19BME308 - Medical Radiation Safety

UNIT I - INTRODUCTION TO RF AND MICROWAVE RADIATION

1.8 The Use of Electromagnetic Fields in Medicine and Its Effect on Patients

• Electromagnetic fields (EMF) of lower frequencies up to 200 MHz are commonly used in medicine for diagnosis and therapy; included are exposures to radiofrequency (RF) fields above 100 kHz (0.1 MHz).

• Three main EMF applications in medicine are magnetic resonance imaging (MRI), radiofrequency ablation (RFA) used in cardiology and tumour therapy, and localized dielectric heating (short wave diathermy) used in physiotherapy.

• MRI produces three different fields to generate images: (1) a static magnetic field of zero frequency; (2) low power time-varying magnetic field gradients (100 Hz to 1 kHz); and (3) RF fields (10 to 400 MHz). No long-term effects of EMF exposures to MRI patients on reproductive, cardiovascular and cognitive function outcomes have been reported. While MRI operators may be exposed to RF when working less than 0.5 meters from the bore, there is no indication of chronic effects from their occupational exposure to the EMF fields.

• RF ablation is a minimally invasive medical procedure that destroys tumours and unhealthy tissue in heart muscle by thermal means from RF. Complications to patients, which may arise due to non-target thermal damage, are usually reversible. We found no studies of occupational health risks for workers administering RF ablation.

• Diathermy is used in physiotherapy to heat surface or deep tissue to relieve joint and muscular problems. There was no literature concerning adverse effects on patients. Although female physiotherapists have been found to be at a slight increased risk for spontaneous abortions and heart disease, these may be relevant only to the older practice of microwave diathermy rather than the more current common use of shortwave diathermy.

EMF Applications in Medicine

A combination of magnetic and RF fields are employed in diagnostic imaging. Applications involving heat-generating RF waves are used for therapeutic purposes.

The three main EMF applications and areas of medicine using EMF sources are:

• MRI – diagnostic imaging

• RF ablation – cardiology and cancer (tumour) therapy

• Localized dielectric heating (shortwave diathermy) – physiotherapy.

Table 1 below summarizes power and frequency ranges applicable to various medical devices: MRI; cardiology; physiotherapy; and tumour therapy.

Table 1. Frequency and power of EMF machines used in medicine

Application		Power or Magnetic Field Strength	Frequency
MRI	Main magnetic field	1.5, 3 Tesla (T)	64, 128 MHz
	Gradient magnetic field	few milliTesla (mT)	Multi-frequency in the MHz range
	Radiofrequency field	Up to few kilowatts but not radiative (no radio waves emitted)	100 to 200 MHz
Cardiology		RF generator: 50 Watts	460–480 KHz
Tumour Therapy		RF generator: 200 Watts	461 KHz
Physiotherapy		RF generator: 500 Watts	27.12 MHz

Adverse health effects for patients exposed to MRI fields

The RF frequencies used in an MRI scanner can result in high absorption of RF over the whole body, with the eyes and testes being especially vulnerable to heating effects. Metal-based pigments such as tattoos increase the probability of burns, as do metallic implants. However, there have been no epidemiological studies on long-term health effects specifically attributed to RF fields associated with MRI procedures. Rather, adverse outcomes for patients who have undergone MRI treatments have been associated with their exposure to static magnetic fields.

***Cancer*:** Although there is no epidemiological literature on cancer attributed to patients being examined by MRI, there is suggestive evidence of possible DNA damage as micronuclei induction (associated with carcinogenesis) has been shown to temporarily increase during MRI diagnostic scans.

Reproductive and development outcomes: The available data on fetal exposure to EMF during MRI examinations do not point to adverse effects on the developing fetus. The main concern would be the temperature increase that could be generated by the RF fields of MRI. However, temperature increases in the fetus during MRI examinations are under strict guidelines and unlikely to reach 0.5^{o}C. A 2008 UK-HPA review of studies related to reproductive and development outcomes concluded that there was no evidence of adverse effects on eye and ear functions or reproductive outcomes on children previously exposed to MRI in utero.

Cardiovascular effects: During MRI examinations, the time-varying magnetic field gradients at frequencies ranging from 10 to 100 Hz could cause cardiac problems to patients if the induced current density is higher than the cardiac stimulation threshold of 1.2 Ampere/m^2. However, modern MRI machines are designed to deliver lower time-varying fields, far below the cardiac stimulation threshold current density. Furthermore, no significant cardiovascular changes in

patients undergoing MRI procedures have been reported. A consideration is that above 100 Hz, muscle tissue (including cardiac muscle) is less responsive to electrical stimulation.

Peripheral nerve stimulation: Time-varying magnetic fields up to 5 kHz can induce currents in the MRI patient. Peripheral nerve stimulation is possible but only when the magnitude of the induced current densities is sufficiently high. The threshold current density for nerve stimulation is comparable to the level for cardiac stimulation, but MRI machines are designed to operate far below this threshold by keeping the current densities below 0.4 Ampere/m^2. At frequencies higher than 5 kHz, nerve cells are less responsive to electrical stimulation.

Effects on cognitive function:

A recent study by Schlamann et al. involved the participation of 25 volunteers without history of neurological diseases in a series of neuropsychological tests before and after undergoing MRI examinations at 1.5 Tesla and 7 Tesla. The testing, which focused on the volunteers' attention capabilities, consisted of paper-based and computer-based neurobehavioral tests. The study did not reveal any adverse effects on cognitive test performance after exposure to MRI fields.

Radiofrequency thermal ablation

Radiofrequency ablation (RFA) procedures in medicine are mainly used in cardiology for the treatment of cardiac disorders and in oncology for tumour treatment.

For interventional cardiology, RFA is a minimally-invasive medical procedure used to correct irregular heart rhythms (primarily atrial fibrillation). The RF device consists of an ablator (catheter), RF generator, and a control console. The energy-emitting probe (electrode) is at the tip of a catheter which is inserted through very large veins into the heart. Ablation involves

destroying small diseased parts of heart muscle by means of the resistive heat due to the electric current generated by high frequency RF waves in the catheter.

RF is also used to treat tumours in lung, liver, kidney, and bone but with the generator at a higher power than used for cardiology purposes. A needle-like RFA probe is placed inside the tumour. RF waves passing through the probe increase the temperature within tumour tissue resulting in its destruction. RFA may be combined with locally delivered chemotherapy treatment, and it is of particular value in reducing the size of inoperable tumours. RFA is minimally invasive and repeated procedures can be done with few complications when performed under radiological guidance.

Adverse health effects of patients undergoing RFA procedures

Generally with RFA, unhealthy tissue is treated by thermal means at RF frequencies up to 200 MHz. However, the heat is generated in a small area. Temperatures in the treated areas could reach 100°C or slightly higher. Some complications are associated with RFA, but they are usually reversible.

The main adverse effects of RFA treatment are reported in the literature to be thermal consequences resulting from direct or indirect RF heating of tissue.

The following thermal effects on patients have been reported after use of tumour therapy:

• Thermal injury to the ureter following ablation of renal cell carcinoma

• Case reports of skin thermal necrosis after treatment of osteoid osteoma

• Non-target thermal damage to adjacent structures after treatment of liver, pulmonary, and renal tumours

• Cardiac complications that can arise from thermal injury due to RFA such as esophageal temperature increase during pulmonary vein isolation

Localized dielectric heating (shortwave diathermy)

Shortwave diathermy is the therapeutic application of high frequency alternating current used in physiotherapy treatments. RF fields are used to speed up the healing of tissues by providing deep heat to a large area of the body positioned under conductance plates. Continuous shortwave diathermy is the technique of choice when heating of deep tissue is required. Diathermy also allows superficial structures to be heated selectively by means of various surface heating techniques. Sub-acute or chronic conditions respond best to continuous shortwave diathermy which, when used properly, can be as effective as high power ultrasound. Diathermy is used to relieve pain and muscle spasm, resolve inflammation, reduce swelling, increase joint range and decrease joint stiffness.

Adverse health effects of patients undergoing diathermy

No published reports could be found concerning chronic effects related to patients' treatments with diathermy. An important precaution when administering shortwave diathermy is to ensure the heating is targeted accurately by using correctly positioned applicators.

Reference: "Radiofrequency Toolkit for Environmental Health Practitioners" (2013)