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NONIONIZING RADIATION

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Information valid as of March 17, 2011.

POISINDEX® Managements

NONIONIZING RADIATION

0.0 OVERVIEW

LIFE SUPPORT

CLINICAL EFFECTS

LABORATORY/MONITORING

TREATMENT OVERVIEW

RANGE OF TOXICITY

0.1 LIFE SUPPORT

A) This overview assumes that basic life support measures have been instituted.

0.2 CLINICAL EFFECTS

0.2.1 SUMMARY OF EXPOSURE

A) Electromagnetic radiation has varying effects on the body, depending on the particular wavelength (or energy level) of the radiation involved.

1) IONIZING RADIATION is electromagnetic radiation with sufficient energy to cause ionization of matter in a living biological system. The spectrum of ionizing electromagnetic radiation includes high energy ultraviolet (UV), x-ray, and gamma frequencies.

2) **NONIONIZING** RADIATION is electromagnetic radiation without sufficient energy to cause ionization of matter in biological systems. The spectrum of **nonionizing** electromagnetic radiation includes RADIOFREQUENCY (Rf), MICROWAVE, INFRARED (IR), VISIBLE, and lower-energy ULTRAVIOLET (UV) frequencies.

a) Energy levels of electromagnetic radiation increase with the frequency of the radiation. There is an inverse relationship between wavelength and energy level. The threshold for ionization effect is found in the UV(B) to UV(C) range, where thiamine-thiamine dimer formation is noted in vitro and induction of skin cancer is seen clinically.

b) Long-wavelength radiation causes biological effects by tissue heating, the primary pathophysiologic mechanism of **nonionizing** radiation.

c) Depth of penetration is also important. Long wavelengths highly penetrate biological matter. Penetration decreases with decreasing wavelength until the ultraviolet radiation level, where increasing energy levels reverse the relationship between wavelength and tissue penetration.

d) There may be a separate mechanism wherein CNS effects are caused by low levels of MICROWAVE and RADIOFREQUENCY radiation. This "athermal" mechanism is the basis for Russian researchers recommending a lower permissible exposure limit for this type of **nonionizing** radiation.

e) **Nonionizing** radiation has VARYING effects on the human body, which depend on its different wavelengths.

B) Adverse biological effects of **NONIONIZING** RADIATION are primarily through mechanisms of tissue heating. There may also be some adverse biological effects from induction of ELECTROMAGNETIC FIELDS (EMFs).

0.2.3 VITAL SIGNS

A) Elevated body temperature, tachycardia, and hypertension have been seen with MICROWAVE RADIATION exposure.

B) RADIOFREQUENCY RADIATION exposure has been associated with bradycardia, as well as both hypertension and hypotension.

0.2.4 HEENT

A) OCULAR EFFECTS - The eye is a key target organ for **nonionizing** ELECTROMAGNETIC FIELD (EMF)

RADIATION.

1) ULTRAVIOLET RADIATION (UV(A, B, or C)) is not highly penetrant but has relatively high energy levels, resulting in significant injury to the superficial structures of the eye. The lower energy (longer wavelength or lower frequency) ultraviolet is relatively more penetrant.

a) UV(C) is high energy UV and is completely absorbed by the superficial layers of the skin and by the cornea. Corneal burns may result from exposure to UV(C) from lasers and welding arcs.

b) UV(B) is medium energy UV and some of the longer wavelength UV(B) is able to penetrate the cornea and reach the lens of the eye. Initiation or exacerbation of cataracts may occur.

c) UV(A) is the lowest energy UV and penetrates to the lens. Initiation or exacerbation of cataracts may occur.

2) VISIBLE RADIATION (LIGHT) may cause eye damage. Retinal damage may occur when light frequency is focused by the lens. Lasers pose a particular hazard. Blue light is more hazardous than red light.

3) INFRARED RADIATION (IR) is focused like light by the lens. Heating of structures of the eye may occur. Cataract formation may occur with chronic exposure ("glassblower's cataract").

4) MICROWAVE RADIATION may damage the crystalline lens. This part of the lens is vulnerable because the avascular tissue has relatively poor heat dissipation qualities.

0.2.5 CARDIOVASCULAR

A) HYPOTENSION/BRADYCARDIA - Chronic exposure to radiofrequency radiation (Rf) may cause hypotension and bradycardia through an unknown mechanism.

B) HYPERTENSION/TACHYCARDIA - Hypertension and tachycardia have been reported after massive exposure to MICROWAVE RADIATION; overexposure to Rf RADIATION has caused tachycardia.

0.2.6 RESPIRATORY

A) IRRITATION - UV-ARC welding in the presence of CHLORINATED SOLVENTS may generate irritating ozone, nitrogen oxides, or phosgene and result in respiratory tract irritation.

0.2.7 NEUROLOGIC

A) MICROWAVES - NEUROLOGIC MANIFESTATIONS have been noted to be associated with MICROWAVE exposure.

1) Headache, fatigue, and hyperactivity may occur subsequent to exposure to low energy MICROWAVES. This is NOT thought to be a heat-related effect.

2) Cases of Parkinson syndrome, meningoencephalitic syndrome, and organic memory loss have been reported after episodes of massive MICROWAVE exposure.

3) In mice, convulsant dose, lethal dose, and seizure onset times were significantly increased compared to sham controls for bicuculline-induced seizures in mice exposed to extremely low frequency magnetic fields. NMDA and picrotoxin produced no significant differences in convulsant dose or lethal dose. Seizure onset time decreased in the picrotoxin group and showed no change in the NMDA group.

0.2.8 GASTROINTESTINAL

A) DIGESTIVE DISORDERS - Chronic exposure to radiofrequency radiation (Rf) may be related to increased rates of digestive function disorders. Nausea and dizziness may occur with MICROWAVE RADIATION (RADAR) exposure.

B) CHOLECYSTOPANCREATITIS and unspecified liver disorders were noted with increased incidence in a group of workers occupationally exposed to RADIOFREQUENCY RADIATION.

0.2.10 GENITOURINARY

A) MALE REPRODUCTIVE EFFECTS - Reduction of spermatocytes and damage to the cells lining the seminiferous tubules may follow exposure to MICROWAVES at high energy levels.

0.2.13 HEMATOLOGIC

A) WBC CHANGES - Chronic exposure to radiofrequency radiation (Rf) may be related to changes in the white blood cell count (increased total WBCs, lymphocytopenia, monocytosis).

0.2.14 DERMATOLOGIC

A) ULTRAVIOLET RADIATION (UV) may have acute and chronic effects on the skin.

1) Acute exposure to UV may cause erythema and sunburn.

2) Chronic exposure to UV, particularly UV(B), accelerates skin aging and increases the risk of developing skin cancer.

B) A dermal warming sensation and thermal burns may result from exposure to INFRARED, VISIBLE SPECTRUM, and RADIOFREQUENCY radiation.

0.2.15 MUSCULOSKELETAL

A) A cystic mass in the neck was reported in one case of acute high-dose MICROWAVE RADIATION (RADAR) exposure.

0.2.16 ENDOCRINE

A) Changes in sympathetic adrenergic hormone excretion were seen in adolescents exposed to INFRARED RADIATION.

0.2.18 PSYCHIATRIC

A) PSYCHIATRIC MANIFESTATIONS (CASE REPORTS) - Cases of psychiatric manifestations have been reported after acute exposure to MICROWAVE RADIATION. Effects have included anxiety, sleep disturbance, and short term memory impairment.

B) CIRCADIAN RHYTHM - VISIBLE WAVELENGTH RADIATION in the setting of poor quality and excessive artificial illumination may have adverse psychological effects through disruption of circadian rhythm cycles and changes in hormone levels.

C) ANXIETY - RADIOFREQUENCY RADIATION (Rf) in acute exposure situations may be associated with anxiety.

0.2.19 IMMUNOLOGIC

A) HERPES (HSV) ACTIVATION - ULTRAVIOLET RADIATION (UV) may activate HSV, particularly on the lips and mouth. This effect does not appear to involve immune mechanisms.

0.2.20 REPRODUCTIVE

A) ULTRASOUND in treatment quantities for acute Pelvic Inflammatory Disease (PID) (NOT DIAGNOSTIC quantities) may cause spontaneous abortion.

B) CONGENITAL ANOMALIES and spontaneous abortion have been associated with paternal occupational exposure to MICROWAVE and INFRARED radiation.

0.2.21 CARCINOGENICITY

A) SKIN CANCER - UV(B) exposure increases the risk of developing skin cancer. This is more likely in individuals with light-colored skin.

B) CNS malignancies, leukemias, and lymphomas have been found in higher incidence in some epidemiological studies of ELECTROMAGNETIC FIELD (EMF) exposed workers, but the association is unclear.

0.3 LABORATORY/MONITORING

A) Extensive laboratory tests in the absence of positive findings on a careful history and physical are NOT indicated.

0.4 TREATMENT OVERVIEW

0.4.4 EYE EXPOSURE

A) KERATOCONJUNCTIVITIS - UV radiation may cause keratoconjunctivitis. Treatment is similar to that for other causes of acute conjunctivitis, including topical antibiotics, topical mydriatics (short-acting), and eye patching if indicated.

B) A number of frequencies of **NONIONIZING** RADIATION may cause CATARACTS. Slit lamp evaluation may be necessary.

1) CAPSULAR CATARACTS - ophthalmology referral indicated

2) CATARACTS INVOLVING the CRYSTALLINE LENS - ophthalmology referral indicated

0.4.5 DERMAL EXPOSURE

A) OVERVIEW

1) Thermal considerations are of primary importance in treatment of acute exposure cases where infrared and microwave radiation are concerned. If total body heating is encountered, treatment should follow guidelines for hyperthermia.

2) DERMAL BURNS - from **nonionizing** radiation are treated as THERMAL (or CHEMICAL) BURNS.

0.5 RANGE OF TOXICITY

A) Infrared radiation affects the eyes of humans and animals at varying doses. Microwave radiation did not yield any exposure-related complaints in workers.

1.0 SUBSTANCES INCLUDED/SYNONYMS

1.1 THERAPEUTIC/TOXIC CLASS

A) ULTRAVIOLET, VISIBLE, INFRARED, MICROWAVE, and RADIOFREQUENCY radiation are all components of the spectrum of ELECTROMAGNETIC RADIATION. This is photon radiation and travels at the speed of light. Photons have characteristics of both particles and waves. Interaction with matter is required for biological effects. The mechanism through which most non-ionizing radiations cause biologic damage is the production of heat. Unless exposure to non-ionizing radiation produces so much heat that it overwhelms the body's capacity to dissipate it, there will be no damage. When more heat is produced than can be dissipated, heat builds up, and burns occur.

B) High exposure to non-ionizing radiation produces acute effects on sensitive organs, mostly depending on radiation intensity, frequency and exposure duration. Energy level is directly proportionate to frequency, and is inversely proportionate to wavelength. Energy varies widely across the electromagnetic spectrum: one photon of ULTRAVIOLET at 250 nm has 400,000 times as much energy as one photon of 10 cm MICROWAVE radiation.

1) **Nonionizing** electromagnetic radiation does not have sufficient energy to cause ionization in tissue. The energy threshold for ionization is within the ULTRAVIOLET range, where UV (B) begins to cause low energy ionizations and chemical reactions such as thiamine-thiamine dimer formation, thought to be a molecular biological factor in skin cancer causation.

C) Biological effects are produced at the molecular level by heating and electric field effects. Heating of tissue is the primary pathophysiologic mechanism.

1) Depth of penetration is also important for site of biological effect, particularly in the eye.

a) Depth of penetration is greatest for low energy/long-wavelength RADIOFREQUENCY and MICROWAVE RADIATION, and less for high energy/short-wavelength HEAT, VISIBLE SPECTRUM, and ULTRAVIOLET.

b) As electromagnetic radiation increases in energy level into the X-ray and gamma radiation wavelengths, tissue penetration again begins to increase as a function of energy level.

1.2 SPECIFIC SUBSTANCES

A) CONSTITUENTS OF THE GROUP

1) Electromagnetic fields
2) Electromagnetic radiation
3) Fields, electromagnetic
4) Ultraviolet
5) Visible
6) Infrared
7) Infrared Radiation
8) IR
9) IR radiation
10) Lasers
11) Light, visible
12) Low frequency magnetic fields
13) Low frequency MFs
14) Magnetic Fields, LF
15) Magnetic Fields, Low Frequency
16) Microwave
17) Microwaves
18) Microwave Radiation
19) Radiation, Infrared
20) Radiation, IR
21) Radiation, UV

22) Radiation, Ultraviolet
23) Radiation, Microwave
24) Radiation, **Nonionizing**
25) Radiation, Visible
26) Radar
27) Radiofrequency
28) Terminals, Video Display
29) Ultraviolet Radiation
30) UV
31) UV Radiation
32) UV(A)
33) UV(B)
34) UV(C)
35) Visible Light
36) Visible Radiation
37) Visible Spectrum
38) Video display terminals

1.4 GEOGRAPHICAL LOCATION

A) ULTRAVIOLET RADIATION due to SUNLIGHT EXPOSURE varies significantly with latitude and atmospheric conditions.

1) HIGH ALTITUDE is particularly significant in increasing UV exposure.

a) The earth's ozone layer excludes much UV(B) and all UV(C) radiation.

2) SOLAR RADIATION as it traverses the earth's atmosphere is composed of 55% INFRARED RADIATION (which WARMS the earth), 40% VISIBLE RADIATION (Light), and 5% ULTRAVIOLET RADIATION (Knave et al, 1994).

B) MICROWAVE RADIATION exposure may occur among POLICE TRAFFIC RADAR OPERATORS (pp 1-53).

C) RADIOFREQUENCY RADIATION BURN HAZARD onboard US Navy ships may occur when metal structures such as wire rigging, boat davits, cranes, and helicopters are irradiated with Rf (Rogers, 1981a) 1981b). Cranes may be particularly associated with Rf burn hazards.

1.6 AVAILABLE FORMS/SOURCES

A) FORMS

1) There are a variety of different schemata for describing **nonionizing** radiation (Conrad, 1994). "**Nonionizing** radiation" is that part of the electromagnetic spectrum of which the energies of emitted photons are NOT sufficient to produce ionization in atoms of molecules which absorb such radiation (Matelsky, 1983).

2) The following are generally based on the schema developed by the International Commission on Illumination (CIE) (Raffle et al, 1987).

a) ULTRAVIOLET RADIATION includes electromagnetic radiation between 100 and 400 nanometer (nm) wavelength.

1) UV(C) is ultraviolet radiation from 100 to 280 nm
2) UV(B) is ultraviolet radiation from 280 to 315 nm.
3) UV(A) is ultraviolet radiation from 315 to 400 nm.

3) LIGHT or VISIBLE ELECTROMAGNETIC RADIATION extends from the ULTRAVIOLET endpoint at 400 nm to the short wavelength boundary of INFRARED at 760 nm in the CIE schema (Raffle et al, 1987).

4) INFRARED RADIATION is that region of the electromagnetic spectrum from 760 nm to 1.0 millimeter (mm) in the CIE schema (Raffle et al, 1987).

5) MICROWAVE RADIATION wavelengths extend from 3 mm to 10 meters.

a) HIGH POWER MICROWAVE DEVICES produce electromagnetic pulses with pulse widths from about 10(-9) nanoseconds (Albanese et al, 1994).

6) RADIOFREQUENCY (Rf) wavelengths are from 1 mm to 10,000 km (Mikolajcyk, 1983).

a) Rf can be characterized by the following parameters (Mikolajcyk, 1983):

1) VELOCITY: which in normal conditions and free space, approximates the speed of light (300,000 km/second)
2) WAVELENGTH: measured in meters (or proportionate metric units)
3) FREQUENCY: measured in hertz (Hz; Cycles/Second)

b) RF includes FREQUENCIES from about 30 Hz to 300,000 megahertz (MHz).

B) SOURCES

1) ULTRAVIOLET, VISIBLE, INFRARED, MICROWAVE, and RADIOFREQUENCY radiation are all components of the spectrum of ELECTROMAGNETIC RADIATION. This is photon radiation and travels at the speed of light. Photons have characteristics of both particles and waves. Interaction with matter is required for biological effects.

a) ELECTRICAL FIELDS can be shielded relatively easily, while MAGNETIC FIELDS can traverse most types of matter (including human tissues) while losing little, if any, energy (Conrad, 1994).

b) IN THE HOME, EMF Fields can be generated by (Knave et al, 1994):

1) Television Sets
2) Refrigerators
3) Electric Stoves (cookers)
4) Microwave Ovens
5) Electric Razors
6) Hair Dryers
7) Clock-Radios
8) Electric Wiring
9) Electric Heaters

1) HOWEVER, such fields generated by HOUSEHOLD APPLIANCES are most likely NEGLIGIBLE (Knave et al, 1994).

c) OCCUPATIONAL EXPOSURES may occur to (Knave et al, 1994):

1) Arc Welders
2) Blast Furnace Workers
3) Electric Power Workers (Linemen & Switchgear Workers)
4) Electrical Engine Drivers (and assistants)
5) Electrical Engineers (and technicians)
6) Miners
7) Radio and Television Repairmen
8) Railway Workers
9) Seamstresses
10) Telephone Workers

C) USES

1) Military Battlefield Lasers (Thomas, 1994)

a) Effects of OCULAR EXPOSURE to NEAR INFRARED (NIR) and VISIBLE RADIATION MILITARY LASERS:

1) Glare
2) Flashblindness
3) Thermal lesions
4) Hemorrhagic lesions

2) Lasers

a) LASERS may produce electromagnetic pulses with a pulse width of only a few fematoseconds (fs); however, the associated electrical field amplitudes may exceed 1 million volts/meter (Albanese et al, 1994).

b) Laser classification (Knave et al, 1994)

CLASS I:	Incapable of producing damaging radiation levels
CLASS II:	Low hazard potential; COULD cause an aversive (blink) response
CLASS IIIa:	Capable of causing injury when the energy is collected and focused at the eye

CLASS IIIb:	The beam or its reflections can produce permanent eye damage
CLASS IV:	Lasers which require controls to prevent eye or skin exposure to prevent damage

3.0 CLINICAL EFFECTS

SUMMARY OF EXPOSURE

VITAL SIGNS

HEENT

CARDIOVASCULAR

RESPIRATORY

NEUROLOGIC

GASTROINTESTINAL

GENITOURINARY

HEMATOLOGIC

DERMATOLOGIC

MUSCULOSKELETAL

ENDOCRINE

PSYCHIATRIC

IMMUNOLOGIC

REPRODUCTIVE

CARCINOGENICITY

GENOTOXICITY

3.1 SUMMARY OF EXPOSURE

A) Electromagnetic radiation has varying effects on the body, depending on the particular wavelength (or energy level) of the radiation involved.

1) IONIZING RADIATION is electromagnetic radiation with sufficient energy to cause ionization of matter in a living biological system. The spectrum of ionizing electromagnetic radiation includes high energy ultraviolet (UV), x-ray, and gamma frequencies.

2) NONIONIZING RADIATION is electromagnetic radiation without sufficient energy to cause ionization of matter in biological systems. The spectrum of **nonionizing** electromagnetic radiation includes RADIOFREQUENCY (Rf), MICROWAVE, INFRARED (IR), VISIBLE, and lower-energy ULTRAVIOLET (UV) frequencies.

a) Energy levels of electromagnetic radiation increase with the frequency of the radiation. There is an inverse relationship between wavelength and energy level. The threshold for ionization effect is found in the UV(B) to UV(C) range, where thiamine-thiamine dimer formation is noted in vitro and induction of skin

cancer is seen clinically.

b) Long-wavelength radiation causes biological effects by tissue heating, the primary pathophysiologic mechanism of **nonionizing** radiation.

c) Depth of penetration is also important. Long wavelengths highly penetrate biological matter. Penetration decreases with decreasing wavelength until the ultraviolet radiation level, where increasing energy levels reverse the relationship between wavelength and tissue penetration.

d) There may be a separate mechanism wherein CNS effects are caused by low levels of MICROWAVE and RADIOFREQUENCY radiation. This "athermal" mechanism is the basis for Russian researchers recommending a lower permissible exposure limit for this type of **nonionizing** radiation.

e) **Nonionizing** radiation has VARYING effects on the human body, which depend on its different wavelengths.

B) Adverse biological effects of **NONIONIZING** RADIATION are primarily through mechanisms of tissue heating. There may also be some adverse biological effects from induction of ELECTROMAGNETIC FIELDS (EMFs).

3.3 VITAL SIGNS

3.3.1 SUMMARY

A) Elevated body temperature, tachycardia, and hypertension have been seen with MICROWAVE RADIATION exposure.

B) RADIOFREQUENCY RADIATION exposure has been associated with bradycardia, as well as both hypertension and hypotension.

3.3.3 TEMPERATURE

A) HYPERTHERMIA - Rise in body temperature may occur in response to whole body exposure to MICROWAVE RADIATION. Significant exposure time is required. Radar operators and microwave technicians are the population at risk. Exposure to electromagnetic fields at frequencies above 100 kHz can lead to significant energy absorption and temperature increases (Anon, 1998).

1) A SENSATION OF HEAT in EXPOSED AREAS may be noted immediately (Reeves, 2000; Anon, 1996; pp 197-184; Castillo & Quencer, 1988; Hill, 1985; Williams & Webb, 1980).

B) RADIOFREQUENCY RADIATION -

1) Deep body heating, sweating, and metabolic heat production equal to 15 to 20 degrees C can be produced in primates with exposure to Rf with a power density of 4 to 6 megawatts/cm(2) (Adair, 1985).

3.3.4 BLOOD PRESSURE

A) HYPERTENSION -

1) Two individuals developed hypertension and psychological symptoms several months after massive exposure to MICROWAVE RADIATION. A heating sensation of the chest and head and headache have developed in some cases (Forman et al, 1982).

2) A flight mechanic overexposed to RADIOFREQUENCY RADIATION had an elevated blood pressure (Williams & Webb, 1980).

B) BRADYCARDIA/HYPOTENSION -

1) An increased incidence of bradycardia and hypotension was noted in a labor pool of individuals chronically exposed to significant amounts of RADIOFREQUENCY RADIATION (Glotova & Sadcikova, 1970).

3.3.5 PULSE

A) TACHYCARDIA - Tachycardia has been documented in a case of MICROWAVE overexposure (pp 197-184).

B) BRADYCARDIA/HYPOTENSION - An increased incidence of bradycardia and hypotension was noted in a labor pool of individuals chronically exposed to significant amounts of RADIOFREQUENCY RADIATION (Glotova & Sadcikova, 1970; Wilen et al, 2007).

3.4 HEENT

3.4.1 SUMMARY

A) OCULAR EFFECTS - The eye is a key target organ for **nonionizing** ELECTROMAGNETIC FIELD (EMF) RADIATION.

1) ULTRAVIOLET RADIATION (UV(A, B, or C)) is not highly penetrant but has relatively high energy levels, resulting in significant injury to the superficial structures of the eye. The lower energy (longer wavelength or lower frequency) ultraviolet is relatively more penetrant.

a) UV(C) is high energy UV and is completely absorbed by the superficial layers of the skin and by

the cornea. Corneal burns may result from exposure to UV(C) from lasers and welding arcs.

b) UV(B) is medium energy UV and some of the longer wavelength UV(B) is able to penetrate the cornea and reach the lens of the eye. Initiation or exacerbation of cataracts may occur.

c) UV(A) is the lowest energy UV and penetrates to the lens. Initiation or exacerbation of cataracts may occur.

2) VISIBLE RADIATION (LIGHT) may cause eye damage. Retinal damage may occur when light frequency is focused by the lens. Lasers pose a particular hazard. Blue light is more hazardous than red light.

3) INFRARED RADIATION (IR) is focused like light by the lens. Heating of structures of the eye may occur. Cataract formation may occur with chronic exposure ("glassblower's cataract").

4) MICROWAVE RADIATION may damage the crystalline lens. This part of the lens is vulnerable because the avascular tissue has relatively poor heat dissipation qualities.

3.4.3 EYES

A) KERATOCONJUNCTIVITIS - ULTRAVIOLET RADIATION in the actinic range (UV(B) and (C)) is strongly absorbed by the conjunctivae and cornea, causing keratoconjunctivitis (Anon, 1996). UVA radiation is absorbed mainly in the lens.

1) Ultraviolet radiation is not highly penetrant but has relatively high energy levels, resulting in significant eye injury.

a) There is generally a 6 to 12 hour latent period until conjunctivitis symptoms appear.

b) Photophobia, lacrimation, and blepharospasm accompany a sensation of foreign body or "sand" in the eyes.

c) Acute symptoms last from 6 to 24 hours. The patient is visually incapacitated during this period.

d) It is rare for permanent ocular injury to occur as a result of UV keratoconjunctivitis.

B) CORNEAL BURNS - UV(C) is high energy UV and is completely absorbed by the superficial layers of the skin and by both the cornea and the conjunctiva. CORNEAL BURNS may result from exposure to UV(C) from LASERS and WELDING ARCS. Superficial thermal injury to the cornea occurs at wavelengths greater than 1400 nm (Anon, 1996).

C) CATARACTS - UV(B) is medium energy UV and some of the longer wavelength UV(B) is able to penetrate the cornea and reach the lens. The threshold for this penetration is 295 nm, with longer wavelengths (lower energy levels) being able to reach the lens. Initiation or exacerbation of CATARACTS may occur (Anon, 1996).

1) UV(A) is lowest energy UV and penetrates to the lens. Initiation or exacerbation of cataracts may occur.

2) UV light is associated with cortical and posterior subcapsular cataract in a dose-related fashion, as shown in the Chesapeake Bay Waterman studies. While ambient UV(B) fluxes vary by a factor of 3 to 4 over the globe, individual exposures may vary 20-fold in a given location (Taylor, 1994).

3) In the US, where Medicare pays for 85% of all cataract surgeries, the strongest predictor of cataracts in the Medicare cataract cohort is latitude of residence. Latitude determines the incident angle of sunlight on the eye (Javitt & Taylor, 1994).

4) The sunlight theory of cataract formation is controversial, however, and disregards other possible factors such as diet, genetics, and prevalence of other diseases. Laboratory studies have been unable to reproduce biochemical changes seen in cataracts by using UV light alone (Harding, 1994).

D) VISIBLE RADIATION (LIGHT) may cause retinal damage (photoretinitis) when light frequency is focused by the lens. Photoretinitis is the result of a photochemical reaction after exposure of the retina to shorter wavelengths in the visible spectrum (Anon, 1997). Photochemical injury from chronic low-level exposure is related to absorption by the retinal pigmented epithelium and choroid of short-wavelength light in the 380-520 nm region.

1) The ability of the lens to focus LIGHT, near ULTRAVIOLET, and near INFRARED RADIATION onto the retina results in energy densities at the retina several orders of magnitude greater than the radiation intensity at the cornea (Finkel, 1983). Laser wavelengths in the 400-1400 nm band can cause thermal injury to the retina resulting from temperature elevation in the pigmented epithelium and is a primary effect for exposure durations less than 10 seconds (Anon, 1996).

2) A relatively low radiation exposure incident on the cornea can produce a retinal lesion. Since the retina does not have pain perception, damage may occur without symptoms. Laser thermoacoustic injury occurs at pulse durations less than approximately 0.1 ms and can lead to hemorrhagic lesions of the retina from Q-switched lasers. Photochemical injury of lasers predominates in the UV spectral region and is the principal type of injury due to lengthy exposures (10 seconds or more) to short-wavelength visible radiation (principally "blue light") (Anon, 1996).

a) LASERS pose a particular hazard in this regard (ACGIH, 1991) with potential complications of (Thomas, 1994):

1) Glare

2) Flashblindness

3) Thermal (ocular) lesions

4) Hemorrhagic (ocular) lesions

3) Blue light is more hazardous than red light. Thus, sunlight is more likely to cause retinal burns when the sun in overhead than when it is close to the horizon (where blue light wavelengths are filtered by the atmosphere).

E) GLASSBLOWER'S CATARACT - INFRARED RADIATION is focused like light by the lens. Heating of structures of the eye may occur. CATARACT formation may occur with chronic exposure, as seen in glass workers ("glassblower's cataract"). Epithelial hazing and erosions may also occur (Pitts et al, 1980).

1) With INFRARED or NEAR-INFRARED LASERS (NIR), there is a threshold for retinal injury (Wolbarsht et al, 1977). There are some sharply defined spectral variations in thresholds for retinal injury (Pitts et al, 1980; Lund & Beatrice, 1989), making a precise definition of exposure limits very frequency-specific.

a) The reason for sharply defined variations is a high degree of variability in spectral absorption in the INFRARED range by retinal chromophores (Lund & Beatrice, 1989).

b) BATTLEFIELD LASERS IN THE INFRARED/NEAR INFRARED (NIR) SPECTRUM (Possible Effects) (Thomas, 1994):

1) Glare

2) Flashblindness

3) Thermal Lesions (ocular)

4) Hemorrhagic lesions (ocular)

2) With INFRARED or NEAR-INFRARED LASERS (NIR), there is a threshold for lens injury (Pitts et al, 1980; Lund & Beatrice, 1989). Mechanism of lens injury sustained as a result of INFRARED exposure is that the proportion of insoluble protein to soluble protein is increased once lens temperature is increased by the infrared to over 38.5 to 40 degrees (Lund & Beatrice, 1989).

a) CORNEAL, IRIS, and LENTICULAR injuries may also result from INFRARED RADIATION (Pitts et al, 1980; Curtis & Nichols, 1983).

b) Epidemiologic study of GLASS WORKERS reveals an increased prevalence of cataracts with the relative risk by age 60 to 70 being 2.5 over controls (Lydahl & Philipson, 1984a) 1984b).

F) MICROWAVE RADIATION has been suggested to have the ability to damage the crystalline lens producing vacuoles and opacities (Castrena et al, 1982), although such changes have been more correlated with AGE than with duration or intensity of microwave exposure (Shimkovich & Shilyaev, 1959; Zaret & Snyder, 1977). This avascular tissue is microwave-sensitive because it has poor heat dissipation qualities.

1) Amongst RADAR WORKERS with MICROWAVE RADIATION exposure (generally less than 5 milliwatts/cm(2)), there was NO increased incidence of cataracts (Djordjevic et al, 1979). Complaints of headache, fatigue, and irritability were more likely related to JOB STRESS (Djordjevic et al, 1979).

2) In a study of Polish workers with MICROWAVE RADIATION exposure, NO CORRELATION was found between duration of exposure and fitness for work (Siekierzynski, 1974).

3) Military workers with long-term exposure to MICROWAVE RADIATION did NOT develop cataracts at a greater incidence than the general population (Appleton & McCrossan, 1972).

a) Some individuals with Rf exposure to the head have had lenticular abnormalities (vacuoles and opacities) (Hill, 1985).

4) EYE IRRITATION was noted in 23% of male and 40% of female plastic welding operators with Rf exposure (Kolmodin-Hedman et al, 1988).

3.5 CARDIOVASCULAR

3.5.1 SUMMARY

A) HYPOTENSION/BRADYCARDIA - Chronic exposure to radiofrequency radiation (Rf) may cause hypotension and bradycardia through an unknown mechanism.

B) HYPERTENSION/TACHYCARDIA - Hypertension and tachycardia have been reported after massive exposure to MICROWAVE RADIATION; overexposure to Rf RADIATION has caused tachycardia.

3.5.2 CLINICAL EFFECTS

A) HYPERTENSIVE EPISODE

1) Two individuals developed hypertension and psychological symptoms several months after massive exposure to MICROWAVE RADIATION. A heating sensation of the chest and head and headache

developed (Forman et al, 1982).

2) A flight mechanic overexposed to Rf radiation had an elevated blood pressure (Williams & Webb, 1980).

3) An airline technician was hospitalized for 4 days following exposure to non-ionizing radiation from an aircraft radar unit. He experienced a sensation of warmth, nausea, apprehension and hypertension, which fully resolved in 2 to 3 weeks (Reeves, 2000).

B) TACHYARRHYTHMIA

1) Tachycardia has been documented in a case of MICROWAVE overexposure (pp 197-184).

C) BRADYCARDIA

1) A minor reduction in heart rate during or immediately after ELF field exposure may occur, but is transient and not associated with any long-term health risk (Anon, 1998). An increased incidence of bradycardia and hypotension was noted in a labor pool of individuals chronically exposed to significant amounts of RADIOFREQUENCY RADIATION (Glotova & Sadcikova, 1970).

2) When human volunteers were exposed to combined 60 Hz electric and magnetic fields (9 kV/m, 0.02 mT), a significant decrease in resting heart rate (3-5 beats/min) was found. This response did not occur to stronger or weaker fields. Intermittent exposure to the same field resulted in both slowing and increasing heart rate. None of the changes exceeded the normal range (Repacholi & Greenebaum, 1999).

3.6 RESPIRATORY

3.6.1 SUMMARY

A) IRRITATION - UV-ARC welding in the presence of CHLORINATED SOLVENTS may generate irritating ozone, nitrogen oxides, or phosgene and result in respiratory tract irritation.

3.6.2 CLINICAL EFFECTS

A) IRRITATION SYMPTOM

1) PHOSGENE FORMATION -

a) When a UV-ARC is used for welding in the presence of CHLORINATED SOLVENTS, highly toxic OZONE, NITROGEN OXIDES, and PHOSGENE may be produced, resulting in UPPER RESPIRATORY TRACT or LUNG IRRITATION, or NONCARDIOGENIC PULMONARY EDEMA (Knave et al, 1994).

3.7 NEUROLOGIC

3.7.1 SUMMARY

A) MICROWAVES - NEUROLOGIC MANIFESTATIONS have been noted to be associated with MICROWAVE exposure.

1) Headache, fatigue, and hyperactivity may occur subsequent to exposure to low energy MICROWAVES. This is NOT thought to be a heat-related effect.

2) Cases of Parkinson syndrome, meningoencephalitic syndrome, and organic memory loss have been reported after episodes of massive MICROWAVE exposure.

3) In mice, convulsant dose, lethal dose, and seizure onset times were significantly increased compared to sham controls for bicuculline-induced seizures in mice exposed to extremely low frequency magnetic fields. NMDA and picrotoxin produced no significant differences in convulsant dose or lethal dose. Seizure onset time decreased in the picrotoxin group and showed no change in the NMDA group.

3.7.2 CLINICAL EFFECTS

A) CENTRAL NERVOUS SYSTEM FINDING

1) ELF-EMF (Extremely Low Frequency Electric and Magnetic Field) exposure has been associated with central nervous system adverse outcomes in experimental animals (Conrad, 1994).

B) HEADACHE

1) Headache, fatigue, and hyperactivity may occur subsequent to exposure to low energy MICROWAVES, but have been documented to be more likely due to JOB STRESS (Djordjevic et al, 1979).

a) Such neurologic complaints are thought Not to be heat-related effects. Several cases have been reported with neurologic and psychological symptoms following MICROWAVE overexposure.

2) Visual reaction times and memory sensory scores were lower than those of controls in persons working near radar installations or radio antennae (Chiang et al, 1989).

3) In one case of extreme MICROWAVE overexposure, an individual was hospitalized with meningoencephalitic syndrome. There was a prolonged but complete recovery after termination of

exposure (pp 197-184).

a) Short, high-peak-voltage transients which might alter the conformations(s) of large macromolecules could possibly be a mechanism for central nervous system (CNS) disturbances from exposure to MICROWAVE RADIATION (Albanese et al, 1994).

C) EXTRAPYRAMIDAL DISEASE

1) Cases of Parkinson syndrome, meningoencephalitic syndrome, and organic memory loss have been reported following episodes of massive MICROWAVE overexposure (pp 197-184).

D) NEUROPATHY

1) RADIOFREQUENCY RADIATION - Acute exposures may be associated with neurologic complaints. Intense ELF magnetic fields can elicit direct peripheral nerve and muscle tissue stimulation (Anon, 1998).

2) A labor pool exposed to large amounts of RADIOFREQUENCY RADIATION in Russia was found to have poorly defined neurologic and cardiac signs and symptoms (Glotova & Sadcikova, 1970).

3) Diminished two-point discrimination with some changes on electroneurography were noted in some plastic welding operators with Rf exposure (Kolmodin-Hedman el at, 1988). The possible contribution of repetitive motion or other ergonomic factors was not reported for this cohort.

4) CASE SERIES - A review of 34 patients with confirmed exposure to radiofrequency radiation (RFR) exceeding the permitted exposure limits revealed a sensation of warmth which was positively associated with power density. A negative correlation was described between an abnormal tissue destruction screen and power density. Extensive neurological tests and psychometric and psychological exams showed NO neurological findings attributable to RFR. Burning pain described by a few patients resolved spontaneously over a few weeks (Reeves, 2000).

5) "NEURASTHENIC SYNDROME" with complaints of headaches, fatigue, and indigestion has been described amongst 33% of workers with Rf exposure from RADAR or plastic welding units; EEG's were abnormal in 15% of female workers with more than 6 years exposure (Slensky et al, 1968).

a) Such complaints have generally decreased once workers were removed from further exposure (pp 219-215).

E) ALTERED MENTAL STATUS

1) MICROWAVE EXPOSURE - has been associated with development of psychological symptoms in several individuals.

a) Symptoms included irritability, insomnia, and emotional lability, accompanied by development of hypertension in two individuals (Forman et al, 1982).

2) Other individuals have been diagnosed with memory problems, weight loss, insomnia, and other neuropsychological manifestations in the setting of CHRONIC MICROWAVE (RADAR) exposure (pp 197-184), although such complaints may have been more likely due to JOB STRESS in some cases (Djordjevic et al, 1979).

a) In these cases, symptoms gradually resolved after removal from exposure (pp 197-184).

3.7.3 ANIMAL EFFECTS

A) ANIMAL STUDIES

1) LEARNING CHANGES

a) MICROWAVE RADIATION has caused alterations in learning behavior in experimental animals, with a direct relationship to the power density of exposure (McRee et al, 1979).

2) SEIZURES

a) MICE - In mice, exposure to extremely low frequency magnetic fields (ELF-MFs) did not significantly affect convulsant dose or lethal dose for NMDA-induced or picrotoxin-induced seizures, compared with controls. At 8mg/kg and 10 mg/kg doses of picrotoxin, seizure onset time for the ELF-MF exposure group showed a significant decrease compared with controls. For bicuculline-induced seizures, the convulsant dose and lethal dose were significantly increased for the ELF-MF group; at 4mg/kg and 4.5 mg/kg doses, seizure onset time was significantly increased for the ELF-MF group. The authors speculated that seizure susceptibility may be altered by ELF-MF through a GABAergic mechanism with involvement of the level of glutamate and GABA (Sung et al, 2003).

3.8 GASTROINTESTINAL

3.8.1 SUMMARY

A) DIGESTIVE DISORDERS - Chronic exposure to radiofrequency radiation (Rf) may be related to increased rates of digestive function disorders. Nausea and dizziness may occur with MICROWAVE RADIATION (RADAR) exposure.

B) CHOLECYSTOPANCREATITIS and unspecified liver disorders were noted with increased incidence in a

group of workers occupationally exposed to RADIOFREQUENCY RADIATION.

3.8.2 CLINICAL EFFECTS

A) DRUG-INDUCED GASTROINTESTINAL DISTURBANCE

1) DIGESTIVE FUNCTION DISORDERS - Increased rates of digestive function disorders were noted in a radio and television broadcasting labor pool. This population was significantly exposed to RADIOFREQUENCY RADIATION.

2) There was a dose-response effect, with length of service associated with increased frequency of gastroenteric disease.

3) Disorders included peptic ulcer, chronic gastritis, cholecystopancreatitis, and unspecified liver disorders (Klejner, 1974).

B) NAUSEA

1) Nausea and dizziness may occur soon after MICROWAVE RADIATION (RADAR) exposure (pp 197-184).

C) PANCREATITIS

1) Cholecystopancreatitis and unspecified liver disorders were noted with increased incidence in a group of workers occupationally exposed to RADIOFREQUENCY RADIATION (Klejner, 1974).

3.10 GENITOURINARY

3.10.1 SUMMARY

A) MALE REPRODUCTIVE EFFECTS - Reduction of spermatocytes and damage to the cells lining the seminiferous tubules may follow exposure to MICROWAVES at high energy levels.

3.10.2 CLINICAL EFFECTS

A) DISORDER OF TESTIS

1) MALE REPRODUCTIVE EFFECTS - Reduction of spermatocytes and damage to the cells lining the seminiferous tubules may follow exposure to microwaves at high energy levels.

3.13 HEMATOLOGIC

3.13.1 SUMMARY

A) WBC CHANGES - Chronic exposure to radiofrequency radiation (Rf) may be related to changes in the white blood cell count (increased total WBCs, lymphocytopenia, monocytosis).

3.13.2 CLINICAL EFFECTS

A) LEUKOCYTOSIS

1) In a working population exposed to RADIOFREQUENCY RADIATION, lymphocytopenia and monocytosis were noted (pp 443-446).

2) Workers exposed to electromagnetic fields from RADARS and HIGH-FREQUENCY RADIOS developed increases in the white blood cell count which significantly correlated with average daily exposure, months of exposure, and total duration of exposure (Marino, 1995).

a) ALL WBCs remained within the normal range, however.

3.14 DERMATOLOGIC

3.14.1 SUMMARY

A) ULTRAVIOLET RADIATION (UV) may have acute and chronic effects on the skin.

1) Acute exposure to UV may cause erythema and sunburn.

2) Chronic exposure to UV, particularly UV(B), accelerates skin aging and increases the risk of developing skin cancer.

B) A dermal warming sensation and thermal burns may result from exposure to INFRARED, VISIBLE SPECTRUM, and RADIOFREQUENCY radiation.

3.14.2 CLINICAL EFFECTS

A) PHOTOSENSITIVITY

1) The skin is a primary target organ for ULTRAVIOLET RADIATION, particularly UV(B) and UV(C).

2) With respect to the skin, there are two general classes of ultraviolet radiation -- "near" UV (320 to 400 nm) and "actinic" UV (200 to 320 nm).

3) ERYTHEMA (Skin ("Sun") Burn) is the most commonly observed acute effect of skin overexposure to UV (Knave et al, 1994). The degree of erythema is dependent on wavelength, duration of exposure, and skin pigmentation (ACGIH, 1991; Knave et al, 1994).

a) UV erythema is a photochemical response of the skin resulting from overexposure to wavelengths in the actinic range of 200 to 320 nm. Maximum sensitivity of the skin occurs at 295 nm (ACGIH, 1991).

b) ARC WELDERS may also be susceptible to developing such "sunburns," unless shielded by materials opaque to UV (Knave et al, 1994).

4) Chronic exposure to UV(B) accelerates the skin aging process (Curtis & Nichols, 1983). This occurs because of selective biological effects on elastin in dermal connective tissue.

5) SKIN CANCER - UV(B) exposure increases the risk of developing skin cancer, especially in individuals with light-colored skin.

B) THERMAL BURN

1) Thermal burns may occur with exposure to INFRARED and VISIBLE SPECTRUM RADIATION. The mechanism is direct thermal injury from radiation absorption by tissue. Skin thermal injury is rare from most non-laser sources and is highly dependent upon the source size and the initial skin temperature (usually 22-25 degrees C). Significantly high irradiances are necessary to produce thermal injury within the pain reaction time (< 1 second) (Anon, 1997).

2) RADIOFREQUENCY RADIATION may cause REGIONAL THERMAL BURNS by a conductive mechanism (Kolmodin-Hedman et al, 1988).

a) Metallic structures may be activated by radiofrequency radiation and become hot (Rogers, 1981a) 1981b; (Kolmodin-Hedman et al, 1988). Conductive heat transfer occurs when an individual touches the activated metallic object and a thermal burn may be sustained.

3) An airline pilot who stood in front of an F-16 microwave radar felt heat in his neck and head, with a right neck mass apparent the following day. CT scan one month later revealed a mass extending from the base of the tongue to the epiglottis. Interstitial edema and coagulation necrosis compatible with thermal injuries were seen on biopsies (Reeves, 2000).

C) HYPERESTHESIA

1) A warming or heating sensation in directly exposed areas may be the first indication of RADAR or RADIOFREQUENCY overexposure (Reeves, 2000; Anon, 1996; Marino, 1995). ERYTHEMA or EDEMA of the affected areas may occur, but is rare (Hill, 1985; Williams & Webb, 1980).

3.15 MUSCULOSKELETAL

3.15.1 SUMMARY

A) A cystic mass in the neck was reported in one case of acute high-dose MICROWAVE RADIATION (RADAR) exposure.

3.15.2 CLINICAL EFFECTS

A) CYST

1) CASE REPORT - Acute high-dose MICROWAVE RADIATION (RADAR) exposure resulted in development of a cystic mass in the neck in one case. The lesion was consistent with a thermal injury on microscopic analysis (Castillo & Quencer, 1998).

3.16 ENDOCRINE

3.16.1 SUMMARY

A) Changes in sympathetic adrenergic hormone excretion were seen in adolescents exposed to INFRARED RADIATION.

3.16.2 CLINICAL EFFECTS

A) HORMONE LEVEL - FINDING

1) In a human experiment, adolescents aged 13 to 15 years exposed to INFRARED RADIATION had changes in sympathetic adrenergic hormone excretion with modifications in the amounts and ratios of epinephrine and norepinephrine excreted in the urine (Knish, 1973).

3.18 PSYCHIATRIC

3.18.1 SUMMARY

A) PSYCHIATRIC MANIFESTATIONS (CASE REPORTS) - Cases of psychiatric manifestations have been reported after acute exposure to MICROWAVE RADIATION. Effects have included anxiety, sleep disturbance, and short term memory impairment.

B) CIRCADIAN RHYTHM - VISIBLE WAVELENGTH RADIATION in the setting of poor quality and excessive

artificial illumination may have adverse psychological effects through disruption of circadian rhythm cycles and changes in hormone levels.

C) ANXIETY - RADIOFREQUENCY RADIATION (Rf) in acute exposure situations may be associated with anxiety.

3.18.2 CLINICAL EFFECTS

A) DISTURBANCE IN THINKING

1) VISIBLE LIGHT - Some evidence suggests that VISIBLE RADIATION has deleterious effects on workers' psychology, with poor quality and increased exposure to artificial illumination possibly affecting hormone production and circadian rhythm cycles (Anon, 1989; Curtis & Nichols, 1983).

B) ANXIETY

1) RADIOFREQUENCY EXPOSURE - Exposure at a level 38 times the permissible exposure level was followed by onset of nausea, lightheadedness, and extreme apprehension.

a) The involved individual noted a warm feeling on the left side, neck, and head immediately after exposure.

b) The blood pressure was elevated in this case.

c) These symptoms most likely reflected anxiety about the exposure.

d) Subsequent treatment for anxiety resulted in full recovery.

3.19 IMMUNOLOGIC

3.19.1 SUMMARY

A) HERPES (HSV) ACTIVATION - ULTRAVIOLET RADIATION (UV) may activate HSV, particularly on the lips and mouth. This effect does not appear to involve immune mechanisms.

3.19.2 CLINICAL EFFECTS

A) HERPES SIMPLEX

1) HERPES VIRUS (HSV) ACTIVATION - ULTRAVIOLET RADIATION can activate HSV, particularly on the mouth and lips.

a) This effect increases markedly at high altitude, where UV(B) levels increase significantly due to decreasing amounts of filtration of this high energy radiation by the atmosphere.

b) Activation appears to be mediated through damage to cellular suppressive control of viral replication and not through an immune-mediated affect.

3.19.3 ANIMAL EFFECTS

A) ANIMAL STUDIES

1) ALTERED IMMUNITY

a) RADIOFREQUENCY RADIATION in thermogenic doses appears to cause immunologic effects in mice. There is no evidence that exposure to radiofrequency at environmental levels causes any adverse alterations in the human immune system (Smialowicz, 1987).

1) Radiofrequency exposure for 60 minutes to 2450 megahertz (MHz) radiation resulted in increased numbers of complement receptor positive splenic B-lymphocytes in some strains of mice.

2) This was apparently due to radiofrequency radiation stimulated maturation of B-lymphocyte precursors. Exposure to thermogenic doses of radiofrequency radiation was found to suppress natural killer cell activity in mice.

3) Increased susceptibility to infection and cancer was noted in mice following exposure to radiofrequency radiation in thermogenic quantities.

b) In rats, Rf exposure at 2450 megahertz (MHz) for 13 months was associated with an increase in splenic B- and T-cells, but no changes in the reticuloendothelial system (Krupp, 1985).

c) UV light is a potent immunosuppressive agent in experimental animals and humans, and this may be a mechanism for its role in causing skin cancer (Ullrich, 1995).

3.20 REPRODUCTIVE

3.20.1 SUMMARY

A) ULTRASOUND in treatment quantities for acute Pelvic Inflammatory Disease (PID) (NOT DIAGNOSTIC quantities) may cause spontaneous abortion.

B) CONGENITAL ANOMALIES and spontaneous abortion have been associated with paternal occupational exposure to MICROWAVE and INFRARED radiation.

3.20.2 TERATOGENICITY

A) LACK OF EFFECT

1) At the present time, there is no convincing evidence that low frequency electromagnetic fields or non-ionizing radiation that are encountered in occupational or daily life exposures have a harmful effect on the human reproductive process (Robert, 1996).

B) ANIMAL STUDIES

1) A risk ratio of 1.88 for fetal malformation was noted in mice exposed to 8 hours of 5 to 30 mW ULTRASOUND at 2.45 MHz over multiple days (Nawrot et al, 1981).

2) Most other animal studies have been negative for teratogenicity (Shepards, 1994).

3) Teratogenicity of RADIOFREQUENCY RADIATION found in rats is primarily related to hyperthermia (Brown-Woodman et al, 1988; Krupp, 1985).

4) Localized high-energy Rf exposure to the ovaries or testes may produce impairment of fertility (Cohen, 1986).

5) Fetal resorption, intracranial hemorrhage, decreased brain weight, cranioschisis, and exencephaly have been reported in experimental animals exposed to high-level power densities from MICROWAVE or RADIOFREQUENCY RADIATION (pp 219-215).

3.20.3 EFFECTS IN PREGNANCY

A) ABORTION

1) Ultrasound in treatment frequencies caused miscarriage in 1/4 pregnant women treated for Pelvic Inflammatory Disease (PID) at 100 watts/2450 MHz over a 10 day period (Shepards, 1994). (Fetal heart detectors use only 5 to 20 milliwatts). DIAGNOSTIC ULTRASOUND produces exposures WELL BELOW levels known to cause harmful effects (Suess, 1985).

B) FERTILITY DECREASED FEMALE

1) Increased frequency of adverse reproductive outcome in a female labor population was found to be more likely related to organic solvent exposure than to RADIOFREQUENCY RADIATION (Fidler & Crandall, 1988).

2) Amongst a cohort of 305 female plastic welding operators with Rf exposure, NO EFFECTS on FERTILITY were noted (Kolmodin-Hedman et al, 1988).

3) VIDEO DISPLAY TERMINALS (VDTs) - Meta-analysis of studies on adverse reproductive outcomes in women who work with VIDEO DISPLAY TERMINALS (VDTs) failed to reveal any significant association (Conrad, 1994; Knave et al, 1994).

a) Researchers concluded that self-reported stress and cigarette smoking were higher in VDT operators, and that these were the factors related to adverse reproductive outcomes (Mackay, 1986).

b) Experimental animal studies with pregnant mice and rats and chicken embryos did NOT demonstrate evidence of teratogenicity from ELF-EMF fields (Knave et al, 1994).

C) CONGENITAL ANOMALY

1) Offspring of male physical therapists were found to have increased rates of congenital anomalies, including Talipes Equinovarus ("Clubfoot" deformity), cardiac anomalies, and anomalies of the limbs and musculoskeletal system, especially amongst first-born children (Logue et al, 1985).

2) In Swedish studies from the 1970s, the incidence of congenital malformations and spontaneous abortions was higher when the MALE parent worked in the electrical distribution field; however, studies from Germany did NOT confirm these results (Knave et al, 1994).

3) These pregnancy outcomes have NOT been definitely proven to be related to exposure.

3.21 CARCINOGENICITY

3.21.2 SUMMARY/HUMAN

A) SKIN CANCER - UV(B) exposure increases the risk of developing skin cancer. This is more likely in individuals with light-colored skin.

B) CNS malignancies, leukemias, and lymphomas have been found in higher incidence in some epidemiological studies of ELECTROMAGNETIC FIELD (EMF) exposed workers, but the association is unclear.

3.21.3 HUMAN STUDIES

A) LACK OF INFORMATION

1) INCONCLUSIVE STUDIES (MICROWAVE RADIATION/RADAR) - In 2 studies of US Navy personnel with RADAR exposure, neoplasms of the gastrointestinal and respiratory tracts and leukemias were found at a higher (but NOT statistically significant) frequency than in unexposed controls (Robinette & Silverman, 1977; Robinette et al, 1980).

2) In a study involving over 40,000 radar workers exposed to low levels of Rf radiation for 2 years and followed up for 20 years, NO increased risk of cancer was noted (Anon, 1996b).

3) Epidemiological research of ELF-EMF exposures and cancer, including childhood leukemias, are inconclusive. With an absence of support from experimental research and inconclusive data, no scientific basis is available for setting exposure guidelines (Anon, 1998).

B) NON-HODGKIN LYMPHOMA

1) In a large case-control study of 694 patients with non-Hodgkin lymphoma and 694 controls, the application of a population-based job-exposure matrix showed a weak positive association between occupational exposure to 50/60 Hz magnetic fields and the risk of non-Hodgkin lymphoma. In the highest exposure group, workers had odds ratio (OR) of 1.48 (95% confidence interval [CI] 1.02 to 2.16) for the entire work history, compared to the referent (lowest quartile; p value for trend was 0.006). The OR was 1.59 (95% CI 1.07 to 2.36) (p value for trend was 0.003) for the 5-year lag exposure period. Adjustment for other occupational exposures did not significantly alter the results (Karipidis et al, 2007).

C) SKIN CARCINOMA

1) UV(B) increases the risk of developing skin cancer (Anon, 1996a; Suess, 1985; Curtis & Nichols, 1983). This is more likely in individuals with light skin.

D) BRAIN CARCINOMA

1) Individuals engaged in certain electrical end electronics occupations have an increased incidence of brain tumors, primarily astrocytic tumors (Thomas et al, 1987).

a) A specific etiologic agent cannot be identified due to multiple and varied exposures (Thomas et al, 1987).

2) Mutnick & Muscat (1997) determined that there was NO increased risk of brain cancer in adults, in an ongoing case-control study of primary malignant brain cancer, with the use of common household appliances. Household appliances with extremely low frequency electromagnetic fields of 50-60 Hz were analyzed in this study, and included personal computer monitors, electric blankets, electric hair dryers, electric dial clocks and other appliances.

E) CARCINOMA

1) POTENTIALLY INCREASED CANCER RATES - A general increase in cancer rates was noted in individuals living in close proximity to US Air Force bases (Lester & Moore, 1982), but this study was seriously flawed by the lack of assessment for other carcinogenic risk factors.

2) MICROWAVE RADIATION-INDUCED CANCER has NOT been documented conclusively to date (Silverman, 1980).

a) Significant changes in cell proliferation at various temperatures for 30 minutes were shown in exposed cells (microwave radiation) in comparison to control cells. These changes were of the same magnitude as experiments conducted isothermally at 37 degrees C, thus changes in cell proliferation (biological effects) due to exposure to Rf/MW fields cannot be attributed only to change of temperature. Cellular stress due to electromagnetic fields may initiate changes in cell cycle reaction rates (Velizarov et al, 1999).

F) PEDIATRIC

1) POSSIBLE EMF-INDUCED CHILDHOOD CARCINOGENICITY - Although epidemiological studies using surrogate measures of EMF exposure have suggested that there might be an increased incidence of childhood cancer due to exposure to electromagnetic fields, considerable controversy (and NO definite proven causal relationship) exists regarding this possibility (Jones, 1993; Savitz & Kaune, 1993).

G) LEUKEMIA

1) ELF-EMF EXPOSURE (Conrad, 1994; Knave et al, 1994):

a) TYPES OF IMPLICATED CANCERS include:

1) Leukemia(s)

2) Lymphoma(s)

3) Nervous System Cancers

4) Brain Cancers

2) HOWEVER, persons involved in such studies have (generally) received UNMEASURED AMOUNTS (if ANY) ELF-EMF exposure(s).

a) TO DATE, there has been a LACK of POSITIVE DOSE-RESPONSE RELATIONSHIPS;

b) AND, DESPITE a several times doubling of CONSUMPTION of ELECTRICITY over the past 40 years, there has NOT been a corresponding increase in the incidence of leukemia(s) or other implicated cancers.

c) Epidemiological studies of certain workers with "electrical" occupations have shown an increased incidence of cancers, especially CNS malignancies and leukemias (Knave et al, 1994).

3) There is, to date, NO COMPELLING EVIDENCE that ELF-EMFs either cause or promote the development of cancer (Horn, 1995).

a) While no possible pathological mechanisms for cancer induction, either biochemical or biophysical, have been discovered, MAGNETIC FIELDS are suspected to be cancer promoters (Knave et al, 1994).

3.22 GENOTOXICITY

A) Animal research on possible **nonionizing** radiation genetic toxicity has generally been inconclusive (Anon, 1996b).

B) In a study exposing human peripheral blood lymphocyte cultures to low frequency pulsed magnetic fields to evaluate possible genotoxic effects of non-ionizing radiation, no genotoxic effects and increased mitotic index were found when compared with controls (Scarfi et al, 1994).

C) An overexpression of the ets1 mRNA in Jurkat T-lymphoblastoid and Leydig TM3 cell lines (in hemopoietic and testicular cell types) was observed under electromagnetic field conditions (50 MHz radiofrequency non-ionizing radiation modulated with a 16 Hz frequency), but only in the presence of the 16 Hz modulation, corresponding to the resonance frequency for calcium ion with a DC magnetic field of 45.7 mcT (Romano-Spica et al, 2000).

4.0 LABORATORY/MONITORING

4.1 MONITORING PARAMETERS/LEVELS

4.1.1 SUMMARY

A) Extensive laboratory tests in the absence of positive findings on a careful history and physical are NOT indicated.

4.1.2 SERUM/BLOOD

A) BLOOD/SERUM CHEMISTRY

1) Extensive laboratory tests in the absence of positive findings on a careful history and physical are NOT indicated.

4.1.4 OTHER

A) OTHER

1) MONITORING

a) SLIT LAMP EXAMINATION is useful for surveillance of individuals occupationally exposed to RADIOFREQUENCIES known to cause lens or retinal damage (Reeves, 2000). This will serve as a baseline rather than a diagnostic tool; many patients get cataracts with aging, and a prompt slit lamp exam will rule out (or in) pre-existing disease and heat-related changes.

5.0 ABSTRACTS

5.2 CASE SERIES

A) ROUTE OF EXPOSURE

1) The scientific literature regarding **nonionizing** radiation exposure consists primarily of case reports and case series.

a) Specific case reports are briefly summarized under the appropriate organ system (in CLINICAL EFFECTS above).

2) CANCER CASE CLUSTERS - Isolated cancer case clusters suggest a possible etiologic link with exposure to **nonionizing** radiation. However, conclusive evidence for cancer causation has NOT been elaborated to date.

3) PANCREATIC CANCER - Two cases of pancreatic cancer occurred in a labor pool of RADIOFREQUENCY equipment repairmen (Zaret, 1986).

4) INSULINOMA - One case of insulinoma occurred in an individual exposed to RADIOFREQUENCY radiation (Zaret, 1986).

5) COHORT STUDIES - Two cohorts of US Navy personnel with Rf exposure were identified and followed medically (Olsen, 1981).

a) The first group were aircraft RADAR security personnel with about 7 months exposure to 9.36

gigahertz (GHz) Rf.

b) The second group were electronics technicians exposed to 10 GHz Rf while doing troubleshooting tasks aboard ships. Preliminary findings indicated NO Rf-exposure-related health effects (Olsen, 1981).

6) EPIDEMIOLOGICAL STUDIES - Studies of workers with long-term, low-level Rf exposure have NOT revealed any related health effects (Cohen, 1986); this, however, is somewhat CONTROVERSIAL (Goldsmith, 1995).

6.0 TREATMENT

LIFE SUPPORT

PATIENT DISPOSITION

MONITORING

EYE EXPOSURE

DERMAL EXPOSURE

OTHER

6.1 LIFE SUPPORT

A) Support respiratory and cardiovascular function.

6.3 PATIENT DISPOSITION

6.3.4 DISPOSITION/EYE EXPOSURE

6.3.4.3 CONSULT CRITERIA/EYE

A) OPHTHALMOLOGIC CONSULTATION - is indicated if there is any evidence of lens or retinal involvement after exposure to INFRARED, VISIBLE SPECTRUM, or ULTRAVIOLET RADIATION when exposure quantification is uncertain.

1) Ophthalmologic consultation is indicated when exposure exceeds the TLV for frequencies known to cause lens or retinal damage.

6.3.4.5 OBSERVATION CRITERIA/EYE

A) Individuals who sustain eye injury from INFRARED, VISIBLE SPECTRUM, or ULTRAVIOLET RADIATION should be observed for ophthalmologic sequelae of retinal and lens involvement.

6.3.5 DISPOSITION/DERMAL EXPOSURE

6.3.5.3 CONSULT CRITERIA/DERMAL

A) Consultation for specialty burn care is the same as for thermal burns.

6.4 MONITORING

A) Extensive laboratory tests in the absence of positive findings on a careful history and physical are NOT indicated.

6.8 EYE EXPOSURE

6.8.2 TREATMENT

A) OPHTHALMIC EXAMINATION AND EVALUATION

1) OPHTHALMOLOGY CONSULTATION - Comprehensive ophthalmology evaluation is needed if there is an exposure in excess of the TLV for frequencies known to cause lens or retinal damage.

a) Slit lamp examination is helpful in examination of the lens.

b) Indirect ophthalmoscopy is needed to assess the retina thoroughly for lesions.

1) This is particularly important in cases of LASER INJURY.

2) Visual fields testing is also necessary in cases of LASER INJURY.

B) INJURY OF GLOBE OF EYE

1) KERATOCONJUNCTIVITIS - Treatment is similar to that for other causes of acute conjunctivitis, and

includes topical antibiotics, topical mydriatics (short-acting), and eye patching if indicated.

6.9 DERMAL EXPOSURE

6.9.2 TREATMENT

A) BURN

1) Acute burns resulting from INFRARED, VISIBLE SPECTRUM, and ULTRAVIOLET RADIATION exposure are treated as thermal (or CHEMICAL) burns.

2) APPLICATION

a) These recommendations apply to patients with MINOR chemical burns (FIRST DEGREE; SECOND DEGREE: less than 15% body surface area in adults; less than 10% body surface area in children; THIRD DEGREE: less than 2% body surface area). Consultation with a clinician experienced in burn therapy or a burn unit should be obtained if larger area or more severe burns are present. Neutralizing agents should NOT be used.

3) DEBRIDEMENT

a) After initial flushing with large volumes of water to remove any residual chemical material, clean wounds with a mild disinfectant soap and water.

b) DEVITALIZED SKIN: Loose, nonviable tissue should be removed by gentle cleansing with surgical soap or formal skin debridement (Moylan, 1980; Haynes, 1981). Intravenous analgesia may be required (Roberts, 1988).

c) BLISTERS: Removal and debridement of closed blisters is controversial. Current consensus is that intact blisters prevent pain and dehydration, promote healing, and allow motion; therefore, blisters should be left intact until they rupture spontaneously or healing is well underway, unless they are extremely large or inhibit motion (Roberts, 1988; Carvajal & Stewart, 1987).

4) TREATMENT

a) TOPICAL ANTIBIOTICS: Prophylactic topical antibiotic therapy with silver sulfadiazine is recommended for all burns except superficial partial thickness (first-degree) burns (Roberts, 1988). For first-degree burns bacitracin may be used, but effectiveness is not documented (Roberts, 1988).

b) SYSTEMIC ANTIBIOTICS: Systemic antibiotics are generally not indicated unless infection is present or the burn involves the hands, feet, or perineum.

c) WOUND DRESSING:

1) Depending on the site and area, the burn may be treated open (face, ears, or perineum) or covered with sterile nonstick porous gauze. The gauze dressing should be fluffy and thick enough to absorb all drainage.

2) Alternatively, a petrolatum fine-mesh gauze dressing may be used alone on partial-thickness burns.

d) DRESSING CHANGES:

1) Daily dressing changes are indicated if a burn cream is used; changes every 3 to 4 days are adequate with a dry dressing.

2) If dressing changes are to be done at home, the patient or caregiver should be instructed in proper techniques and given sufficient dressings and other necessary supplies.

e) Analgesics such as acetaminophen with codeine may be used for pain relief if needed.

5) TETANUS PROPHYLAXIS

a) The patient's tetanus immunization status should be determined. Tetanus toxoid 0.5 milliliter intramuscularly or other indicated tetanus prophylaxis should be administered if required.

6) RADIOFREQUENCY BURNS - are usually confined to a relatively small region and burn therapy is often intensive because of the energy concentration sustained via conduction from the activated object to the affected body part (Rogers, 1981a) 1981b; (Kolmodin-Hedman et al, 1988).

B) DRUG WITHDRAWAL

1) TREATMENT OF RADIOFREQUENCY (Rf) EXPOSURE - includes REMOVAL from FURTHER EXPOSURE, treatment of BURNS if present, and followup for psychological, neurologic, and blood pressure effects (Cohen, 1986).

6.12 OTHER

A) OTHER

1) Neurology consultation should be sought if neurological sequelae appear after significant regional or whole person exposures to MICROWAVE RADIATION.

2) Individuals with MICROWAVE overexposure who relate an immediate sensation of heat, headache, or pain should be observed for neurological sequelae.
3) DISTANCE - from ELECTRICAL and/or MAGNETIC FIELDS is the BEST DEFENSE against possible adverse effects (Conrad, 1994; Knave et al, 1994).

7.0 RANGE OF TOXICITY

SUMMARY

MAXIMUM TOLERATED EXPOSURE

CALCULATIONS

7.1 SUMMARY

A) Infrared radiation affects the eyes of humans and animals at varying doses. Microwave radiation did not yield any exposure-related complaints in workers.

7.4 MAXIMUM TOLERATED EXPOSURE

A) SPECIFIC SUBSTANCE
1) INFRARED RADIATION -
a) In rabbits, INFRARED RADIATION at >4.0 watts/cm(2) resulted in a threshold radiant exposure to the CORNEAS of 1250 Joules/cm(2), to the IRIS of 1250 Joules/cm(2), and to the LENS of 2250 Joules/cm(2) (Pitts et al, 1980).
b) In primates, INFRARED RADIATION at >4.0 watts/cm(2) resulted in a threshold radiant exposure to the IRIS of 8,000 Joules/cm(2), and to the LENS of 10,000 Joules/cm(2) (Pitts et al, 1980).
1) A threshold induced tissue temperature change for INFRARED LASER RADIATION for producing LENS CHANGES of 38.5 to 40.0 degrees C exists in experimental animals (Wolbarsht et al, 1977).
2) MICROWAVE RADIATION -
a) Workers exposed to MICROWAVE RADIATION at 6 to 138 microwatts/cm(2) for periods ranging from 23 to 317 minutes per exposure did NOT have exposure-related complaints (pp 21-25).
3) RADIOFREQUENCY RADIATION (Rf) (RADAR) -
a) US Naval shipboard RADAR units may produce potential Rf exposures between 0.4 and 7.58 milliwatts/cm(2) (Olsen, 1981).
1) Amongst US Air Force personnel, those working in the vicinity of fixed-base search RADAR were exposed to average power densities of less than 1 microwatt/cm(2);
2) Those exposed to height-finder RADAR had short-term (0.5 to 2 minute) exposure in the TENS of microwatts/cm(2);
b) Exposures to phased-array RADAR systems were much lower; and
c) Exposures which occurred in the vicinity of aircraft were difficult or impossible to quantify because of their intermittent nature (Hunt & Allen, 1981).
4) LASERS -
a) Reference: (Thomas, 1994)
1) TIME necessary for temporary LASER FLASH-BLINDNESS-INDUCED scotomata to resolve depends on:
1) Target Contrast
2) Target Brightness
3) Target Size
4) Visual System Adaptation (Overall)
b) Reference: (Albanese et al, 1994)
1) When an electromagnetic pulse hits human tissue, charged entities become moved by the pulse passing through the tissue, such that displaced particles radiate a portion of the applied energy in a propagating electromagnetic field.
5) ELF-EMFs (Knave et al, 1994) -
a) A magnetic flux density of about 0.2 uT has generally been estimated in epidemiological studies of residential ELF-EMF exposure.

b) Certain "electrical" occupations may have magnetic flux density exposure up to 10,000 times greater than that found in residences.
c) Repacholi & Greenebaum (1999) reported no health hazards were associated with exposure to low-level fields, including environmental levels, with static magnetic fields at flux densities below 2T (Repacholi & Greenebaum, 1999).

7.8 CALCULATIONS

A) BIOLOGICAL CONVERSIONS

1) OTHER

a) General wavelength/frequency formula for electromagnetic radiation:

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Wavelength = (light velocity)/(frequency)
Units:  Frequency in Hz (1 Hz = 1 cycle per second)
        Wavelength in meters
        Light velocity is 300,000 km/sec
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b) Ultraviolet radiation exposure TLV calculation (ACGIH, 1991) -

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For 320 to 400 nm:
 total irradiance should not exceed 1 mW/cm(2) for
 periods greater than 16 minutes and should
 not exceed 1 J/cm(2) for exposures less than
 16 minutes
For 200 to 315 nm:
 radiant exposure may vary according to the
 spectral weighting function outlined by
 ACGIH (1991)
 The spectral weighting formula is based on
 the relative energy levels compared to a
 standard wavelength of UV:  270 nm
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c) ELF-EMF LEVELS (Conrad, 1994)

1) Digital or Analog Meters give readings in either milligauss (mG) or microtelsa (uT);

a) One Telsa = 10,000 Gauss (or 10,000,000 mG)

2) There are TWO types of such meters: Single Axis and Three Axis

a) Such instruments should be calibrated annually

9.0 PHARMACOLOGY/TOXICOLOGY

9.2 TOXICOLOGIC MECHANISM

A) ULTRASHORT ELECTROMAGNETIC PULSES -

1) POTENTIAL TISSUE DAMAGE MECHANISMS (Albanese et al, 1994) -

a) Changes in macromolecular conformation
b) Effects on chemical reactions
c) MEMBRANE Alterations
d) TEMPERATURE-MEDIATED Adverse Responses

B) NEAR INFRARED (NIR)/VISIBLE SPECTRUM LASERS -

1) Reference: (Thomas, 1994)

2) Effects of Exposure

a) Glare
b) Flashblindness
c) Thermal Lesions (ocular)
d) Hemorrhagic Lesions (ocular)

C) RADIOFREQUENCIES (Rf) -

1) Three levels of RF exposure are defined: (1) HIGH Rf exposure (thermal regime) where the core temperature of the organism may rise several degrees; (2) INTERMEDIATE Rf exposure, or "athermal"

exposure, where thermoregulation maintains the organism's temperature at its nominal value; and (3) LOW-LEVEL Rf exposure, or "nonthermal" exposure, where no challenge to thermoregulation exists and no significant change in organism temperature occurs (Repacholi, 1998).

a) It has been reported that Rf fields affect a variety of ion-channel properties, including decreased rates of channel formation, decreased frequency of single channel openings, and increased rates of rapid, burst-like firing. The cell membrane may be susceptible to low-level Rf fields, particularly when these fields are amplitude-modulated at ELF frequencies. At high frequencies low-level Rf fields do not induce appreciable membrane potentials. Low-level Rf fields can penetrate cell membranes and possibly influence cytoplasmic structure and function, although this is only poorly understood at this time (Repacholi, 1998).

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