METALLIC IMPLANTS AND EXPOSURE TO RADIOFREQUENCY RADIATION

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There is increasing use of radiofrequency radiation (RFR) in industry for communications, welding, security, radio, medicine, navigation etc. It has been recognised for some years that RFR may interact with cardiac pacemakers and steps have been taken to prevent this interference. It is less well recognised that other metallic implants may also act as antennas in an RFR field and possibly cause adverse health effects by heating local tissues. There are a large and increasing number of implants having metal components which may be found in RFR workers. These implants include artificial joints, rods and plates used in orthopaedics, rings in heart valves, wires in sutures, bionic ears, subcutaneous infusion systems and (external) transdermal drug delivery patches[1]. The physician concerned with job placement of such persons requires information on the likelihood of an implant interacting with RFR so as to impair health. The following outlines the approach developed in Telecom Australia, beginning with the general principles and then presenting a discussion of a specific example.

PRINCIPLES

The following approach is used to assess the possible health hazard to staff with metallic implants who are exposed to RFR.

1. Information is obtained on the type of implant, its anatomical location, geometry and type of metal used. The implant is then classified as either a rod, ring, plate, or solid, or combination thereof.

2. Information is obtained on the frequencies, field strengths and likely duration of exposure.

3. The interaction between the incident fields and the implant is then modelled using two approaches:
(i) Where the maximum dimension of the implant is equal to one half of a wavelength of the RFR in tissue. Here the implant is behaving as a resonant object which is considered to be the worst case and a detailed analysis is necessary.
(ii) Where the maximum dimension of the implant is less than one-quarter of a wavelength of the RFR in tissue. Here the implant is considered to be electrically short and simplifying quasi-static approximations can be used.

Rates of energy deposition in surrounding tissues are then calculated.

4. The effect of any excess heat in tissues surrounding the implant is then considered with due consideration to cooling efficiency and sensitivity of that tissue. The interaction must not cause more than a 1°C temperature rise.

5. Medical advice is then given to the individual and to management on what precautions, if any, are to be taken.

CASE EXAMPLE

The above points are illustrated in the case of a 32 year old male radio technician who has undergone cardiac surgery and still has the wire sutures securing the sternum.

1. The chest X-ray and clinical notes revealed 1mm stainless steel wires forming loops and near-vertical twists of wire some 2mm in diameter (Fig. 1). These structures were classed as both rods (the wire twists) and rings.

2. The subject is predominantly exposed to frequencies between 6 and 22 MHz at very low levels ($<2mW/cm^2$) but the possibility exists of exposure to the allowable limit of $25mW/cm^2$ for up to 8 hours with provision for a short term (<6 minutes) exposure limit (STEL) of up to $100mW/cm^2$ (AS2772-1985[2], Fig. 2). In future he may be required to work at frequencies above 30MHz where the exposure limit is $1mW/cm^2$ for up to 8 hours with provision for a STEL of $5mW/cm^2$.

3. The interaction between the incident fields and the implants was assessed by the following two methods and subsequent tissue temperature calculated.
(i) Although the implants shown in Fig. 1 are a combination of wires and loops the approach was to first model the wire twist and then investigate the effect of adding the loop. This approach is justified because vertical electric (E)-fields produce the strongest absorption in the body and the wire twists are so oriented as to maximize pick up; conversely the loops are so oriented as to minimize pick up. In treating the case of the wire twists acting as half wave resonant objects in a complex medium, use was made of a mini-numerical electromagnetics code (MININEC) which is a method of moments analysis of thin wire antennas in free space[3]. The actual computer code used was a very recent and improved version written in PASCAL by Dr A.W. Davis*. The code was altered to accept a complex medium and currents calculated in the wire twists at resonance assuming an incident plane wave. These results compared favourably with

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others[4]. The effect of the loop on the induced currents in the wire twists was also investigated. The maximum E-field enhancement at a distance of half a wire radius from the tip of the implant was then calculated. The final two steps in arriving at a temperature rise included, (a) calculation of the fraction of the incident E-field that reaches the implant assuming a planar tissue geometry, and (b) calculation of the heat flow assuming a small cylindrical tissue volume centred on the tip of the implant. The temperature rises are listed in Table 1 for the resonant range of the implants of 1650 to 3000MHz corresponding to wire twist lengths of 12 and 7mm respectively. At the STEL the tissue temperature rise exceeds 1°C.

(ii) The quasi-static approximation consisted of modelling the wire twists as prolate spheroids (the body obtained by rotating an ellipse about its major axis) and calculating the enhancement in the E-field at the tip of the implant[5]. That fraction of the incident E-field reaching the implant was found from calculations of the internal E-field distribution in whole body block models of man[6]. Note that the maximum induced E-field occurs at 80MHz where the whole body is acting as a resonant object. The resultant temperature rises at frequencies of 3, 9.5 and 80MHz are also listed in Table 1. The frequencies of 3 and 9.5MHz were chosen for calculation because the exposure limits reach maximum values of 100 and 10mW/cm^2 respectively (Fig. 2). At the STEL the tissue temperature rise approaches 1°C.

Table 1 Tissue temperature rises at the exposure limits.

Frequency (MHz)	Exposure Limits (mW/cm2)	Temperature Rise (deg. C)
1650-3000	1	0.27
1650-3000	5 (STEL)	1.4
80	1	0.15
80	5 (STEL)	0.77
9.5	10	0.011
3	100	0.0045

4. The implants are embedded in cartilaginous bone which is in contact with skin tissue capable of readily dissipating heat. Although some of the wire loops protrude inside the rib cage the most critical parts were found to be the tips of the wire twists which are external to the rib cage and not in contact with overtly sensitive tissue.

5. The advice given to the subject and management was that work can proceed at exposure levels up to the occupational limits for frequencies below 30MHz. However, no STEL work is permitted particularly at frequencies between 50-150MHz and in the gigahertz range.

Future work will include the evaluation of plates, particularly those in the skull, and solids such as hip replacements. In addition experimental verification of the calculations is a priority.

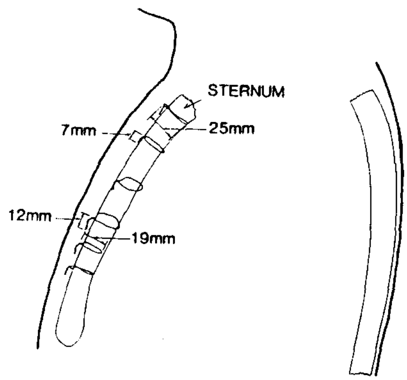

Figure 1: Schematic of sternum from the side showing wire implants.

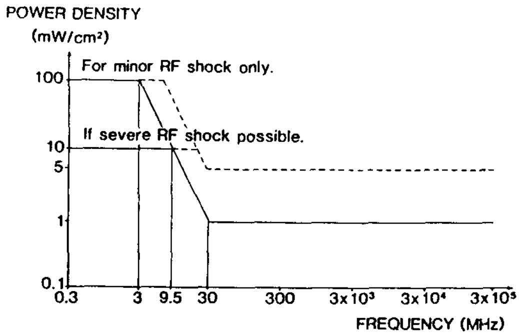

Figure 2: Australian exposure limits - occupational. The dashed lines represent the maximum short term exposure limits.

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