Exposure to EM Radiation from Radar:

Health Implications for

Navy Personnel

Aviators & other Military Servicemen / Radar Personnel

Band PR, et. al. *Am J Epidemiol* , Jan 15;143(2):137-43 (1996)

These authors investigated the potential link between pilots' exposure to non-ionizing radiation and the incidence of cancer. Mortality statistics were reviewed for 2,740 pilots using standardized mortality and incidence ratios (SMR) & (SIR). Rates were contrasted with a non-exposed referent population. The preferred relative risk model for radiation-induced nonchronic lymphoid leukemia (Beir V report) was applied to the cohort by using published estimates of in-flight radiation exposures (conceivably emitted from radar installations). Ninety percent confidence intervals of the SMR and SIR were also calculated. These authors found statistically significant increases in the incidence of acute myeloid **leukemia** (SIR = 4.72, 90% CI 2.05-9.31 and **prostate cancer** (SIR = 1.87, 90% CI 1.38-2.49) in the pilots when compared to the referent population. They suggest that that closer monitoring of aviators' in-flight exposure to non-ionizing radiation and long-term follow-up of aviation crew members is needed.

Band PR, *Aviat Space Environ Med.* Apr;61(4):299-302 (1990)

This study investigated the relationship between pilots' exposure to non-ionizing radiation (conceivably from radar installations) and the incidence of cancer. Mortality statistics were reviewed for 891 pilots using standardized mortality and incidence ratios (SMR) & (SIR). Rates were contrasted with a similar but non-exposed referent population. These authors found that when compared to the referent group, aviators experienced excess deaths due to **brain cancer** (No. = 4; SMR = 4.17, p = 0.017; CI 1.40, 9.50) and **rectal cancer** (No. = 3; SMR = 4.35; p = 0.033; CI 1.20, 11.20). Pilots also had **excessive incidence rates of brain cancer** (No. = 4; SIR = 3.45; p = 0.030; CI 1.20, 7.90), **Hodgkin's Disease** (No. = 3; SIR = 4.54; p = 0.030; CI 1.20, 11.70) and non-melanoma **skin cancer** (No. = 26; SIR = 1.59; p = 0.017; CI 1.10, 2.20).

Budinscak V, et. al., *Arh Hig Rada Toksikol* 42(4):367-373, (1991)

This study looked at the incidence blood cell abnormalities is radar operators. Hematological parameters were measured in 43 radar operation personnel exposed to microwave radiation of low intensity over a period of four years. Exposures to soft X-ray radiation were within maximally allowed limits. Personnel assigned to radar operations showed hematological changes which included a **decreased number of erythrocytes, reticulocytes, platelets, segmented granulocytes** and **monocytes,** and an **increased number of leucocytes and lymphocytes.**

Davis RL, et. al. *Am J Ind Med* 24(2):231-233, (1993)

This study looked at the incidence of testicular cancer in security officers to see if those exposed to non-ionizing radiation from radar was related to an increased incidence of cancer. Out of the cohort of 340 officers examined, six incident cases of **testicular cancer** occurred between 1979 and 1991. This study found that occupational use and close proximity exposure to EM radiation from radar was the only shared risk factor among all six officers.

Flaherty JA, *Austr Fam Physician*, 23(5), 902-904 (1994)

This opinion piece suggests that exposure to non ionizing EM radiation / microwaves from radar may in the short term have a stimulating effect on the anterior pituitary gland, and in turn on the gonads of both sexes in Air Force personnel. He hypothesizes that the long-term effect of non-ionizing radiation on Air Force personnel may be related to increased risks for adenoma and carcinoma. He also cites research that suggests that X-rays to the head and neck in infancy, childhood or adolescence are associated with a high incidence of thyroid disease later in life. Ionizing radiation from X-rays is also related to increases in nodular diseases which may not be apparent until 30 years or more after exposure. One-third of these nodular type illnesses are found to be carcinomatous. This author hypothesizes that non-ionizing radiation may have a similar long-term carcinogenic effect and suggests that there is a need for more investigation into the possible relationship between non-ionizing EM radiation from radar and the incidence of cancer.

Garland FC, et. al., *Int J Epidemiol* Sep;16(3):367-372 (1987)

US Navy sailors working as Machinists' mates face probable exposure to **ionizing** radiation. Though not directly related to lower frequency EM Radiation of a non-ionizing type, this study is important since it is conducted by US Naval researchers at the Occupational Medicine Department, Naval Health Research Center in San Diego. These researchers looked at **Navy** personnel to see if occupational exposures were related to excessive rates of Hodgkin's disease. It found that machinists' mates had about double the risk of **Hodgkin's disease** when compared to sailors from all other occupations in the **Navy** (SIR = 2.3, p = 0.004). The rate of Hodgkin's disease was also about double in this group when compared to the general US population (SIR = 1.8, ns). They also observed an increased incidence of the disease in this group with increasing length of **Navy** service. The authors conclude that Machinists' mates face probable exposure to ionizing radiation as well as other potential toxins and that further studies are needed to clarify the association between this exposure and the incidence of Hodgkin's disease.

Garland FC, et. al., *Amer J. Epidemiol*, 132(2): 293-303 (1990)

These authors from the US Naval Health Research Center in San Diego looked at Leukemia rates in the US Naval personell as they related to exposure to EM radiation. Historical computerized military career records maintained at the Naval Health Research Center were used to determine risk. Computerized inpatient medical records were searched for first hospitalizations for leukemia. Cases of leukemia (n = 102) were verified by using pathology reports or **Navy** Medical Board or Physical Evaluation Board findings. For comparisons, age-adjusted incidence rates and standardized incidence ratios were calculated by using rates for the US population provided by the Surveillance, Epidemiology, and End Results program of the National Cancer Institute. Of all classes studied, only one class of sailor, electrician's mate, assumed to be subject to greater exposure to electromagnetic radiation generated by radar and other instruments, showed a statistically significant excess risk of **leukemia** (standardized incidence ratio compared referent population = 2.4, 95% confidence interval 1.0-5.0). This was the only occupational class that demonstrated an increased

rate of leukemia when compared to the referent population. These authors suggest there may be a connection between exposure to EM radiation in this population and the excessive incidence of cancer.

Goldsmith JR, *Int J of Occup Environ Health* Jan (1): 47-57 (1995)

This author compiled and reviewed collective studies and data from multiple sources including peer reviewed research. This review looked at the possible health effects of radar exposure in US military (**US Navy** personnel) and other occupational designations. Some of the data sources include: 1) historical data, 2) data on the experiences of soldiers, 3) research on U.S. **Navy** personnel using radar in wartime, 5.) reproductive outcomes among physiotherapists using short-wave and microwave diathermy, and 6.) U.S. foreign service personnel chronically exposed to non-ionizing radiation from radar at embassies in Eastern Europe. This author reviewed: 1) **blood count changes**, 2) evidence of **somatic mutation**, 3) **reproductive impairment**, especially increased spontaneous abortion, and 4) increases in **cancer incidence** and mortality, especially **of the hematopoietic system, brain**, and **breast**. The author presents evidence for each which suggests that sufficient microwave exposures from radar are associated with an increased incidence of pathology in all four of these areas. The author also proposes that the effects of non-ionizing radiation and their timings (with respect to exposure) are qualitatively similar to those of ionizing radiation. Because of this, the review concludes that a prudent course of action would be to provide more protection for exposed personnel than is currently required by existing (IEEE) recommendations and regulations.

Goldoni J, et. al., *Health Physics* 58:205-207 (1990)

This study looked at the potential relationships between EM radiation exposure experienced by radar workers and blood cell abnormalities. Hematological examinations were performed at an interval of 2 years on 14 male radar workers who were exposed to microwaves from radar installations. These personnel were exposed for between 7-14 years to pulsed microwaves from radar. Exposure to various frequencies ranging across the entire spectrum of those used such systems also occured. The authors indicate that they observed significant decreases in thrombocyte and leukocyte counts in the cohort population than could be expected. The number of leukocytes and erythrocytes in the peripheral blood was also significantly lower in individuals in the exposed as compared to those in the referent group.

Goldoni J, *Arh Hig Rada Toksikol* 44(3):223-228 (1993)

This study looked at the relationships between EM radiation exposure experienced by radar workers (as well as other occupational groups) and blood cell abnormalities, electrical brain activity abnormalities, and capillaroscopic & ophthalmological abnormalities. Examinations were performed twice over an 18 month period on a group of 49 male radar operators who were exposed to non-ionizing radiation from radar. The exam results were compared to a non-exposed referent group. The results showed that the radar operators had significant changes in hematological and biochemical parameters, as well as abnormalities in electrical brain activity. Additionally, a cross-sectional study of the differences in general health status showed that radar operators showed the highest rate of changes of any group studied. The authors conclude that long-term occupational exposure to microwaves / RF radiation may damage sensitive organic systems.

Grayson JK, et. al., *Aviat Space Environ Med* Feb;67(2):101 4 (1996)

This is a US Air Force study based out of Armstrong Laboratory, Occupational and Environmental Health Directorate, at Brooks AFB in Texas. These researchers compared the rate of cancer in US Air Force aviators (342 cancers,) with non-flying USAF officers (827 cancers,). Incident rates of cancer for both aviators

and non-flying officers were obtained from hospitalization records. Age-adjusted standardized incidence ratios (SIR's) were calculated for aircrew using data from the National Cancer Institute's Surveillance Epidemiology and End Results (SEER) program. Aviator age-adjusted cancer rate ratios were also obtained using non-flying officers as an internal comparison group. When contrasted to the reference group, they found that aviators had statistically significant excesses of testicular cancer, and urinary bladder cancer. Aviators also had excessive rates of cancer in all sites combined when compared to the non-flying officers. One characteristic all USAF aviators have in common is repeated exposure to non-ionizing radiation from radar.

Grayson JK, *Am J Epidemiol* 143(5):480-486 (1996)

This nested, case-referent study looked at electromagnetic field exposures and brain tumor risk in the US Air Force servicemen. Air Force servicemen exposed to EM radiation/microwave EM fields were found to have an increase risk of brain tumors. This risk increased with age and length of service. The author indicates that these results support an association between extremely low frequency and radio frequency/microwave electromagnetic field exposure and brain tumors. Military rank also was consistently associated with brain tumor risk. Officers were more likely than enlisted men to develop brain tumors (age-race-adjusted odds ratio (OR) = 2.11, 95% CI 1.48-3.01), and senior officers were at increased risk compared with all other US Air Force members (age-race-adjusted OR = 3.30, 95% CI 1.99-5.45).

Groves FD, *Am J Epidemiol* May 1;155(9):810-8 (2002)

This study conducted by The Division of Cancer Epidemiology and Genetics at the National Cancer Institute reports on over 40 years of mortality follow-up of 40,581 US **Navy** veterans who had exposure to high-intensity radar. The cohort death rates were compared with mortality rates for white US men using standardized mortality ratios. Additionally, the death rates for men in occupations considered a priori to have high radar exposure were compared with the rates for men in low radar exposure occupations using Poisson regression. Non-lymphocytic leukemia was significantly elevated among sailors in one of the three high radar exposure occupations, namely, electronics technicians in aviation squadrons (SMR = 2.2, 95% CI: 1.3, 3.7).

Hjollund NH, et.al., *Reprod Toxicol* 11(6):897 (1997)

These authors conducted a survey of semen quality among military servicemen operating mobile ground-to-air missile units that use EM radiation emitting radar systems. The median sperm density of the servicemen was significantly low compared to those in the referent group. The authors suggest that the decreased semen sperm count was potentially due to the effects of microwaves emitted by the radar system.

Irvine D, *Aviat Space Environ Med* Apr;63(4):276-279 (1992)

This study looked at aviators and the unique environmental risks they face including repeated exposure to non ionizing radiation from sources such as radar. This study looked at 441 pilots and reviewed mortality data on each using the Proportional Mortality Ratio (PMR) technique in order to compare actual cancer rates with expected rates. When contrasted with expected mortality rates this study found that pilots experienced an excessive number of deaths due to brain cancer / CNS cancer (2.68), colon cancer (2.30) and malignant melanoma (6.68). They also experienced excessive mortality due to cancer as whole. (PMR 1.31). The study concludes that further investigation is warranted given that pilots are exposed to a variety of environmental risks including non-ionizing radiation from radar.

Hardell L, et. al. *Int J Oncol* 13(6):1299-1303 (1998)

Occupational exposure to non-ionizing radiation from radar was assessed in this case-referent study on testicular cancer. Answers on a health questionnaire were obtained and analyzed from148 (91%) individuals with cases of testicular cancer and 314 (87%) individuals from a referent cohort group. Of the personnel with cancer, 101 had seminoma and 47 had embryonal testicular cancer. Increased risks of cancer were found for workers who were exposed to radar (OR 2.0; CI 0.3-14.2). Increased risks were also found for engineers in electronics and personnel in the telecommunication industry (OR 2.3; CI 0.8-6.7) both groups who are exposed to EM radiation fields.

Holly EA, *Epidemiology* 7(1):55-61 (1996)

In this study, exposure to radar as an occupational hazard was linked to uveal melanoma. This case-controlled study was conducted in the Western United States. The subject population consisted of 221 male patients and 447 case referent controls. This research was undertaken to determine the relationship between occupational status and the risk for developing intraocular melanoma. These authors found that occupational groups exposed to radar/microwaves had significant increased risks for developing uveal melanoma (eye cancer).

Moszczynski P, et. al., *Wiad Lek* 52(1-2):30-34 (1999)

This study looked at radar operators who were presumably exposed to EM radiation fields and found they had decreased counts of lymphocytes and T8 cells. These authors measured immunoglobulin concentrations and T lymphocyte subsets in personnel who had occupational exposure to EM radiation from radar. They found that IgM concentration was elevated in radar operators more than could be expected. They also found that these personnel had a decrease in the total T8 cell count. Personnel who were exposed to EM radiation emitted from other specific sources also had increased IgG and IgA concentrations and decreased counts of lymphocytes and T8 cells. These authors suggest that these biological effects on immunoglobulin concentrations and T8 cell count are related to exposure to EM radiation both from radar and non-radar sources.

Richter ED, et. al., *Int J Occup Environ Health* 6(3):187-193 (2000)

This study examined the health risks to young military personnel from exposure to electromagnetic / radio-frequency irradiation (RF/MW) from radar. The authors report exposure-effect relationships in servicemen serving as radar technicians and their co-workers. The study group was composed of service men who were exposed to high levels of RF/MW radiation from radar installations. The authors estimated relative risks for cancer in this group and latency periods for a larger group of soldiers. Index soldiers with melanoma of the eye, testicular cancer, nasopharyngioma, non-Hodgkin's lymphoma, and breast cancer were in the 20-37 year age group. These authors found that soldiers with occupational service assignments that included prolonged exposures to high levels of RF/MW radiation from radar had higher cancer risks for the entire body. Cancer clusters involved many different types of tumors and latency periods were also extremely brief in these young index soldiers. Briefer than could be expected in fact. The authors conclude that the very short latency periods suggest high risks from high-level exposures. Calculations derived from a linear model of dose-response suggest the need to prevent exposures in the range of 10-100 muw/cm(2).

Richter ED, et. al., *Arch Environ Health* 57(4):270-272 (2002)

This study examined 5 military servicemen who had brain tumors that appeared within 10 years of their initial occupational exposures to radar. Four of the patients were less than 30 years of age when the diagnoses were initially made. The authors indicate that brief induction periods that follow high exposures in individual sentinel patients are a recognized indicator of impending group risk for **brain cancer**. This study suggests that soldiers or other military personnel who are stationed or working near vicinities where they could sustain brief high exposure to EM radiation from radar need to take precautions.

Robinette CD, et. al., *American Journal of Epidemiology*, 112(1):39-53 (1980)

In this study, the authors looked at the health and mortality records for about 40,000 U.S. **Navy** sailors. These authors indicate that **Navy** personnel who were exposed to EM radiation from radar had increased mortality due to respiratory cancer ($p<0.05$). Furthermore, radar exposed sailors showed a trend (though one which did not reach statistical significance) toward increases in total mortality as well. This study is interesting because the original data was later reviewed and reanalyzed by Goldsmith, **(Goldsmith, J R, *Environm Health Perspectives*, 105, (Suppl 6),: 1579-1587 {1997}).** Based on job descriptions, Goldsmith re-assigned specific occupational classes so as to more accurately group those occupation classes that were most likely to have high EM radiation exposure levels from radar. After re-analyzing the original data using the re-assigned groups this author found increases in muscular, bone and joint illnesses including **bone and muscle cancer**, ($p<0.001$) as well as increased rates of **cardiovascular illnesses** ($p<0.001$) and **psychophysiologic disorders** ($p< 0.05$).

Salisbury DA, et. al., *Aviat Space Environ Med* Apr;62(4):351-352 (1991)

These authors studied the mortality experience of 341 aviators. They used proportional mortality ratios (PMR) and proportional cancer mortality ratios (PCMR) to measure differences in the expected rates of cancer versus the actual rates of cancer in these pilots. They report that aviators showed a (non statistically significant) trend towards have comparatively elevated rates of brain & central nervous system cancer, Hodgkin's disease and colon cancer. These authors suggest that because this study was based on a small number of deaths and statistical significance could not be demonstrated, there is a need for further epidemiologic studies.

Santana VS, et. al., *Int J Occup Environ Health* Apr-Jun;5(2):88-94 (1999)

This study looked at the risk for primary malignant brain tumors in **Navy** personnel. These authors reviewed death certificates and corresponding occupational assignments of **Navy** servicemen from 1991 to 1995. The goal of the study was to see if differing occupational assignments were related to higher than expected cancer rates. They studied 40 sailors with brain and CNS cancer as well as 671 sailors who also went on to develop and succumb to other types of cancer. They found that sailors engaged in direct combat training (conditions where sailors are often in close proximity to and exposed to EM radiation from radar) had excessive brain tumor mortality (OR = 2.30; 95% CI: 0.89, 5.99). These authors indicate that there is a need for a more detailed study of environmental exposures to address brain cancer risk factors in **Navy** personnel.

Silva M, et. al., *Rev Saude Publica* Aug;34(4):373-9 (2000)

These authors looked at differences in cancer mortality among **Navy** servicemen and compared them to a referent population. The authors attempted to review potential occupational assignment and

exposure risk factors among sailors. They found that **Navy** servicemen are more likely to die from brain cancer/ neoplasm (age-adjusted cancer proportionate mortality ratio - ACPMR=339.27), non-Hodgkin lymphoma (ACPMR=152.28) and prostate cancer (ACPMR=135.04), than their counterparts in the referent population. They concluded that Naval servicemen have a cancer mortality profile distinct from the general referent population and urge further study of occupational-related environmental exposure data.

Szmigielski S, *Sci Total Environ* 180(1):9-17 (1996)

Cancer morbidity was measured in a very large cohort (128,000 per year) of military career personnel during a 15 year period. Servicemen exposed occupationally to electromagnetic radiation (RF) and microwaves (MW), likely emmitted from radar systems, were selected from the population on the basis of their service records and documented exposures at service posts. When these soldiers were compared with non exposed servicemen, those who were exposed had higher risks of brain tumors and nervous system tumors. This finding was consistent across all three categories of exposure low radiation exposure, mid radiation exposure and high radiation exposure. Cancers included neoplasms of the alimentary, malignancies of the haemopoietic system and lymphatic organs, chronic myelocytic leukaemia , acute myeloblastic leukaemia and non-Hodgkin lymphomas. The cancer rates for exposed servicemen for all age groups (20-59 years) reached 119.1 per 100,000 annually compared to 57.6 in the non-exposed group (significant at $p < 0.05$.). It is not statistically likely that the differences in cancer rates between these two groups can be attributed to chance.

Weyandt TB, et. al. *Reprod Toxicol* 10(6):521-528 (1996)

This was a collaborative study between the U.S. Army Biomedical Research and Development Laboratory (USABRDL) and the National Institute for Occupational Safety and Health (NIOSH) that was designed to assess fecundity of male soldiers who experienced microwave EM radiation exposure as radar equipment operators. These army researchers conducted analyses of blood hormone levels and semen analyses on soldiers assigned as radar equipment operators (n = 20), and soldiers who were selected for the comparison referent group (n = 31). Soldiers classified as radar operators showed significantly lower sperm counts/mL ($p = 0.009$) as well as lower sperm / ejaculate ($p = 0.027$) when compared to soldiers in the referent group.

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