in a fully anechoic range (5 ft²). A parabolic surface intercepting the field axis 154 cm from the antenna was selected for the first experiments. Shielded mice were placed 25 cm (2 wavelengths) apart to minimize interactions between assemblies. Within a region 50 cm from the field central axis, up to 13 mice may be accommodated on the equi-power surface. Bolus spheres were formed within identical molds of dense styrofoam to replicate the standard bolus
geography. These molds also located the mouse shield and tumor relative to the bolus sphere, allowing optimum placement of the tumor in bolus. A 6-mm spacer of dense styrofoam extended the tumor away from the perturbed field adjacent to the metal shield. Graphs of vertical and horizontal temperature profiles indicated an overall temperature uniformity to within ± 0.1 C vertically and ± 0.05 C horizontally. Thus, heating uniformity to within 0.1 C may be achieved when tumors are encapsulated in a well-defined volume of tissue-equivalent material. The relatively large bolus volume tends to govern both temperature elevation and heating uniformity in the tumor, both of which are largely independent of tumor size between 0.5 and 1.5 cm. Phantom studies of heating at off-axis locations on an equi-power surface agree well with on-axis tumor heating. Those data suggest equivalent heating on the equi-power surface. The technique appears to be viable for simultaneous microwave hyperthermia of up to 12 tumors in this particular range configuration.


The designs of multiple-beam hyperthermia systems for obtaining enhanced deep heating without excessive heating of superficial tissue layers are described. For the first attempt at multibeam diathermy, a dual-beam, parallel-opposed set of TEM applicators was constructed for operation at 2,450 MHz. Microwave power was electronically time multiplexed between either of the two beams or off to a dummy-matched load. The treatment field at the apertures was bolus to plane parallel geometry. The resultant thermal field with equal power and "on time" from each applicator was approximately parabolic along the propagation axis and uniform to within ± 0.1 C perpendicular to that axis. The apparatus was used to treat murine C3H mammary tumors on the flank of mice, with the core tumor temperature being controlled to within ± 0.1 C. Treatment at temperatures between 42 and 44°C resulted in progressively increasing delay in tumor growth and redoubling time for increased treatment time and temperature. Comparison of thermal sensitivity versus treatment temperature for water bath-heated tumors and microwave treated tumors showed the same slope but a lower sensitivity for microwave heating. A multiple-beam microwave thermotherapy system was also designed and was being tested at the time of this report. The system consists of a data acquisition and control section, a microwave power source, a coaxial microwave power switching sub-system, and miniature diathermy applicators. The system will allow control of superimposed microwave radiation patterns and resultant thermal field patterns by regulating the total energy radiated by each diathermy applicator, the total time that each diathermy applicator is radiating energy, the position of the multiple applicators, and the sequence in which each applicator is turned on and off. The microwave power is designed to give up to 915 MHz, and it has external voltage-controlled power leveling and contains integral forward and reflected power monitors. Its output is passed through a triple-stub tuner to coaxial Transco Products solenoid switches where it is diverted to the miniature diathermy applicators. The current diathermy applicators are rectangular low-loss ceramic dielectric bars that are the size of an X-band waveguide (2.5 cm by 1.3 cm). A coaxial connector is mounted on each bar matching the applicator to a 50-ohm coaxial line. This multiple-beam system provides a method for obtaining enhanced deep heating without excessive heating of superficial tissue layers. Experiments with a dual-beam system resulted in enhanced heating effects that compared favorably with nonmicrowave heating. The computer-controlled multibeam system will be used to produce the controlled thermal fields necessary for hyperthermia cancer therapy.

In vivo temperature measurements were performed in 9- to 10-wk old female German domestic pigs (28 to 30 kg) to determine the heat distribution following the application of decimeter-wave local hyperthermia in the gluteal regions (Phillips DM 691: frequency, 433.52 MHz; wavelength, 69 cm; high frequency output, 200 W; power range, step 1-8). Optimal energy transmission was established by contact of the radiant field. Heating periods of 10, 15, and 20 min were used with power steps 4, 6, and 8. Temperature measurements were performed before and immediately after microwave application using a NiCr-Ni coated thermocouple (0.5-mm diameter, measuring accuracy ± 0.2°C, reference temperature 0°C). Measurements were done at the site of skin contact with the radiator (center) and at distances of 1, 2, 3, and 5 cm around the center. An examination of the temperature increase after 15-min of heating (power step 8) up to 5-cm depth within a cylindrical volume of 10-cm diameter in the muscle mass of the gluteal region showed that a relatively homogeneous temperature elevation from the center to the periphery (5 cm around central axis) could be achieved within the first few centimeters of tissue depth. At a depth greater than 3 cm, the temperature increase was only about 1°C. The range of temperature increases after 15 min of heating was significantly higher with power step 8 compared to power step 6 (maximal temperature increase in thurinosis is 3.6°C at 4.5 cm by 2.5 C; minimal temperature increases, 2.5 versus 1.1°C). With power step 4, there was a further
decline in temperature increases. Heating periods of 10 min (power steps 6 and 8) gave a maximum temperature increase at 1 cm depth of only 1.5 C. When the time was increased (power step 8), there was a more homogeneous heat distribution in deeper tissue layers in comparison with heating times of 15 min; however, the maximal temperature increases of 0.5 C (on the average) was obtained; at a depth of 4-5 cm, there was no longer a significant measurable difference. Because a time of about 4 min was needed to measure the entire volume in an experiment, the effective temperature increase were slightly higher than the ones recorded. These data show that with decimeter waves and heating periods of 15 min (power step 8), clinically useful temperature elevations can be obtained within the first few centimeters in depth and in a sufficiently large volume. Tumors with an impaired circulation and a low cooling capacity are likely to show higher temperature increases than normal tissue. Heating with decimeter waves can be performed immediately before or after radiation therapy without causing the patient any significant discomfort. The use of decimeter-wave therapy in combination with radiation therapy is currently being evaluated in cancer patients, e.g., with bulky recurrences on the chest wall or in the regional lymphatics, for superficial inoperable tumors, and for uncontrollable neck disease in patients with head and neck cancer.


The effect of microwave (MW)- or ultrasound (US)-induced hyperthermia combined with ionizing radiation on the rat testis was investigated. Sixty sexually mature male rats were divided into the following six groups: controls (no treatment), US alone (3,000,000 Hz, 1 W/cm² for 5 min), MW alone (12.2 cm wavelength, 30 W for 5 min), x-ray alone (600 rads), x-ray plus MW (same parameters as above), and x-ray plus US (same parameters as above). A thermocouple was inserted in one testis for recording temperature during treatment, and the blood level of testosterone (TST) was measured by protein binding assay. Animals were sacrificed 60 days after treatment, and the testes were examined for weight and histology; the prostate was examined for weight. The temperature variations in the testes were nominal for the various modes of irradiation as follows: control = 35.0 ± 0.2 C, US = 37.6 ± 0.7 C, MW = 39.9 ± 0.4 C, and x-ray = 35.2 ± 0.2 C. A reduction in spermatogenesis was seen in all treated animals, with no difference between the testis punctured by the thermocouple and the contralateral one. The degree of disruption was scored as follows: moderate in rats treated by single modalities of radiation, severe in rats treated with x-rays and MW, and complete in rats treated by x-rays and US. The percent of tubules affected by the various treatments was as follows: 0% for controls, 58% for US alone, 68% for MW alone, 72% for x-rays alone, 87% for x-rays and US, and 85% for x-rays and MW. Only the combination of US and x-rays resulted in a 75% reduction of the blood level of TST, an 80% reduction in prostate weight, and a significant reduction in the number of Leydig cells. An insignificant reduction in testicular weight was noted only in the x-ray-treated groups.


The antitumor effects of a triple combination of radiotherapy (RT), local microwave hyperthermia (LMHT), and clostridial oncolysis were compared with the effects of each modality alone in female NMRI mice bearing Harding-Passey melanoma transplanted as a neck tumor. LMHT was applied with an inductive Eddy current applicator (3.8-cm diameter) at 461 MHz with a Siemens generator. Mice receiving the triple combination first were irradiated with 2,000 R of x-rays followed immediately by 2 min of LMHT (40-41°C); 12 hr later, they received an intravenous injection (tail vein) of 10⁸ spores of Clostridium thermobutyricum. Animals receiving single modality treatment were treated with the same dose-schedules as above. The mean survival times for 49 untreated controls, 51 mice treated with RT only, 46 mice treated with LMHT only, 51 mice treated with Clostridium spores only, and 38 mice receiving a combination of the three treatments were 26.53 ± 0.87, 50.08 ± 1.64, 26.89 ± 0.89, 26.25 ± 0.84, and 69.03 ± 2.28 days, respectively. No animals were cured (150 days without relapse) in any treatment group with the exception of the triple combination group where the cure rate was 18%. The triple combination also caused the greatest reduction in tumor volume. Treatment with LMHT alone caused only a minor growth arrest after which tumors grew again unhindered.


Three lines of human colon cancer xenografts in nude mice (NIH-Swiss, 4 wk old) were treated with either whole-body hyperthermia (WBM) or continuous wave (CW) microwave-induced local hyperthermia
(LH). WBH was achieved by confining metabolic heat in a 39.5°C ambient temperature environment with high humidity. LH was produced by electically loaded direct contact applicators (15 x 10 mm surface) operating at 2,450 MHz. The microwave source was an Elmed Microwave 150, which generates up to 50 W of CW microwave power. By switching the microwave power either to the applicator or to a matched load, a tumor core temperature of 42.5 ± 0.1°C was maintained. Tumor core temperature was measured by a 0.13-mm copper/constantan thermocouple placed through the tumor with a 25-gauge needle and oriented perpendicularly to the direction of the electromagnetic field. Mice were randomized into treatment groups of four to six animals when tumors had reached a palpable size (about 60-100 mg). WBH at rectal temperatures of 40.0°C for 45 min reduced the survival of mice to 50% in comparison with untreated controls, but was ineffective in controlling tumor growth. However, LH (3 x 60 min at 42.5°C) produced a complete regression rate of 50% for tumor line 8E, which was 100% sensitive to the anticancer nitrosourea methyl-CCNU at a single intraperitoneal dose of 18 mg/kg. Only transient regressions were observed in tumor line CA after treatment with either LH or methyl-CCNU, and line HT was completely resistant to both LH and methyl-CCNU. No potentiation of methyl-CCNU by concomitant LH (42.5°C for 60 min) was observed in any of the three colon tumor xenografts. All studies with LH were performed on mice bearing bilateral tumor implants, and growth patterns of unheated tumors did not differ from those obtained in untreated mice. Thus, LH did not appear to enhance host immunogenicity. These findings support a role for LH in the treatment of colon cancer that is often resistant to either chemotherapy or conventional radiotherapy. Four of the patients had previously received radiotherapy, and one had received combination chemotherapy and immunotherapy. The first patient (57 yr old) presented with a squamous cell carcinoma of the base of the tongue, recurrent and with widespread metastases. After receiving one noninvasive LCF treatment (44°C, 90 min), good pain palliation and tumor regression were observed. However, the patient died of cardiopulmonary arrest 6 days after treatment. The second patient (77 yr old) presented with advanced local disease at the base of the tongue. Good pain palliation and tumor regression for 1 mo were achieved after one noninvasive LCF treatment (44°C, 60 min). The patient died of progressive disease 15 wk after treatment. The third patient (76 yr old) presented with a rapidly regrowing 3-cm mass in the floor of the mouth. Two courses of invasive LCF using biplanar interstitial implants (43°C, 30 min; 44°C, 25 min) were given over a 2-wk period. Pain relief with complete tumor regression was seen after the second treatment. The patient is alive with no evidence of disease 14 mo after treatment. The fourth patient (43 yr old) had large-cell undifferentiated carcinoma of the lung that was metastatic to the axilla and supraclavicular and hip regions. Two noninvasive treatments (42°C, 34 min; 43°C, 32 min), separated by 7 days, produced local pain palliation. The patient died of progressive disease 27 days after treatment. The last patient (52 yr old) had a history of extensive recurrent malignant melanoma of the right leg, metastatic to the right thigh and groin region. Six lesions in a disarticulated hip stump region were treated with eight noninvasive LCF treatments (42-44°C, 10-36 min) over an 8-day period. Slight regression and pain palliation were achieved. The patient is alive with disease and is currently undergoing chemotherapy.


The use of a localized radio frequency current field (LCF) technique with continuous automatic temperature control for the treatment of five patients with oral cavity carcinomas or metastatic malignancies is reported. The shape of the LCF fields was determined by electrodes of an invasive (internal) or noninvasive (external) type. An error signal modulated the radio frequency generator to minimize any variation from the set-point temperature so that temperature at the control location in the treatment volume (hot-test point) was held to within ±0.2°C of the specified level during treatment. A frequency of 500 kHz was used to enable accurate temperature monitoring without interference.
MEETING ABSTRACTS

6492 CARDIOVASCULAR RESPONSE OF RATS EXPOSED TO 60-Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hilton, D. L. ( Battelle Pacific Northwest Lab., Richland, WA 99352); Phillips, R. D. Physiology 22(4): 56; 1979. (0 refs)

The possible influence of exposure to high-strength electric fields on electrocardiogram (ECG) patterns, heart rate, and blood pressures that has been observed in various animal species was investigated. Sprague-Dawley rats were exposed (or sham-exposed) to 60-Hz, 80-kV/m, or 100-kV/m fields for periods from 4 mos. No significant differences were found between exposed and sham-exposed rats for any of the cardiovascular parameters examined (ECG, blood pressure, vascular reactivity) after 8 hr, 40 hr, 1 mo, or 4 mo of exposure. Exposure to a 100-kV/m field for 1 hr also had no significant effect on blood pressure and heart rate measured during the exposure. Physiologic reserve capabilities were measured in rats exposed to 100 kV/m for 1 mo and then subjected to cold stress; electric field exposure had no significant effect on the animals' response to the latter. These studies cannot be compared directly with other investigations because of differences in animal species and electric field characteristics.

Failure to detect any cardiovascular changes could have resulted from the elimination of secondary field effects such as microcurrent shocks, corona, and ozone.

6493 EFFECTS OF MICROWAVE-INDUCED HYPERTHERMIA ON THE RAT BLOOD-BRAIN BARRIER (MEETING ABSTRACT). (Eng.) Sutton, C. H. (Dept. Neurologic Surgery, Univ. Miami, Miami, FL 33152); Carroll, F. B. Physiology 22(4): 121; 1979. (0 refs)

See Current Literature 5440 for description of this article.

6494 INHIBITION OF TUMOR GROWTH BY RADIO FREQUENCY THERAPY (MEETING ABSTRACT). (Eng.) Tazawa, K. (Dept. Surgery, Toyama Medical and Pharmaceutical University, Toyama, Japan); Abe, R.; Salto, J.; Shinohara, T.; Fujita, T.; Ito, M.; Fujimaki, M.; Salto, Y. Proc Jpn Cancer Assoc p. 315; 1979. (0 refs)

The effect of selective heating in radio frequency (RF) field on experimental tumors (Sato's lung cancer and AH109A) was analyzed in rats. The RF generator had an output in excess of 500 W at a crystal-controlled frequency of 13.59 MHz. The energy was transmitted from the amplifier to an impedance matching circuit. Selective heating with RF raised the temperatures from 5 to 12 °C above that of the surrounding tissue. RF therapy produced tissue necrosis or substantial regression of the experimental tumors. Local heating with RF (40-46 °C, 20-30 min) resulted in regression and delay in tumor growth. Complete regression was seen in 7 of 23 rats. After treatment with RF (40-46 °C, 10 min), an increase in tumor growth occasionally occurred.

6495 INTERACTION OF 2.45 GHz MICROWAVE RADIATION WITH EMBRYONIC QUAIL HEARTS (MEETING ABSTRACT). (Eng.) Galvin, M. J. (Research Triangle Park, NC 27710); Lieberman, M.; McRee, D. F. Physiology 22(4): 42; 1979. (0 refs)

The effects of microwave radiation were examined in Japanese quail embryos exposed during the first 8 days of development to 2.45-GHz microwaves (incident power density, either 5 or 20 mW/cm², with 4.03 and 16.2 mW/g specific absorption rates, respectively). Ambient temperature was maintained at 37.5 °C, but thermal gradients in the irradiated
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Embryos could not be eliminated entirely, due to possible nonuniform absorption of microwaves. Neither morphologic nor ultrastructural changes in embryonic heart and myocardial cells was observed at either exposure level. Lactate dehydrogenase and glutamic oxaloacetic transaminase activities did not differ from those in controls. Creatine phosphokinase activity was lower in the 20-mW/cm² exposure group than in the 5-mW/cm² exposure group or the controls (p < 0.01). These data indicate that 2.45-GHz microwaves at 5 mW/cm² have no effect on the developing myocardium, however, at 20 mW/cm² the cytoplasmic enzyme content is affected.

6496 MICROWAVE INDUCED HYPERTHERMIA ± RADIOTHERAPY IN THE TREATMENT OF SUPERFICIAL HUMAN MALIGNANCIES (MEETING ABSTRACT). (Eng.) Harvey, H. A. (Dept. Medicine, Milton S. Hershey Medical Center, Pennsylvania State Univ., Hershey, PA); Lipton, A.; Lookingbill, D.; White, D.; Schelzel, D.; Stryker, J.; Sharkey, F. Clin Res 27(3): 583A; 1979. (0 refs)

Superficial tumors in 10 patients with metastatic cancers (breast, lung, cervix, head and neck, melanoma, and sarcoma) were treated experimentally with 2.450-MHz microwave hyperthermia alone or in combination with radiation therapy (RT) after conventional RT had proven unsuccessful in most cases. Either a dielectrically-loaded tapered or conformed waveguide applicator was used, and temperatures on the surface and within the tumor were recorded with small thermistors. The lesions (mean diameter 0.5-4 cm) were treated at 43°C for 45 min periods; regimens varied from one weekly to five daily treatments. Six of the lesions received electron beam therapy (300 rads x 12) immediately after hyperthermia. One complete response (CR), one partial response (PR, > 50% reduction), and one minor response (< 50% reduction) were observed after hyperthermia alone. Five lesions unresponsive to heat alone were subsequently treated with heat plus RT, and three CR and 2 PR were observed. In a melanoma patient with multiple metastases, three similar lesions were treated with heat alone, RT alone, and the combination therapy; PR, no response, and CR were achieved, respectively. These studies suggest that localized hyperthermia, while relatively ineffective as a single modality, is promising when used in combination with RT, particularly for treatment of recurrent lesions of epidermoid carcinoma of the head and neck and cutaneous metastases of melanoma.
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This quarterly digest presents current awareness information on the biological effects of nonionizing electromagnetic radiation (microwave and radio frequency) in the range of 0 Hz to 100 GHz. The effects of magnetic and electric fields (static and alternating) are also covered. Each issue contains abstracts of English and foreign current literature, summaries of ongoing research investigations, news items, and a directory of meetings and conferences.

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