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OCCUPATIONAL EXPOSURE OF POLICE OFFICERS

TO MICROWAVE RADIATION FROM

TRAFFIC RADAR DEVICES

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Contents

Executive Summary

In August 1992, a Congressional hearing was convened by Senator Joseph Lieberman of Connecticut, Chairman of the Ad Hoc Subcommittee on Consumer and Environmental Affairs of the Senate Committee on Governmental Affairs, on the safety of police traffic radar devices. Congress subsequently directed the National Institute for Occupational Safety and Health (NIOSH) to study the cancer incidence among law enforcement officers who had used traffic radar devices. In response, NIOSH conducted a feasibility assessment to determine whether an epidemiologic study was possible and would provide meaningful information about potential risks. This report describes our findings. Included is an exposure assessment, an analysis of existing record sources, and a summary of our recommendations, including five specific recommendations to reduce or prevent exposure to microwave radiation from traffic radar devices.

Exposure Assessment:

Extensive assessments of exposure to microwave radiation emitted from traffic radar devices were conducted under a variety of conditions. These assessments indicated that present day exposures of law enforcement officers were consistent with published studies reporting low exposures. (Exposures to the police officers operating radar guns are, in most cases less than 20 μW/cm^2.)

In addition to evaluating current exposure, we also sought to determine whether past radar exposure could be assessed among police officers. Because law enforcement agencies do not systematically record traffic radar use, surrogates for exposure, such as citation records, were sought to reconstruct past radar use. Unfortunately, no suitable records were found.

Feasibility of Epidemiologic Study of Cancer and Use of Radar Guns:

The purpose of an epidemiologic study would be to determine whether police officers who use radar guns are at an increased risk of disease, specifically, testicular cancer. Several types of epidemiologic study designs, including cohort mortality, incidence, and case-control, were considered. Each of these study designs has advantages and limitations. NIOSH investigators contacted police officers from several states, as well as officials of other federal agencies and selected state health departments, to assess whether existing data sources (such as historical police records and cancer incidence registries) would support an epidemiologic study.

We determined that there were several problems in conducting an epidemiologic study of testicular cancer and radar exposure. First, the low incidence rate of the disease would necessitate the pooling of data from many state police departments to detect an association between testicular cancer and radar use. Second, there is no national tumor registry from which cases can be identified. Finally, no record system exists that specifically identifies officers exposed to traffic radar, the specific types of radar used, and the amount of radar exposure.

In summary, these problems limit the ability to conduct a successful and scientifically valid epidemiologic study of radar gun use and risk of cancer.

Recommendations to Reduce Exposure:

Although conducting a definitive epidemiologic study of health risks associated with traffic radar devices does not seem feasible at this time, we are able to make concrete recommendations to reduce exposure. Following these recommendations should virtually eliminate exposure to microwave radiation while still permitting the use of radar guns. Several recommendations, specified in the technical report, pertain to the type, operation, placement, maintenance, and proper usage of traffic radar devices.

The following procedures are recommended to reduce or prevent exposure to microwave radiation emitted from traffic radar devices:

1. Hand-held devices should be equipped with a switch requiring active contact to emit radiation. Such a switch, referred to as a "dead-man switch," must be held down for the device to emit radiation, even though the electrical power to the device is on. Adherence to this recommendation should permit the continued use of one-piece, or hand-held radar units.

2. Older hand-held devices that do not have a "dead-man switch" should not be placed with the radiating antenna pointed toward the body, whether it is held in the hand or placed near the officer. A holster or other similar device should be used as a temporary holder for the radar when not in use.

3. When using two-piece radar units, the antenna should be mounted so that the radar beam is not directed toward the vehicle occupants. The preferred mounting location would be outside the vehicle altogether, although this may not be practical with older units that cannot withstand adverse weather conditions. Other options, e.g., mounting on

the dashboard of the vehicle, are acceptable if the antenna is at all times directed away from the operator or other vehicle occupants. Mounting the antenna on the inside of a side window is not recommended.

4. Radar antennas should be tested periodically, e.g. annually, or after exceptional mechanical trauma to the device, for radiation leakage or back scatter in a direction other than that intended by the antenna beam pattern.

5. Each operator should receive training in the proper use of traffic radar before operating the device. This training should include a discussion of the health risks of exposure to microwave radiation and information on how to minimize operator exposure.

These exposure control recommendations can be implemented without delay, and are not contingent upon further epidemiologic studies.

Recommendations for Future Work:

In conducting this feasibility assessment, several papers were identified suggesting that police are at greater risk than the general population for a number of adverse health outcomes. Excess risks have been observed for premature death, specifically from cardiovascular disease, homicide, suicide, and certain cancers. The results of these studies and the large population of municipal, state, and federal police officers demonstrate the public health importance of better understanding the relationship between the many occupational exposures and health problems experienced by police.

To learn more about the risks of job-related injury and disease for police officers, data concerning exposures and health outcomes should be collected for a large number of officers representing a variety of state and local law enforcement departments. Then, if disorders for which police appear to be at higher risk (e.g., testicular cancer) are identified, specific epidemiologic analyses could be completed more quickly and economically.

INTRODUCTION

The number of police traffic radar (speed-measuring) devices now in use in the United States has been variously reported to be between 75,000 and 100,000 units.[1, 2] Although no census exists of traffic radar operators, it is likely that there have been hundreds of thousands of police officers who have used these devices at some time during the last twenty years. Considerable publicity was given to this issue following an investigation in 1990 conducted by an Ohio State Highway Patrolman, Officer Gary Poynter, of officers who have used traffic radar and have developed cancer.[3-5] The data obtained by Officer Poynter, combined with the publicity that followed, increased the concern of law enforcement officers that the use of such devices may have produced an increased risk of certain cancers.

In August 1992, a Congressional hearing was conducted on the safety of police traffic radar devices. The hearing was convened by Senator Joseph Lieberman of Connecticut, Chairman of the Ad Hoc Subcommittee on Consumer and Environmental Affairs of the Senate Committee on Governmental Affairs.[6] Dr. Bryan Hardin, Assistant Director, National Institute for Occupational Safety and Health (NIOSH) testified at those hearings on behalf of NIOSH, the Food and Drug Administration (FDA), and the National Institute of Environmental Health Science (NIEHS).[7] In summary, these three Public Health Service agencies testified that available experimental and epidemiologic evidence did not suggest that the levels of radiation emitted by traffic radar devices are hazardous; however, there was insufficient scientific evidence to answer the question if exposure to these devices could cause an increased cancer risk.[8]

Congress directed NIOSH to study cancer incidence among law enforcement officers who had used traffic radar devices. In correspondence with Senator Lieberman [9,10], NIOSH presented plans to conduct a feasibility assessment to determine whether an epidemiology study of police officers who have used radar could provide meaningful information about potential risks. The objective of such an epidemiology study would address the questions of whether associations exist between police traffic radar and the development of specific types of tumors (e.g. testicular, brain, skin) and if such an association does exist, what is a reasonable estimate of the magnitude of the risk.

In a related development, NIOSH began a Health Hazard Evaluation (HHE) in early 1992 to examine the question of health effects of police traffic radar use in the Norfolk, Virginia police department.[11]

This report describes the NIOSH feasibility assessment, its findings and five specific recommendations to minimize future exposure of police officers to microwave radiation emitted by traffic radar devices.

FEASIBILITY ASSESSMENT DESIGN

As noted above, the purpose of this effort was to determine the feasibility of doing a meaningful epidemiologic study of cancer incidence in police officers who have used police traffic radar, to determine the required steps to completion of such an epidemiological study, and the resources and time needed to complete it. The essential components of the feasibility assessment were:

A. Exposure Assessment

B. Epidemiology Design Considerations: Analysis of Records

C. Conclusions: Report of Feasibility

There were three exposure assessment objectives for this project:
(1) determine, by measurement, actual present-day exposures for police officers now using police traffic radar; (2) compile and interpret historical data on police radar emissions and exposures; and (3) establish relative ranges of potential exposure to microwave energy from radar use for various models of radar.

The Analysis of Records area of work had two main parts, (1) evaluate records to determine their adequacy to support epidemiologic study; and (2) determine if records could be used to estimate historical exposure of individual police officers.

In an attempt to determine a basis for estimating historical exposure to radar, we sought to answer the questions, "Do records exist that identify models of radar used by a particular police organizational unit?" and "Are these records available and sufficiently specific to identify individual police officers who may have been exposed?"

In addition to making measurements and surveying the literature for relevant information on traffic radar use, we also contacted individuals, companies, and agencies, including law enforcement agencies, who could provide information on this subject. A list of the organizations and individuals contacted is provided in Appendix I of this report.

BACKGROUND

Historical Development of Traffic Radar

Radar was developed for military purposes during the 1940s. Radar was first used by police for traffic speed-measuring purposes in the 1950's, although their use was relatively infrequent until the early 1970's. The very early traffic radar devices were large, cumbersome, and suitable only for stationary use, i.e., the speed-measuring device had to be stationery itself to obtain an accurate indication of the speed of oncoming vehicles. In the early 1970's the use of radar speed-measuring devices increased rapidly. It was during this period that large numbers of police officers began to have radar units at their disposal for common, and in many cases, almost daily use.

All radar devices emit non-ionizing radiation in the region of the electromagnetic spectrum referred to as microwave radiation. The early traffic radar devices were designed to operate at 10.525 gigahertz (GHz), in which the electromagnetic energy wave oscillates at a frequency of 10.525 billion cycles per second. In accordance with nomenclature developed by engineers for the microwave portion of the electromagnetic energy spectrum, these

devices also came to be known as X-band radars. In 1975, a second traffic radar frequency was introduced that uses the higher frequency of 24.15 GHz, which lies in the portion of the spectrum known as K-band. In the 1990's a third frequency of traffic radar was introduced that operates at about 35 GHz (33.4 - 36.00), in what is known as the Ka-band. Ka-band devices, however, are not yet in widespread use. Traffic radar devices operate in a doppler mode, meaning that they use the doppler effect of a frequency shift in the signal reflected from a moving target vehicle to detect the speed of the vehicle. As doppler radars, these devices emit what is known as "continuous-wave," or CW, radiation. CW radiation is emitted in a continuous, rather than pulsed or intermittent manner.

In 1976, the International Association of Chiefs of Police (IACP) called for Federal Government involvement in developing standards for health, safety, performance, and testing.[12] In 1977, the National Bureau of Standards (NBS) (now know as the National Institute for Standards and Technology (NIST)) and the National Highway Transportation Safety Administration (NHTSA) signed an interagency agreement to develop model performance standards.[12] In 1982 the model performance specifications were adopted.[13] These specifications were updated in 1989.[12] In 1989, Officer Gary Poynter of the Ohio State Highway Patrol first began to focus attention on concerns about potential health risks of working with radar. In 1992, the state of Connecticut passed legislation that eliminated the use of all hand-held radar units and prescribed that all two-piece units have the antenna mounted outside the patrol vehicle.[14] This legislation helped fuel the growing controversy over the health concerns of police exposed to traffic radar.

Police Traffic Radar Characteristics

Traffic radar devices have been manufactured using one of three microwave frequencies, either the X (10.525 GHz), K (24.15 GHz), or Ka-Band (33.40-36.00 GHz). All of the devices emit less than 100 milliwatts of microwave power, an amount considered by nearly all concerned to be rather low. Most radar units manufactured in the last twenty years have had emitted power in the range of 15 to 50 milliwatts. Compared to any other type of radar, e.g., military, commercial aviation, marine, etc., the power levels of police traffic radar devices are orders of magnitude lower. The emitted power of traffic radar devices is lower than or comparable to other microwave or radiofrequency (RF) radiation-emitting devices used in close proximity to persons in the general public, such as garage door openers, cellular telephones, and infant monitors.

Traffic radar units have been produced in two basic types, a one-piece unit designed for hand-held use, and a two-piece unit designed for a fixed mount. Hand-held units were first introduced in the late 1970's. A few hand-held models have been designed for optional fixed mount use, although most models produced were exclusively designed and used for either hand-held or fixed mount operation. Both types have been and are widely used since the introduction of hand-held models in the late seventies, with the large majority of units having been the two-piece units. The two-piece units consist of an antenna and a separate electronics component that contains the controls and the display panel. Normally, the electronics (display) component is mounted on the dashboard or among instruments beside the officer in the patrol vehicle. The antenna can be mounted in various locations, and has been used with mounts on the front dashboard, the rear dashboard (at the rear windshield behind the seat), or with a bracket on one of the side windows, which can hold the antenna inside or outside, facing forward or back. In some cases, two antennas are used in the same vehicle (usually one front and one back dashboard mount) with a switch provided to choose one or the other antenna at a given time.

In the 1970's radar units became available that could operate in either a stationary mode, or a moving mode. Stationary mode radars had to be used by an officer in a fixed position, but moving mode radars could correctly adjust for the motion of the patrol vehicle while determining the speed of the target vehicles coming toward the patrol. Moving mode use has always been with a fixed mounted radar. The determination of which mode to use was entirely a matter of choice of the officer and was usually a function of the standard operating procedure of the law enforcement agency or traffic control unit of that agency.

Other Studies of Traffic Radar Exposure

A number of studies have been conducted and some published concerning the potential operator exposure to the radiation emitted by traffic radars. Most of these studies measured some feature of the emitted radiation intensity, and some of them measured levels of exposure at other locations away from the aperture of the antenna. The most widely referenced of these studies was published by Baird et al.[15] of the National Bureau of Standards (NBS), now known as the National Institute of Standards and Technology (NIST). The Baird et al. study was significant in that it

established an NBS protocol for measuring exposures in the vehicle in which a traffic radar is used. Some studies, like one done at the Environmental Protection Agency by Hankin et al.[16] measured only a few radar units, but others measured many units. The largest study of traffic radar unit exposures has been conducted by Fisher[17] who measured over 5000 radar units.

NIOSH EXPOSURE ASSESSMENT

Methods

We measured and evaluated microwave emissions from, and operator exposure to, ten models of radar guns. (Table 1) Specific measurements included both fixed-mount and hand-held radar units operated both inside and outside the police vehicle. The measurement procedures were based, in part, upon the *IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields-RF and Microwave*[18], a technical report by Dr. P. David Fisher[17], and a technical report from the National Bureau of Standards.[15]

Test equipment included the Narda 8716 Power Density Meter with the model 8721 probe, the Hewlett Packard 435B Power Meter with frequency specific power sensors and standard gain horn antennas, a Hewlett Packard 5385A Frequency Counter, a Holaday 3003 RF Survey Meter, and a Ballantine 3440A RF millivolt Meter. Power density emissions and operator exposures were measured with the Narda 8716 and with the HP 435B using the appropriate frequency (X-band or K-band) standard gain horn antenna and power sensor. The HP 5385A and the Holaday 3003 was used to measure frequency output, and power density emissions, respectively, from various RF communication devices. The Ballantine 3440A was used to measure induced body current from any RF communication devices operating in the frequency range of 30 to 155 MHz. Power density survey monitors have NIST-traceable calibrations within the appropriate frequency range for the radars being surveyed.

Measurements of radar emissions and operator exposures from both fixed mount and hand-held units operating under normal conditions (i.e., typical locations for both operator and radar units) were made to estimate potential exposure levels. Equipment measurements for each radar unit included the power density at the aperture of the radar antenna, at 5 cm and 30 cm in front of the antenna and area measurements of power density behind and around the unit (i.e., backscatter, and or back lobes and side lobes) and in the position of the operator. Aperture power density was defined as "the maximum power density external to the radar device" and "occurs at the interface between the radar antenna and the open space directly in front of the antenna."[17] Power density was measured at the aperture and 5 cm in front of the aperture in order to allow suitable comparison to other published data, even though it is known to have limitations and some inaccuracy.[19] Potential operator exposures (power density measurements) were measured at the head and groin levels in the absence of an operator. All measurements were made twice to assess repeatability. Power densities less than about 20 microwatt per square centimeter ($\mu W/cm^2$) cannot be accurately measured using the Narda 8716/8721 instrument and probe, and thus represented the minimum detectable level (MDL) with that instrumentation. Lower level power measurements (e.g. backscatter, and at the operator's head and groin) were made using standard gain horns and a HP435B radiofrequency power meter. Due to measurement limitations, aperture power density was not determined using horns and a power meter.[17] The power meter was connected to a coaxial power sensor and then to the horn using a waveguide-to-coaxial adapter. Low power measurements at 10.525 GHz (X-Band) were made using a Narda Model 640 horn, a Narda 601A adapter and a HP8481A power sensor. Low power measurements at 24.15 GHz (K-Band) were made with a Narda 638 horn, a Narda 4608B adapter and an HP8485A power sensor. Baird et al. at NBS used comparable equipment to determine power density from power measurements made with standard gain horns and a power meter.[15] Thus, procedures comparable to those of Baird et al. were followed to convert power measurements to power density. Narda provided the necessary horn gain factors and insertion losses for the waveguide-to-coaxial adapters. Minimum detectable power density levels with this equipment, after converting power measurements to power density, were 7.3 nanowatts per square centimeter (nW/cm^2) at 10.525 GHz, and 32.5 nW/cm^2 at 24.15 GHz. Power densities below the minimum detectable level were recorded as not detectable (ND).

The specific procedures for making measurements were as follows:

1. The equipment was examined to determine make, model number, serial number and specified frequency of operation.

2. We then measured the radar unit's aperture power density*, beam power density at 5 cm and then at 30 cm in front of the antenna (on axis) with the Narda 8721 probe. Power density was also measured at 5 cm and 30 cm in front of the antenna with the appropriate standard gain horn and power meter.

3. Power density was measured behind and around the radar unit and at the locations of the operator's head and groin (with the operator absent from that location) with the appropriate horn and power meter.

4. An inventory was made of other sources of electromagnetic radiation by unit type, unit location, antenna type, antenna location, frequency and nature of use.

* Power density [milliwatt per square centimeter (mW/cm^2)] measurement data were collected using a Narda 8716 meter with 8721 probe (minimum detectable power-density level: 0.02 mW/cm^2). The probe had a cover over the sensing elements, so that the intersection of the three orthogonal sensing elements was actually 2 cm from the lens of the radar device for the measurement.

Results

The results of the measurements of aperture power density and potential operator exposure (using Narda 8716 meter and 8721 probe) at selected locations for the radar units we measured are shown in Table 2. For comparison purposes, selected measurements made 5 cm in front of the aperture in other studies are shown in Table 3. All of the individual and mean values we measured at this location were within the range of values reported for other studies. For potential personnel exposures, we found that only in cases where the person would actually be in the main beam path in close proximity to the radar would the exposure be above 20 $\mu W/cm^2$, the lowest limit of detectability on the exposure survey meter we used (Narda Model 8716 with the Model 8721 probe). In practical terms, this meant that only if the radar antenna were mounted (or resting, in the case of a handheld device) inside the car and directed toward an occupant was the exposure strong enough to be measured with our techniques.

The results of selected power measurements using the horn antenna, microwave power sensor, and power meter designed to detect even smaller levels of reflected microwave energy inside the vehicle are shown in Table 4. The radar emission measurements made at 5 cm and 30 cm in front of the aperture are in good agreement with the Narda 8716/8721 measurements made at these locations (Table 2). The potential operator exposure measurements (at eyes, waist and knees) indicated that, even when the radar antenna was very near a door or windshield, the power density at the operator's location was very low, and, in some cases, not detectable (Table 5). These data are consistent with low backscatter (reflected power density) from a door, windshield or other interior part of a vehicle and/or low back and side lobes from the radar antenna (direct power density- no reflected/scattered power density).

In the course of making measurements in a number of different law enforcement departments, conversations with police officers indicated that there were concerns about the maintenance and operating characteristics of traffic radar devices that needed to be answered. For example, can a traffic radar device have component failure in a way that would increase the microwave power emitted as performance deteriorated? If a radar has poor range performance (cannot detect a vehicle at a sufficient distance) can the output microwave diode be changed to increase the power emitted? Do manufacturers make the same model with customized power levels, making them with higher power for some customers than others? Are today's new traffic radar devices more or less powerful or equal in power emitted to older models or units?

Our efforts to answer these and similar questions included visits to the maintenance departments of two law enforcement agencies who use hundreds of radar devices, discussions with both the maintenance technicians and maintenance supervisors, inquiries with major manufacturers, and discussions with other knowledgeable experts in traffic radar. We found that the operating characteristics of traffic radar devices are very similar among all of the manufacturers. These devices use a Gunn diode to produce the microwaves. The absolute output power is a characteristic of the particular diode built into the radar. The emitted beam characteristics are also dependent on the actual antenna design, but the total power generated depends solely upon the diode used. The diodes are relatively simple modules, and are easily replaced when they fail. The diodes are not, however, adjustable. In a study designed to test whether the output power of traffic radar devices changed with various conditions, it was found that reasonable variations in input voltage did not alter the output microwave power.[20] With respect to wide variations in environmental temperature, the same study reported that traffic radar devices emitted more power at lower ambient

temperatures, but this variation in output power was not large. On a related point, the adjustment labeled "range sensitivity" on some models does not alter the output power, but adjusts that part of the circuitry that determines detector sensitivity.

With respect to ageing of the Gunn diode, a given radar unit will usually emit the same power for years of normal operation before requiring replacement of the diode. The maintenance technicians we spoke to told us that they only use the rated diode from the manufacturer for a given radar model. Substitutes, or alternative diodes are not used. In many cases, alternative diodes could not be used because the circuitry of a given model is built with a restricted fit to the specified diode, so that only the standardized replacement part could be used.[21-23] Microwave emitting diodes may fail abruptly, or they may experience gradual failure, emitting less power as failure proceeds, never more. The more common feature of Gunn diode performance over the life of the component is for it to gradually degrade in time with respect to both output power and the signal-to-noise ratio of its emission. The ability of a radar unit to detect and process speed information is also negatively affected by an increase in the signal-to-noise ratio.

The most common maintenance need for traffic radar devices is simply that from physical deterioration, e.g., the power cord is broken, or the unit fails to function after being dropped. However, with respect to the radiation beam, the most common source of maintenance trouble is the receiving function of the radar, not the transmitting function. Thus, when a radar is not operating properly, or has poor range characteristics, it is most often due to a problem with the receiving function, not the transmitter.[20-22] The most effective way to increase the range of traffic radar is to repair or improve the circuitry for the signal reception and processing. Significant increases in emitted power of traffic radar devices are not necessarily desirable from an operational point of view. This is because the radar device cannot distinguish one vehicle from another, so the officer must make a visual identification to go with the speed measurement. Increasing the power of the radar to extend the range beyond that of visual confirmation would not be advantageous.

On the question of historical patterns of traffic radar power, we have found no evidence of a systematic change in output power. The historical averages, as taken from older studies in the literature, and from the data of the one researcher who has measured this characteristic for over ten years[17,20], have not changed appreciably. Thus, the range of "aperture power density" measurements on new models today is within the range of the models that were produced one or even two decades ago. It is possible that there were some radars produced many years ago that were more powerful (i.e., up to 100 milliwatts output power) than today's newer models, but these models were not present in sufficient numbers to shift the means of studies done as far back as the 1970's and are probably few in number, or nonexistent today. There does seem to be a trend, although it is hard to document, for some modest decrease in output power in the newest models. This is noticeable in that radars with "aperture power density" greater than 1 mW/cm^2 do not seem to appear in newer units, while models with an APD of 0.2 to 0.6 mW/cm^2 are still common. This is consistent with an improvement in the signal-to-noise ratio of the diodes, and an improvement in detector circuitry, which allows comparable performance from the radar with less output power.

EPIDEMIOLOGY DESIGN CONSIDERATIONS

The feasibility of conducting epidemiologic studies of police who used traffic radar was addressed by a number of activities. We began by identifying the specific cancers of concern. This was done by searching the scientific literature, by contacting researchers, and by contacting police personnel and the staffs of regulatory agencies. A meeting was held with Officer Gary Poynter of the Ohio State Highway Patrol, who is also the National Fraternal Order of Police Research Officer. Officer Poynter maintains a list of officers who have had cancer, the type of cancer they had, and information about their past use of traffic radar devices.

From all the sources contacted we determined that there was one specific cancer, testicular cancer, that was of greatest concern for police officers using traffic radar devices. Also, but of lesser concern were leukemia, and cancer of the brain, eye, and skin. We proceeded to consider various epidemiologic options directed at the assessment of these cancers in police officers who have used traffic radar.

Three characteristics of testicular cancer are particularly relevant to conducting epidemiologic study of police officers. They are the incidence rate, age of occurrence, and the mortality rate. The average annual age-adjusted incidence rate of testicular cancer for US males of all races is about 4.1 per 100,000 population, according to the Surveillance, Epidemiology and End Results (SEER) program.[24] SEER, which is operated by the National Cancer Institute, combines the data of 11 population based registries in different parts of the U.S. These registries gather information

on all cancer cases occurring in approximately 10% of the U.S. population and is generally considered the best estimate available of cancer incidence in the U.S. An incidence rate of only 4.1/100,000 means that testicular cancer in the general male population is a rare occurrence. It is infrequent relative to many other cancers such as lung (84.2 cases per 100,000 population), colon (42.2/100,000) and bladder (29.5/100,000), but is more common than some other types. There is a striking trend in the incidence of testicular cancer in the general population. Beginning around age 20 the annual incidence rates increase to 11 per 100,000 population by age 30. Incidence rates do not vary much between ages 30 and 35. Then after age 35 the rate begins to decrease until it falls well below the average rate of 4.1/100,000 by age 50. Testicular cancer, therefore, is primarily a disease of young men, in contrast with most other cancers for which the incidence rates continue to increase with age throughout life.

Another remarkable characteristic of testicular cancer comes from comparison of the incidence rates to the mortality rates. Mortality rates from testicular cancer are far lower than the incidence rates probably in large part due to the high rate of early detection and highly effectual treatments that have been developed, again in contrast with many other cancers.

In order to measure the association that may exist between an exposure and a disease, epidemiologists basically have a choice between two study designs or a combination of them. The first is to identify a cohort (group) of people who have had an exposure, and compare their health status to a group of people who did not have the exposure. This is called a cohort study. The second approach is to identify a group of people with a particular disease and compare their likelihood of having had an antecedent exposure to a group of people who do not have the disease. This is called a case-control study. Both of these techniques have certain advantages and disadvantages. Choosing between these studies is in large part prescribed by the availability of certain information that can support the respective design.

Cohort Study Considerations

To conduct a cohort study of the effect that traffic radar exposure has on police, one would begin by identifying a group of police officers who have used traffic radar devices in the past. Therefore a set of records would have to be located that identifies a large enough cohort of police who have used radar, and the record system must in some way quantify the amount of radar usage each officer has had, e.g. provide the beginning and end dates that an officer used this equipment. Typical records that are used for cohort studies include personnel, comptroller, training, and payroll records.

There are a number of considerations that go into the decision of what constitutes a "large enough" cohort. Generally, when a disease is rare, large numbers of people must be included in the cohort, and they must be observed over a long period of time, so that enough cases occur to allow meaningful statistical analysis.

It is also essential that the researcher be able to determine when a case of disease has occurred. As yet in the United States no centralized tumor registry exists of persons who have been diagnosed as having cancer. There are, however, some individual states that do maintain such registries.

In contrast to the lack of a national registry of newly diagnosed cancers, a well developed registry of all occurrences of death does exist in the United States. Epidemiologists can sometimes use mortality as a surrogate for occurrence of disease if the disease in question has a high case fatality rate, as in the case of most cancers. When a disease is not generally fatal, however, as in the case of testicular cancer, the numbers of deaths available to study are so few as to make necessary an even larger cohort of exposed people to supply enough cases of death on which to make reliable statistical judgements.

All of this applies to the police traffic radar situation as follows. Radar came into general police use only in the early 1970s. If 10,000 officers could be identified who were using radar in 1974, and they were followed 20 years to the present, the study cohort would consist of about 200,000 person-years at risk of developing testicular cancer. (Each officer contributes 1 person-year at risk for each year they are observed after their initial exposure). If the background incidence rate of testicular cancer is about 4.1 per 100,000 person-years at risk, one would expect about 8.2 new cases to have been diagnosed among these 10,000 officers during the 20 years under study. If radar exposure truly causes the incidence of testicular cancer to double, the "power" of the study would be only 66%. (Power is the ability to observe an increase in disease if it actually exists. Therefore, in the present example, if the study of 10,000 officers were repeated 100 times, a two-fold excess would be seen in only 66 of the trials). By

convention, epidemiologists do not like to conduct studies with a power of less than 80% in order to limit the likelihood of equivocal study results. In our hypothetical case, an increase in the risk of testicular cancer of 2.25 fold would be sufficient to result in a power of 80%. If the study were to be conducted using mortality rather than incidence cases, only 0.6 deaths from testicular cancer would be expected and the power to see a two-fold excess would be a mere 9.5%. It would require a cohort of 100,000 radar using officers, followed for 20 years, to identify a doubling of testicular cancer deaths. A doubling of risk is possible among the known human carcinogens, but most of the known carcinogens do not cause this large an increase in risk. The larger the risk the smaller the cohort has to be to observe an effect. Conversely, the smaller the risk the larger the cohort needs to be.

No single police department could contribute 10,000 police officers who have worked with traffic radar since the mid 1970s, let alone the 100,000 that would be needed for a mortality study. Therefore it was assumed that a sufficiently sized cohort would have to be formed by combining several police departments. Complicating the issue further is that these departments would have to be in states where tumor registries have existed since at least the early 1980's in order to identify cases. While there are quite a few states that currently maintain tumor registries, most have been rather recently established. Finally, all of this assumes that sufficient records exist within the police departments to identify who has and who has not used radar, and to provide some estimate of the length of time and type of traffic radar to which they have been exposed.

Case-Control Study Considerations

For a case-control study to determine the association between cancer and traffic radar exposure, we would compile a list of persons from a population who had been diagnosed with cancer (these would be the cases), and another list of persons from the same population who had not been diagnosed with cancer with which to compare (these would be controls). Individual determinations would be made to estimate the extent of traffic radar exposure for each case and control. The two groups would be compared to see if the persons with cancer were more likely to have experienced traffic radar exposure than persons without cancer. Just as for the cohort study design, the ability to successfully conduct a case-control study is dependent on the availability of records (a tumor registry) from which to identify cases, and the availability of record systems that allows identification of those with cancer who worked as police officers, and allows the quantification of the extent of traffic radar exposure experienced by each individual.

An advantage for the case control study over the cohort study is that it does not require the large numbers of people to study. It does, however, require that a sizeable proportion of the population have the exposure.

Methods

Our search for a potential study population of police exposed to traffic radar began by consulting with individuals and organizations involved in assessing the potential health hazards of these devices. We found that municipal police and county sheriff departments and other divisions of governmental police have used radar historically in the management of vehicular traffic, but the actual commitment of personnel to these duties versus other police activities was proportionately very small. For instance, we found that in the Cincinnati Police Division less than ten officers were assigned to the traffic section where they would use radar on a regular basis. Other officers might use radar, but only on an infrequent basis. In contrast, we found that troopers in state highway patrols tended to spend a large proportion of their time with traffic radar devices. For this reason we chose to concentrate on state police departments.

To evaluate the possibility that state police records could be utilized to identify officers who have used radar over the years, we identified several states where radar had been used since the 1970's and where tumor registries exist. The choice of states in which we sought more detailed information was guided by several factors, including preliminary information on radar use provided by other federal agencies, the number of state police likely to have used traffic radar, the availability of a tumor registry within a state, and practical considerations of existing NIOSH occupational health contacts or proximity to reduce travel costs. The states selected for further evaluation, Ohio, New York, Connecticut, and Kentucky, all had tumor registries, and also provided a representative sample of the varied work practices of state police departments in the history of traffic radar use.

Among those occupational health professionals initially contacted was Dr. James Melius, Director of the Division of Occupational Health and Environment, State of New York Department of Health, in Albany. We determined that the New York State Police have routinely used radar over the last 20 years, and New York is a state that maintains a

tumor registry. We contracted with the New York State Health Department to investigate the feasibility of research on the effects of traffic radar exposure among New York State Police.

While the New York State Health Department evaluated the feasibility of utilizing New York State Police in an epidemiologic study, NIOSH personnel conducted similar inquiries into the feasibility of using the Ohio State Highway Patrol, the Kentucky State Police and the Connecticut State Police. Ohio, Kentucky and Connecticut all maintain state tumor registries. We also determined the requirements to access these state's tumor registries for subsequent cohort or case control studies.

In addition, we contracted with the University of Cincinnati, Division of Biostatistics and Epidemiology, to conduct a small demonstration case control study on deaths from testicular cancer and certain other cause specific deaths among Ohio residents. The purpose of this case control study was to evaluate the usefulness of using death information instead of cancer incidence which would only be available from tumor registries, and to determine the background rate of exposure (namely, occupation as a police officer who might have used traffic radar) in a state population based study. The University of Cincinnati maintains a copy of the computerized data base of all Ohio deaths. This file includes cause of death and occupation, abstracted from death certificate, of every decedent in the state.

Results

The New York State Department of Health, estimated that about 4,000 New York State Police have used radar devices at some time over the past 20 years. Dr. Melius found that there is no record system in existence that specifically identifies an individual officer as having used traffic radar. Rather, by examining the personnel records of a New York State Police officer, one would have to deduce whether the officer had worked with traffic radar by evaluating the officer's rank, work assignment and location, and by knowing the historical pattern of traffic radar use by the state police.[25]

Applying the background rates for testicular cancer and leukemia in New York against the particular age distribution of the active and retired Officers of the New York State Police, we estimated that the expected number of testicular cancer cases experienced by this population of 4,000 current and past officers would be about 0.4 cases per year and the number of expected leukemia cases would be 0.78 per year. The New York Department of Health report concluded that a cohort study performed on this population is technically feasible but because of the small number of expected testicular cancers and leukemias, the findings would likely be of limited value. The report suggests that it may be possible to include the New York State Police in some larger pooled analysis which includes other state police departments thereby increasing the size of the study and the number of cases to work with. Another possibility considered was to include municipal and/or county police departments in New York State, but the Department of Health found that these police departments generally had even less documentation than the state police regarding an individual officer's traffic radar use.

In the course of looking for states that maintain a tumor registry and whose state police use traffic radar, NIOSH personnel contacted appropriate officials in Kentucky and Ohio. Kentucky maintains a tumor registry and the State Police have used radar for about twenty years. The Kentucky Cancer Registry (KCR) was established in 1990. Mandatory reporting of all newly diagnosed cancer cases in Kentucky to the KCR officially began January 1, 1991.[26] According to the 1991 KCR the age-adjusted incidence rate for testicular cancer was 3.3 per 100,000 - slightly lower than the SEER rate. This translates to 70 cases out of 1,795,439 males alive in Kentucky in 1991. The registry maintains all requisite identifying and demographic information that would be needed to conduct a cohort incidence study and/or a case-control study. The cases of cancer, however, are only available for the short time the KCR has been in operation.

The Kentucky State Police currently includes about 970 sworn officers.[27] The vast majority of these are male; there are only about 20 female uniformed troopers. Of the active troopers, an estimated 500 to 550 use traffic radar. They have conducted traffic radar patrol, generally in moving mode, (from within a moving patrol car) at about the same complement for the last 10 to 15 years. Currently the model of radar detector used is an S-80, a fixed mount two piece device manufactured by MPH. Prior to that they used the MPH Model K55 as far back as 20 years. As was the case in New York, and ultimately in all of the state police records we evaluated, there is no indication in an officer's personnel or training file that indicates their frequency of traffic radar use. One would have to decipher the specific job assignments of each officer and presume the likelihood of radar exposure.

Although it was determined that a cohort study in Kentucky was technically feasible, the very short period of time that the tumor registry has been in existence renders the Kentucky State Police unsuitable to support a retrospective cohort incidence study at this time. Neither would there likely be enough cases in the registry for a meaningful case-control study.

In Ohio there are currently 1,369 uniformed Highway Patrol personnel. Of these 937 are Troopers and 291 are Sergeants.[28] Personnel records are maintained on all officers back to 1933. These records are on hard copy for active and recently terminated officers, and on microfilm before that. The records are complete for information such as name, race, gender and other demographics required for an epidemiologic study, and they contain a detailed work history in terms of post assignments and rank. From 1978 on it can be assumed that a Trooper or Sergeant assigned to a highway post would frequently work radar. The only exception would be if the assignment was to a truck weigh station or some other similar duty, but all such assignments are clear in an officer's work history. Although traffic radar use in Ohio preceded 1978, prior to that time not all cars had a radar assigned. Therefore, nothing can reliably be inferred from the work histories prior to that date. Each personnel record contains a sheet that describes all of the official training an officer received. Traffic radar school would be included in this training, but early on a new officer would be trained by an experienced officer on radar. It was not clear when school replaced on-the-job radar training. It was also not clear that everyone who completed radar school actually used radar. There were no available records of traffic citations written that may have been used to quantify traffic radar use by an individual officer. It was reported to us that records of citations were historically not computerized and not kept for any appreciable length of time.

The Ohio Tumor Registry was established in 1991. The registry has just become accessible in 1994. Like the Kentucky registry, the Ohio registry maintains all requisite identifying and demographic information that would be needed to conduct a retrospective cohort incidence study and/or case-control studies. It is also similar to Kentucky in that only several years of cancer incidence data are currently included in the registry.

Because the Ohio Highway Patrol is a relatively large police force that has used radar extensively, and because it was determined that personnel records exist that can identify officers with probable exposure to radar, it was decided to test the notion of a population based mortality case control study. This was done in spite of certainty that the proportion of the State of Ohio's population that were state police is clearly inadequate for a sufficiently powerful study.

We contracted with the University of Cincinnati, Division of Biostatistics and Epidemiology, to review the State of Ohio computerized death tapes. These computer tapes contain the identities of every deceased person in the state since 1978 to 1992 (the last year available), listing a code for the cause of death as recorded on the death certificate. Since 1985, a code for the typical occupation and business held during life was also recorded. The University of Cincinnati was asked to identify deaths from testicular, eye, skin, brain and hematopoietic cancers that occurred for each year that such data were available. For each of the deaths identified, they were asked to choose another death randomly that occurred in the same county of residence, to serve as a control. The number of deaths in Ohio from testicular cancer in the mid to late 1970s averaged about 45 per year, and the rate dropped to 21 by 1990. This drop is probably a function of improved detection and treatment regimens. The goal was to carry out some simplistic case-control analyses, designed to measure the association between dying of cancers of interest in Ohio and being a police officer. Although we recognized that this exercise might not provide useable information about the carcinogenicity of traffic radar exposure, we did expect that it would reveal the background proportion of deceased individuals in Ohio who were police officers and therefore potentially radar-exposed. This information was needed to assess the usefulness of conducting population-based case-control studies of mortality among police. As it turned out, however, from a total of 9,526 cases and controls, only 36 death certificates listed a code consistent with having been a police officer. Thus even broadening the scope from Ohio Highway Patrol officers to include all municipal and county police in Ohio, there was still too small a proportion of the population on which to conduct a mortality case-control study.

Connecticut State Police officers, unlike the other State police forces we encountered, spent the majority of their time performing police duties other than highway patrol.[29] They served as the primary police force for municipalities and counties that do not maintain their own police or sheriff departments. Traffic radar use was not uncommon, but it could not be assumed, as in other states we evaluated, that every officer in a particular assignment or section would have frequent exposures. Connecticut has about 1000 officers, of which about 500 use traffic radar at some unspecified rate. Every trooper has access to radar if they want it. When officers in Connecticut are working speed

control they work in teams. Only one of the team members operates radar while the others are involved in chase and apprehension activities. There are no indications in personnel records that would allow quantification of radar exposure for any particular officer.

Connecticut maintains the longest established tumor registry in the U.S. It has comprehensively registered every new incidence case of cancer in the state since 1937. Epidemiologists have for years used this registry as the basis for conducting both cohort incidence and case-control studies. The rate of testicular cancer in Connecticut is similar to that estimated by the SEER registry.

DISCUSSION AND CONCLUSIONS

Exposure Levels

This feasibility assessment was conducted as a first step in an attempt to provide meaningful answers to health concerns about traffic radar use. Our work on exposure assessment, while limited in scope, has helped us to reach some clarification on the issue and on the risk of exposure to microwave radiation. To begin with, our measurements of present-day exposures of law enforcement officers in four departments provided data that are very consistent with results of other published studies. These data confirm that the emitted power from traffic radar devices is low; the maximum power density we could measure was 3 mW/cm^2 in the vicinity of the aperture of the antenna. The mean power density near the aperture of the radars we measured was about 1 mW/cm^2. These data, and the levels we obtained for potential operator exposure in the vehicle from fixed mount radars, agree with other reports that operator exposures are, in most cases less than 20 μW/cm^2.

Fisher[20], in his analysis of radar exposure to the operator, developed a model based on a thirty degree angle cone moving out from the antenna aperture. Our exposure data support his conclusion that the exposures outside this zone around the antenna are always less than one per cent of the aperture power density (APD). Fisher measured APD at 5 cm in front of the aperture (probe used had a 5-cm spacer). Thus, if the APD is about 1 mW/cm^2, the exposure outside this zone would be less than 0.01 mW/cm^2, a small value by any exposure standard. Exposure levels analyzed in other studies also are consistent with the measurements we made.[11,15,16,30-34] Fisher's model would apply to many mounting locations for fixed mount radars, including forward and rear dashboard mounts (with the radar antenna facing out of the vehicle), external mounts on door windows on either side, and mounting on the inside of the left rear window with the radar antenna facing to the rear. Some mounting locations that have been anecdotally reported as having been used in the past would, however, include the operator within the 30 degree zone defined by Fisher's model. These unsatisfactory mounting locations would include any mounts on the inside of side windows with the radar antenna pointed forward, i.e., out the front of the car. The Fisher model would also not apply to the technique of mounting the antenna on the front dashboard, facing to the rear of the vehicle, projecting past the operator.

While some positions of the radar antenna, e.g., inside mounts that aimed the radar antenna toward or near an operator, would have exposed the operator to measurable microwave radiation levels, such exposures would still have been lower than published exposure guidelines for occupationally exposed workers. This assessment is based upon the identified aperture power densities (the maximum power density that could have occurred) and the personal exposure guidelines published in the United States.[35-37]

Biological Effects of Microwave Exposure

At the frequencies of operation of these radars, the penetration of the energy into tissue would be very limited, perhaps no more than a few millimeters for K-band radar and no more than a centimeter for X-band.[38-40] Thus, the greatest exposure that could occur is for an individual to place the aperture of the radar antenna very near the body. Such an exposure would result in localized deposition of some energy in tissues very near the surface of the body in the region intersecting the radar beam. Based upon the evidence of biological effects of short term microwave exposure to date,[35,41,42] there is no reason to suspect that such an exposure would cause an adverse health effect. Nevertheless, the determination that present-day exposures are low does not entirely eliminate the questions of historical exposure nor does it directly address the effects of long-term, low-level microwave exposure because so little research has been done on chronic low-level effects.[43-47]

Some individuals and organizations have argued that the low-level exposure from traffic radar could not cause health effects because it is well below the published recommendations for maximum personnel exposure (MPE) for this type of energy.[6,48] The published guidelines, however, are limited by a lack of chronic, low-level exposure research, and thus, it would not be prudent to dismiss health concerns following these exposures. These concerns are almost entirely based upon anecdotal observations, now numbering over two hundred[5], that officers who have used traffic radar extensively have developed cancer. In at least some of these cases, the cancer occurred in a region of the body for which there was likely exposure from the radar to that area of the body.

Only one paper on any of the case reports has appeared in the scientific literature. Davis et al. investigated a cancer cluster in police officers who used radar and later developed testicular cancer.[49] In that report, the authors found some supporting evidence for the plausibility of an association between radar use and cancer, specifically, the cancers were medically verified to be testicular in origin and the temporal characteristics of the cases were appropriate, i.e., radar use occurred years before the diagnosis of cancer. As this was a study of a cancer cluster it is insufficient to resolve whether radar use had any causal role in the development of cancer.

The scientific literature includes many reports of studies of the biological effects of radiofrequency and microwave radiation. These have been reviewed a number of times previously.[35,50-52] In 1984, the Environmental Protection Agency (EPA) published a report that extensively reviewed the literature to 1982 on this topic.[42] An update of the conclusions from that report was published in 1987[41], and in 1993, the EPA convened another symposium to further update the review. Unfortunately, relatively little research has been conducted on the health effects of RF or microwave radiation in the last five to seven years, and the questions that existed in the mid-1980s on this topic remain essentially the same today.

There are many studies in the scientific literature of the effects of microwave radiation on biological systems, from isolated molecules and cells, to whole organisms. From these reports we know that when the intensity is sufficient to cause heating of the biological system a response of that system can be measured. In the case of animal exposures, these responses can be quite varied, and include changes in temperature regulation, endocrine function, cardiovascular function, immune response, nervous system activity, and behavior, among others.[42,52-54] However, when the intensity of exposure is low enough that overt heating of tissue does not occur, the nature of the biological response is much less clear. Cellular responses to low-level microwave exposure have been reported[55-58], but these changes have usually been small in magnitude, reversible, and of uncertain significance to the health of an intact organism, e.g. humans.

Reports from published research have led reviewers to the conclusion that genetic changes observed in microwave studies only occurred in the presence of a substantial temperature rise.[35,41,52,59] These observations are consistent with the interpretation that microwave radiation, because of the low amount of energy in the photons at these frequencies, does not cause direct damage to the DNA. Experimental studies of cells and molecules exposed *in vitro* to microwaves also support this view.[42,57,60] Thus, microwaves, unlike their higher energy electromagnetic counterpart, x-rays, are not believed to cause mutation to chromosomes (DNA) thought to be related to the initiation of tumor development.

If microwaves are not directly mutagenic, there remains the question of whether they can enhance the development of malignant cells, or alter the repair processes that deal with changes in genetic material resulting from other insults or spontaneous alterations. Related to this question is the concern over the effect on health of prolonged or repeated exposure to low intensity microwaves. Unfortunately, the few experiments that have been done relevant to these questions about cancer and prolonged exposure do not provide a definitive answer. One of the most noteworthy animal experiments of this type was the one done at the University of Washington with laboratory rats. The rats exposed to microwaves had a significantly larger number of malignant tumors at the end of the two-year exposure.[46] The significance of this unique finding has been widely debated[61], but has not been determined. A few other animal experiments have specifically studied the influence of microwaves on tumor development, but these are not definitive either.[62-64] One of the most widely discussed *in vitro* studies of the effects of microwave radiation on cell growth has been the research of Cleary et al.[65] In these studies, microwave or RF radiation at moderate levels has stimulated the growth of isolated or cultured cells. Another recent report specifically used traffic radar (Ka-Band) to expose nude mice and reported that there was a decrease in circulating leukocytes and also in DNA synthesis in the cornea after prolonged exposure at only 20 μW/cm^2.[66] Most of the endpoints measured in the mouse study did not differ between exposed and control animals, and the authors concluded that the results did not suggest any effects that would adversely affect human health in traffic radar operators. These reports, like others available, are insufficient to

resolve the uncertainty concerning the long-term, low-level exposure of human beings to microwaves.

In contrast to the situation that exists with electric and magnetic fields of lower frequency, for which studies of human populations exist[67-69], there is very little epidemiologic data on the effects of RF or microwave radiation on humans. Here again, the data are too few and too limited to either suggest that low-level microwaves could adversely affect health or to exonerate such exposures as being of no consequence.[70-74]

In summary, neither the laboratory nor human research literature is sufficient at this time to make possible a definitive assessment of the health risk of long-term, low-level exposure to microwaves, e.g. that which may have occurred for some police officers using traffic radar in the past.

Recommendations for Traffic Radar Use

In the face of this combination of uncertainty about biological effects and concern of those potentially exposed, some organizations involved with the use of traffic radar have made recommendations or adopted policies that provide direction on the use of the devices. One of the first of these was the Connecticut State Police, which, in 1991, adopted a policy discontinuing any use of traffic radar devices within the patrol vehicle.[75] This policy, while initially intended only for the State Police Department, was subsequently passed into law by the State Legislature to ban all use of hand-held radars in the state.[14] In 1991, The Food and Drug Administration (FDA) recommended that

> "users of police radar should not place the front surface of the radar unit (the antenna) within 15 cm
> (6 inches) of any part of the body, while the unit is transmitting."[76]

Subsequently, in 1992, FDA issued an update on traffic radar devices. In that update77 FDA recommended that

> "police officers can take some simple steps which will sharply reduce their exposure to the low-level microwave radiation which these devices emit.

1. Always point the device away from your body, or your partner's body, while it is turned on.

2. Mount fixed radar antennas so that the beam is not pointed at any occupant of the patrol car.

3. Whenever possible, turn off a hand-held unit when it is not in use. If your unit has a "standby" mode, always use it when not measuring the speed of a vehicle. Never rest the unit against your body when it is turned on.

4. When it is on, try to avoid pointing the device toward metal surfaces inside your car, such as the floor or a door, to avoid microwave reflection. (Measurements have shown that the radiation reflected from nonmetallic surfaces, such as glass in the car's windows, is much less intense than that reflected from metal surfaces.)

> Again, there is no proof at this point that traffic radar devices can be harmful to the police officers who use them. Future information may reveal that these devices are indeed harmless. But until the question is settled, taking the simple precautions outlined above should reduce any possible risk."

The Department of Transportation, National Highway Traffic Safety Administration (NHTSA) also issued recommendations after the FDA Update was released. In their bulletin on the matter, NHTSA referred to the FDA recommendations, and, in addition, made additional recommendations, including:[78]

"- Radar antennas, both mounted and hand-held units, must be properly secured to protect officers during emergency vehicle maneuvers.

- Only officers who have successfully completed a certified training program in the proper use of radar should operate units."

NHTSA also recommends that traffic radar units be tested a minimum of once every three years, to ensure that they comply with the "Model Minimum Performance Specifications for Police Traffic Radar Devices".[12]

The Michigan Speed-measurement Task Force has also been active in this arena, and has developed and distributed a "Model Policy for Radar Use,"[79] with recommendations for law enforcement agencies. The "Model Policy" basically reiterates the FDA recommendations. The Task Force has also developed the "Michigan Radar Standard," and recently revised that standard to recommend that "handheld radar devices shall only emit microwave energy while the trigger is pulled and no mechanism shall exist for locking the trigger."[79] Other states and law enforcement agencies have also issued policies or taken action to address the concerns of officers using traffic radar.[80] Among these is a decision by the Ohio State Highway Patrol, made some months ago, that they would change their operations to always mount the radar antenna outside the car (on the passenger side window). That transition, moving radars from an inside, front dash mount, to the outside mount, was undertaken gradually as radar units could be modified to be able to withstand exposure to weather conditions.[22]

Exposure Reconstruction

The other aspect of the exposure assessment, along with present-day measurements, was to find out what, if any, exposure reconstruction could be done for past radar exposure. With respect to mounting locations, our data, and other data from the literature[11,15,16,20,31,33] are again in good agreement. However, we found that law enforcement agencies do not record traffic radar use in any systematic manner. In some cases, e.g., the Ohio State Highway Patrol, the pattern of duty assignment, e.g. routine highway patrol, coupled with personnel records of assignment and normal operating procedures, could provide a surrogate measure of past radar use (and thus exposure). However, in other cases, e.g., the Connecticut State Police, duty assignments, personnel records, and normal operating procedures would not provide a reasonable surrogate measure of past radar use. Unfortunately, most metropolitan police and county sheriff departments, do not maintain records of radar use, nor can such use be inferred by some surrogate measure. Thus, reconstruction of past radar use for most law enforcement officers might only be accomplished through interviews with individual officers and questionnaires. Other potential exposure surrogates were also sought, e.g., records of traffic citations in which the method of speed detection was recorded. However, the records of traffic citations issued were not available for the departments we contacted. We were also unable to identify any alternate potential surrogate measures of traffic radar exposure that would provide the exposure assessment data desired.

Epidemiologic Study of Radar Users

In the four states in which state police departments were visited, tumor registries exist that identify every case of newly diagnosed cancer. In two of the states, (Ohio and Kentucky) the registries have been established for only a short time, rendering them inadequate to support any historical cohort incidence study. In Connecticut the tumor registry is adequate to support a historical cohort incidence study, but in that state, no cohort can be identified from police records. Only New York has both the police records and a registry adequate to identify and follow-up a cohort of radar exposed officers. But alone, New York does not have nearly enough police officers on which to base a cohort incidence study. If such a study were to be undertaken, additional states with adequate records and tumor registries would have to be identified and the cohorts would have to be pooled to make an adequately sized cohort for study.

The possibilities of conducting case-control studies were explored. It was determined that a population based mortality case-control study would not be possible because of the exceedingly small proportion of the population who had worked as police officers with a potential for radar exposure. A population based incidence case-control study was also determined to be infeasible because even though there would be more cases than a mortality study, the proportion of a population who has worked as police officers with a potential for traffic radar exposure is too small.

The present effort to identify potential populations for further research was not exhaustive, leaving open the possibility that there may be other states that possess both adequate records and appropriate tumor registries.

A potential way to circumvent the problem of there being too small a background proportion of persons with exposure (traffic radar officers) for a population based study, is to limit the study population to only state police. In other words, first establish a cohort of police officers, find every incident case of testicular cancer among them, and

then perform a case-control study using these cases. This is called a nested analysis, and is a combination of a cohort and case-control study design. It requires that a cohort incidence study first be performed. This may be the only possible way to pursue a study of traffic radar exposure in police officers.

If states without adequate tumor registries were to be included in the nested case-control study, the only option would be to conduct interviews with all identified members of the cohort (if living), or with next-of-kin (if deceased). Interview studies can be extremely expensive, and frequently suffer from a number of biases. The difficulties associated with interview studies have been the subject of numerous reviews and books.

Thus, there are a number of impediments to a successful execution of either a cohort or case-control epidemiologic study of testicular cancer and radar exposure. First there is the problem of the low incidence of the disease making it necessary to pool many state police departments in order to achieve the necessary study power. Second is the absence of a national tumor registry from which incidence cases can be identified. Third is a lack of a record system that specifically identifies officers exposed to traffic radar, the specific types of radar used, and the amount of radar exposure. Finally, because of the low case fatality rate of testicular cancer, mortality data cannot practically be used. The other cancers of interest, leukemia, eye, and skin, do have a higher case fatality rate, but their incidence rates are also low, resulting in similar limitations for epidemiologic investigation as exist for testicular cancer.

To conduct a traffic radar epidemiologic study, additional states would have to be found where state cancer registries exist back to the late 1970's and where the state police have used radar extensively. Such conditions may not exist. Other states known to maintain tumor registries are Iowa, New Mexico, Utah, and Hawaii and the Commonwealth of Puerto Rico. States such as Ohio and Kentucky who have recently established tumor registries could be used in a prospective study of the incidence of testicular cancer. However, a prospective study, (one that begins in the present day and continues through time until enough cases have occurred for meaningful interpretation) would take many years to accomplish. These types of studies are not normally done because they do not provide any answers in a timely manner and therefore are not very satisfying. The state of New York is one state where sufficient case information from an established tumor registry exists in a state that used traffic radar extensively. This state alone, however, cannot provide enough officers for a successful study.

In summary, the problems outlined above limit the ability to conduct a successful and scientifically valid epidemiologic study of traffic radar gun use and the risk of cancer.

Epidemiologic Study of Occupational Health Risks for Police Officers

In the course of conducting this feasibility investigation several papers were found in the literature that suggest police are at greater risk than the general population for a number of disorders. Excess risks from all-cause mortality, cardiovascular disease, homicide, suicide, and certain malignant neoplasms including colon, bladder, and testicular cancer have been suggested.[81-89] While the expense and difficulty in conducting an epidemiologic study of testicular cancer alone in traffic radar exposed police may not be acceptable, there is sufficient reason to better understand the relationship between many occupational exposures and disorders experienced by police. It would be feasible to establish a large cohort(s) of police and follow them for mortality and specific morbidity. Then, if specific disorders emerge in which police are at higher risk, additional nested case-control analyses can be performed. Because far fewer people are needed for research with nested case control design than with a cohort design or a population-based case-control design, it is easier to reconstruct work histories and exposures that individuals may have received. Moreover, because the nested case-control design is limited to the cohort population, the proportion of persons with exposure is much higher, resulting in more powerful studies. Therefore, after the initial expense of following-up a cohort, a nested case control study can be performed quickly and at lesser cost. A nested case-control epidemiologic study that measures traffic radar as a risk variable for testicular and other malignancies could be carried out and other risk factors for reported excesses, such as cardiovascular disease, could be performed as well.

Based upon these considerations, we have determined that with appropriate funding, a cohort study of police mortality and specific morbidities, followed by nested case-control analyses, is feasible and needs to be conducted. In fact, the Ontario Ministry of Labor is currently conducting a cohort study of all municipal and provincial police (approximately 30,000 officers) and plans to conduct nested case-control studies[90].

If a study of a large group of U.S. police officers is to be initiated, there are some issues that would have to be decided upon at the outset, such as the optimal size of the study cohort and what type of police (state, municipal,

sheriff's department or combination) would be the subject of study. Approximate costs for studying a cohort of 10,000 and 30,000 police officers are $1.4 and $2.6 million, respectively. However, this study is not within the scope of available fiscal year 1995 funds and no additional funds are requested by the Administration in the fiscal year 1996 budget request.

RECOMMENDATIONS

To Reduce Exposure

The health concerns of officers who have used traffic radar in the past cannot immediately be resolved because of a lack of definitive scientific information on chronic, low-level effects of microwave radiation. It is possible, however, to make concrete recommendations about the use of traffic radar devices that will reduce or prevent future exposure. These recommendations are based upon reasonable and pragmatic work practices, can be implemented with existing technology, and can be used to guide future acquisitions of traffic radar devices. Based on our exposure assessment, these measures are simple, effective, and can be implemented immediately without compromising the operational effectiveness of traffic radar use. Adoption of these procedures is prudent public health practice even in the absence of an identified health risk.

To reduce or prevent exposure to microwave radiation emitted from traffic radar devices, the following procedures or techniques are recommended:

1. Hand-held devices should be equipped with a switch requiring active contact to emit radiation. Such a switch, referred to as a "dead-man switch," must be held down for the device to emit radiation, even though the electrical power to the device is on. Adherence to this recommendation should permit the continued use of one-piece, or hand-held radar units.

2. Older hand-held devices that do not have a "dead-man switch" should not be placed with the radiating antenna pointed toward the body, whether it is held in the hand or placed near the officer. A holster or other similar device should be used as a temporary holder for the radar when not in use.

3. When using two-piece radar units, the antenna should be mounted so that the radar beam is not directed toward the vehicle occupants. The preferred mounting location would be outside the vehicle altogether, although this may not be practical with older units that cannot withstand adverse weather conditions. Other options, e.g., mounting on the dashboard of the vehicle, are acceptable if the antenna is at all times directed away from the operator, or other vehicle occupants. Mounting the antenna on the inside of a side window is not recommended.

4. Radar antennas should be tested periodically, e.g. annually, or after exceptional mechanical trauma to the device, for radiation leakage or backscatter in a direction other than that intended by the antenna beam pattern.

5. Each operator should receive training in the proper use of traffic radar before operating the device. This training should include a discussion of the health risks of exposure to microwave radiation, and information on how to minimize exposure to the operator.

These exposure control recommendations can be implemented without delay, and are not contingent upon further epidemiologic studies.

For Future Study

As noted above, several papers were identified in the literature suggesting that police are at greater risk than the general population for a number of adverse health outcomes. Excess risks have been observed from all-cause mortality, cardiovascular disease, homicide, suicide, and certain malignant neoplasms (cancers). The results of these studies and the total aggregate number of municipal, state, and federal police officers demonstrate the public health importance of improving our understanding of the relationship between the many occupational exposures and health problems experienced by police.

It would be feasible to construct a large group or cohort of police and follow them for mortality and specific morbidity. Then, if specific disorders emerge for which police appear to be at higher risk (e.g., testicular cancer), specific epidemiologic analyses could be completed more quickly and economically. If a study of police officers were to be initiated, several scientific and practical issues would have to be addressed, such as defining the optimal size of the study cohort and the type of police (state, municipal, sheriff's department or combination) to be studied. Once these issues were addressed, this type of study of police officers, using a nested case-control design, has the potential to lead to intervention efforts. As a result of our feasibility assessment, such a study would be the best alternative for addressing occupational health hazards of police officers.

Table 1. Traffic radar units measured.

Manufacturer	Model	Band	Dash	Hand Held
MPH Ind.,Inc.	K-55	X	D	
MPH Ind.,Inc.	S-80	X	D	
Decatur Elec.	MVR724	K	D	
Kustom Elec.	KR-10	K	D	
Kustom Elec.	Trooper	K	D	
CMI Inc.	Speed Gun-8	X		H
Decatur Elec.	RA-GUN	K		H
Kustom Elec.	Falcon	K		H
Kustom Elec.	HR-8	K		H
MPH Ind.,Inc.	K-15	K		H

Table 2. Traffic radar power density (PD) measurements made with a Narda 8716 meter and 8721 probe (mW/cm^2).

ID	N	Band	Type	Aperture (Mean PD)	Aperture (PD Range)	5 cm (Mean PD)	30 cm (Mean PD)
A	4	X	F	.49	0.40-0.60	0.47	0.12
B	2	X	F	1.78	1.70-1.90	1.65	0.33
C	2	K	F	1.60	1.50-1.70	0.95	0.88
D	3	K	F	1.47	0.40-2.60	1.05	0.35
E	2	K	F	2.30	2.10-2.80	2.19	0.70
F	4	X	HH	0.44	0.14-0.80	0.42	0.37
G	3	K	HH	0.74	0.50-0.96	0.65	0.21
H	1	K	HH	2.60	2.20-3.00	2.20	0.90
I	1	K	HH	0.42	0.40-0.44	0.28	0.10
J	1	K	HH	2.80	2.60-3.00	2.10	0.77

A - K-55, B - S80, C - Trooper, D - KR-10, E - MVR724, F - Speed-Gun 8, G - K-15K, H - Ra-GUN, I - Falcon, J - HR-8

Table 3. Comparison of traffic radar power density measurements from different studies.

IPTM (mW/cm²)[31]				
Band	Type - Fixed, Hand Held	Mean	Minimum	Maximum
X	F	0.23	0.07	0.54
K	F	0.14	0.01	0.45
K	HH	0.16	0.05	0.55
X	HH	-	-	-

Fisher (mW/cm²)[17]				
X	F	1.9	0.1	6.4
K	F	0.93	0.2	4.6
K	HH	0.69	0.2	4.3
X	HH	2.66	0.3	4.0

Ontario (mW/cm²)[30]				
X	F	1.82	1.06	2.26
K	F	0.77	0.66	0.88
K	HH	1.39	0.64	3.36
X	HH	0.74	0.33	2.0

NBS (mW/cm²)[15]				
X	F & HH	1.18	0.36	2.82
K	F & HH	1.88	0.25	2.78

Table 4. Traffic radar power density measurements made with a Narda 640(X) or 638 (K) Horn and HP 435B Power Meter (mW/cm²).

ID	N	Band	Type	5 cm (Mean)	30 cm (Mean)
D	3	K	F	0.43	0.16
E	2	K	F	2.65	0.94
F	4	X	HH	0.40	0.10
J	1	K	HH	2.03	1.09

Table 5. Potential operator exposure power density measurements made with a Narda 640(X) or 638 (K) Horn and HP 435B Power Meter (mW/cm²).

| | Approximate Operator Loc. | | | Radar Gun Location and Orientation | |
ID	Eyes	Waist	Knees	Mount Location	Radar Facing
E	0.07	ND	ND	Inside Rear Window - Driver Side	Back
E	0.07	0.05	ND	Inside Rear Window - Passenger Side	Front
F	0.10	0.01	ND	Front Dash Mount - Centered	Front
F	0.07	2.60	ND	Resting on front passenger seat	Driver
F	0.04	0.01	ND	Resting on front passenger seat	Pass. door
F	0.07	ND	ND	Over operator's shoulder	Back
G	0.16	0.16	ND	Resting on front passenger seat	Driver
G	0.13	0.13	ND	Resting on front passenger seat	Pass. door
J	0.20	0.42	ND	Resting on front passenger seat	Driver
J	0.97	0.97	ND	Resting on front passenger seat	Pass. door
J	0.65	ND	ND	Over operator's shoulder	Back

Appendix I. NIOSH contacts for Police Radar Feasibility Assessment.

The organizations and individuals listed below represent those with whom significant contact was made in the course of the NIOSH feasibility assessment. Specific information obtained from these sources is incorporated with references in this report, but a list is provided to acknowledge the cooperation and assistance of these individuals in providing comprehensive information on the subject.

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