

Radiation hazards and fertility. What do we know?

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Introduction

Warships of the Royal Australian Navy (RAN) are equipped with various sources of radio frequency (RF) energy, including communications antennae, radar equipment and aircraft sources. Indeed, this situation applies to other Defence assets as well. However sailors, because of confined space below decks and the presence of fuel and ordnance find that the only opportunity for fresh air and space is on upper decks in close proximity to RF sources. This has the potential for near-field exposures to non-ionizing radiation hazards (RADHAZ). Many anecdotal stories are shared by sailors and other personnel about the supposed effect of RADHAZ on health, most commonly on their 'fertility.' This article reviews the known biological effects of non-ionizing radiation on humans, and any potential effects on fertility.

Non-ionizing radiation

Radiation forms such as ingestion of medical isotopes, X-rays, and gamma rays are sufficiently energetic to cause ionization in tissues (hence the term *ionizing* radiation) and are associated with the development of malignancy and other adverse health effects in humans. The more common forms of energetic radiation encountered in occupational and other settings include RF (or microwave) radiation and extremely low frequency (ELF) radiation. ELF radiation, at about 60 cycles

per second, is the type encountered in the presence of high-tension power lines. ELF and its association with adverse health effects will not be considered here. The widespread use of mobile telephones and other hand-held devices such as iPads with Internet connectivity mean that many people are in regular close proximity to relatively intense RF energy emissions, and this has prompted further study into its biological effects.

Apart from the ubiquitous mobile telephone or iPad, military personnel commonly work in proximity to radars (which radiate microwaves) or communications antennae. In ships, radars are usually mounted so as not to irradiate the decks or superstructure, but communications antennae mounted on the superstructure can give rise to so-called 'hot spots' from resonances and re-radiation. RADHAZ footprints are carefully mapped and marked on decks around antennae and other high-energy sources as exclusion zones.

Radiation in the RF range does not affect DNA, but it does have the potential to cause heating of tissues. The evidence regarding biological effects of RF energy have been well summarized by Goldsmith (1) and I quote his findings here, although readers are encouraged to consult the paper. Of relevance to reproductive effects, Goldsmith quotes two sources. A study comparing female physiotherapists who did or did not use RF or shortwave therapy apparatus during the first trimester of pregnancy, usually with exposures for only a few minutes at a time, revealed increased odds for miscarriage in the first trimester. The odds increased with increasing exposures. (2) The other, a study of embassy personnel who worked in proximity to RF sources, reported an increased rate of pregnancy complications. (3) In addition to these suggestions of adverse reproductive effect, other biological effects have been reported: shifts in red and white cell counts; increased rates of malignancy; and increased somatic mutation rates in lymphocytes. Some of these effects have been noted previously in a report from Australian Defence Force (ADF) personnel with accidental exposure to microwave radar irradiation. (4)

Fertility in military personnel

Before discussing any real or potential effects of RF radiation exposure on the reproductive potential of Defence Force personnel, it is important to review what is known about the

normal 'fertility' of this population. Making such assessments is not as easy as it might appear. The accepted measures of 'fertility' in women are twofold. *Fecundity* is the probability of pregnancy in each month of mid-cycle intercourse, and although it is typically about 25% in healthy young women not using contraception, is influenced strongly by many factors, including the age of the woman and stress (which is associated with anovulation, and indeed reduced sexual receptivity). When pregnancy occurs, the rate of miscarriage is also an important factor and this increases with age. The definition of 'fertility' in males is more difficult, and results of semen analysis cannot be used as a surrogate measure of fertility. A useful working definition of male fertility is, *the ability of a man to consistently make and deliver sufficient numbers of normal sperm into the female reproductive tract at the fertile time.* (5) Unfortunately, studies using such a definition have never been undertaken. The results of semen analysis are notoriously variable, and even fertile men will commonly have surprisingly disappointing semen parameters.

Effects on Semen

The potential effects of military service *per se* on reproductive health have been addressed previously in this journal (6), but important data have become available since that time. A study of US Army soldiers who worked with radar revealed that many of them were concerned about their exposures and the potential effects on their fertility. (7) Such a finding will surprise no one. Although measures of endocrine function showed no differences between the exposed and control groups, it was noted that soldiers with microwave exposure had significantly lower sperm concentrations in their ejaculates. Interestingly, the soldiers who were most concerned about their fertility were found to have lower sperm concentrations and the reason for this finding was not clear. The sample sizes were small and it is difficult to draw a conclusion from the study. A more recent and larger study from China examined sailors exposed to radar, and examined sperm concentrations, motility and morphology in the study subjects. The study reported that radar exposure was associated with reductions in sperm motility and increased proportions of abnormal sperm. (8) However, cessation of exposure resulted in rapid recovery of sperm morphology parameters. A larger study of US soldiers, however, reported no association between radar exposure and either hormonal or semen analysis parameters. (9) The data available are from small groups and the results are contradictory.

Gulf War exposures.

If exposure to active military service does affect fertility, it might be reasonable to ask what larger cohort studies have revealed about fertility during active service. A number of studies have examined reproductive outcomes of veterans of the 1991 Gulf War. A retrospective study was undertaken of all British armed forces personnel deployed to the Gulf War, comparing them with serving personnel deployed elsewhere. Notwithstanding the differing response rates to the surveys, the study found significant increases in self-reported infertility in the Gulf War veterans group that were robust. (10) When reproductive outcomes in the cohort were examined, no association was found between service in the Gulf War

and stillbirth, chromosomal abnormalities, or any specific syndromes. (11) A survey of United States Gulf War veterans revealed no significant differences in self-reported adverse pregnancy outcomes in men or women compared to control groups. (12) A very similar study of French Gulf War veterans did not identify any tendency to infertility or adverse pregnancy outcomes in the study group. (13)

A cross-sectional study of over 1400 male Australian Gulf War veterans was undertaken with a control group of similar size comprising randomly-selected military personnel without the exposure. This was conducted by postal survey with questions relating to fertility delays, pregnancy outcomes including live birth, stillbirth, miscarriages, and other pregnancy losses. For live births, data were obtained regarding sex of the offspring, birthweight, and serious health problems in the progeny. No differences were detected in the rate of adverse outcomes between the groups, although there was a marginally significant trend to fertility delays in males in the Gulf War veterans' group. (14) The difficulty with such retrospective surveys is the self-selected nature of the responses and the consequent difficulty of applying the data more generally.

Pregnancy after RADHAZ exposure. Assuming that exposure to non-ionizing radiation in particular, and active service in general is not associated with subsequent fertility problems; it is also worth examining the effect of such exposures on longer-term pregnancy outcomes. It has already been shown that some data suggest there may be an effect on miscarriage rates. (2, 3) A potentially common situation is inadvertent exposure to radiation before the diagnosis of pregnancy has been made, so this is usually in the first trimester. While it is well-recognised that such exposure to ionizing radiation (X-rays, for example) is associated with teratogenesis that is dose-dependent, fortunately no such association has been found for non-ionizing radiation exposures. (15)

Discussion

Non-ionizing radiation hazards, usually from radar and communications equipment, are well recognized in both military and civilian occupational settings. Mapping of such hazards is routinely undertaken and exclusion zones are usually well-marked and adhered to. Positioning of such apparatus is undertaken to minimize risk. Additional effects, such as re-radiation and resonances around communications equipment, are also recognized and such 'hot-spots' are usually well-known and marked. The typical setting in which inadvertent exposure occurs is during a breakdown in protocols: personnel are present in danger zones during use of equipment or radiation from radar equipment. Temporary biological effects, most likely from microwave heating, are well recognized and temporary with little evidence of cumulative, chronic effects.

Studies of 'fertility' in military personnel to date suffer from major methodological problems – they are typically retrospective (often by many years), there is little or no dosimeter or estimation of exposure, participants are commonly self-reporting which leads to bias, and definitions of 'fertility' or 'infertility' are difficult to standardize. When objective measures are used, such as semen analysis parameters or serum hormone levels, these are notoriously variable and

difficult to compare. Since occupational regulations are in place to minimize exposure, it is unlikely that reliable large scale data will ever be available. The large studies from military populations who would be expected to have the highest risk of inadvertent exposure (that is, during war) are reassuring, with no evidence of differences in fertility or pregnancy outcome between exposed and control groups.

Conclusion

Safety concerns harboured by personnel who are working close to RADHAZ equipment are understandable. However existing safe working protocols are likely to be effective. In cases of inadvertent exposures to radar or RF transmissions, biological effects (presumably from microwave heating or similar) are likely to be temporary and there is no evidence of a long term adverse effect on fertility or pregnancy outcome.

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