Radiation Exposure in Clinical Settings

2.5 contact hours: Free

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This course will be reviewed every two years. It will be updated or discontinued on Dec 1, 2012.

Course Summary: Describes both ionizing and non-ionizing sources of radiation, its effects and mechanisms related to cancer, and potential radiation hazards in healthcare settings.

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Instructional Level: Introductory
Content Focus: Category 1- Domain of OT, Client factors

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Course Objectives

When you finish this course, you will be able to:

- Identify both natural and manmade sources of radiation in the United States.
- Describe the mechanisms and effects of ionizing and non-ionizing radiation related to cancer.
- Explain why exposure to non-ionizing radiation from extremely low-frequency electromagnetic fields and radiofrequency/microwave sources may increase the risk of cancer in children and adults.
- State the types of ionizing radiation used in medicine and discuss their potential for overuse.
- Discuss potential hazards from extremely low-frequency electromagnetic fields and radiofrequency radiation (non-ionizing radiation).
- Summarize radiation safety procedures for both patients and healthcare workers.

Radiation Exposure

Everyone is exposed to a spectrum of radiation from both natural and human-made sources. Natural sources of background radiation include cosmic radiation from the sun and terrestrial radiation from soil, water, and vegetation, which contain low levels of uranium and its decay products, such as radon gas. Human-made sources of radiation include nuclear power and nuclear weapons, as well as medical imaging procedures such as x-rays, scans, and other procedures that involve **radionuclides**.

Some Manmade Sources of Radiation

Nuclear power plant. Source: Wikimedia, public domain.

Source: Radiation and Cancer: A Need for Action.

Radiation exposure is increasing—particularly in industrialized countries—raising the risk of radiation-induced cancers. This course encompasses both ionizing radiation and non-ionizing radiation, and the links of these exposures to cancer.


A soldier being slide into a CAT scan machine. Public domain.

As leading health professionals, patient advocates, health educators, and as parents and individuals, nurses need to understand the risks and benefits of radiation exposure. Medical use of ionizing radiation is important to the diagnosis and treatment of diseases and disorders but also involves health risks, including cancer, both for patients and professionals. Nuclear power is used to generate electricity, but is associated with increased risk of cancer throughout the nuclear fuel cycle. Nuclear energy production also includes the inherent risk of nuclear weapons use. Wireless technologies such as cellular/cordless phones, cell phone towers and antennas, and other wireless infrastructure have added convenience to our lives but have also greatly increased public exposure to non-ionizing radiation, which is associated with a number of health risks, including cancer.

Clinical nursing can involve various occupational exposures to ionizing radiation. For example, surgical nurses who assist during fluoroscopy-guided procedures in cardiology, orthopedics, gynecology, or during sentinel node biopsies for breast cancer are exposed to ionizing radiation. Oncology nurses who work with patients treated with radioactive implants are also exposed. Use of portable x-ray machines in patient rooms also exposes nurses and other care providers.

The cancer risks of radiation may not be apparent until long after exposure. The latency period varies from 5 to 15 years for leukemias and from 10 to 60 years for solid tumors (Hall & Giaccia, 2006). Therefore, children are more vulnerable than adults to the long-term effects of radiation, not only because their cells are dividing more rapidly but also because they have a longer lifespan than adults during which cancer may develop.

To protect the health of patients, themselves, and their communities, nurses need to understand how to reduce or eliminate unnecessary radiation exposure.

Types and Sources of Radiation

Ionizing Radiation

The spectrum of radiation includes both ionizing and non-ionizing radiation. **Ionizing radiation** is any form of radiation with enough energy to detach electrons from atoms or molecules (to ionize them). This type of radiation includes alpha particles, beta particles, neutrons, x-rays, gamma rays, and cosmic rays, which have different energy levels and abilities to penetrate cells. Ionizing radiation is **genotoxic** (damaging to DNA), acting directly on DNA or indirectly by producing free radicals that damage DNA. Damage to DNA can kill cells or interfere with cellular repair mechanisms, thereby putting cells on the pathway to cancer.

Medical radiation accounts for nearly half of the total ionizing radiation exposure of the U.S. population from all sources, primarily due to the significant increase in use of computed tomography (CT) and nuclear medicine procedures. An estimated 67 million CT scans and 18 million nuclear medicine procedures were performed in the United States in 2006. Together these two modalities account for 36% of the total radiation exposure and 75% of the medical radiation exposure of Americans (NCRP, 2009).

Background radiation contributes half of the total population exposure. Sources of background radiation include:

- Natural radiation in soil and rocks
- Radon gas produced by the radioactive decay of radium (found in uranium ore and its wastes)
- Radiation from space
- Radiation from sources found naturally within the human body

Radon gas is the major natural source of radiation exposure. Colorless and odorless, radon gas moves into homes and other buildings. Exposure levels vary across the United States, but radon can be easily detected and inexpensively reduced or eliminated. The U.S. Environmental Protection Agency publishes *A Citizen's Guide to Radon,* which is downloadable from http://www.epa.gov/radon/pdfs/citizensguide.pdf.

Certain consumer products also add a small amount—estimated at 2%—of radiation exposure. These products include tobacco smoke, smoke detectors, microwave ovens, and televisions (NCRP, 2009). Recent reports have highlighted the use of radioactively contaminated metals in a variety of consumer products, including cheese graters, reclining chairs, tableware, and women's handbags. A Scripps-Howard News Service investigation found that there is no federal/state oversight of recycled metals and no incentive for businesses to report contamination of these metals (Wolf, 2009). The U.S. Environmental Protection Agency (EPA) states on its website that "radioactively contaminated scrap threatens both human health and the environment." Lack of oversight and tracking of these metals and the products in which they are used means that the threat cannot be quantified.

Non-Ionizing Radiation (EMF)

Non-ionizing radiation (also called electromagnetic fields, or EMF) is a type of low-level radiation without enough energy to detach electrons from their orbits around atoms and ionize them. Two principal types of EMF discussed in this course are **extremely low-frequency electromagnetic fields (ELF-EMF)**, which are produced when electrical power is transmitted and distributed, and **radiofrequency/microwave radiation (RF)**, which is produced by cellular/cordless phones, other wireless devices, and the towers and antennas that transmit the signals to and from these devices.

Sources of ELF-EMF including high-voltage power transmission lines (usually on metal towers) carrying electricity from power-generating plants to communities, and power distribution lines (usually on wooden poles) that bring electricity into homes, schools, and workplaces. Electric lighting generates ELF-EMF. Fluorescent lighting and other low-voltage lighting produce higher levels than incandescent lighting. Other sources of ELF-EMF including electrical wiring in buildings and electrical appliances such as radios, televisions, hair dryers, microwave ovens, electric blankets, etc.

Ionizing Radiation and Cancer

> Cancer induction is the most important somatic effect of low-dose ionizing radiation.
> Hall & Giaccia, 2006

Exposure to ionizing radiation causes cancer. Ionizing radiation is the most thoroughly studied and longest-known cause of human cancer. Decades of research conducted by national and international agencies have made that fact indisputable. Most sites in the body are vulnerable to the carcinogenic (cancer-producing) effects of ionizing radiation; certain sites, including the thyroid, bone marrow (white blood cells), breast, and lung are particularly vulnerable. In addition, women and children are more at risk of harm from radiation exposure than adult men.

Mechanisms and Effects

Ionizing radiation can increase the risk of cancer through several mechanisms, including direct mutagenesis (altering the structure of DNA) and genomic instability (accelerating the rate of chromosomal changes, thereby increasing the likelihood of future mutations) (Goldberg & Lehnert, 2003; Morgan, 2003; Wright, 2004), and changes in the cellular micro-environments that alter regulation of cell-to-cell interactions (Tsai et al., 2005; Barcellos-Hoff et al., 2005). Radiation not only affects cells directly exposed but can also alter the DNA, proliferation, and interactions of neighboring cells, a phenomenon referred to as the "bystander effect" (Little, 2003; Murray et al., 2007).

There are two categories of biologic effects from exposure to ionizing radiation: deterministic effects and stochastic effects. **Deterministic effects**, such as cataracts or erythema, are those produced above a certain threshold dose; exposures below the threshold dose do not produce these effects. **Stochastic effects**, such as radiation-induced cancer and heritable genetic defects, assume no known threshold dose, and the risk of these effects increases with each additional dose of radiation. Susceptibility to and severity of these effects may differ among individuals (Andreassi, 2004).

Lines of Evidence

Four principal lines of evidence point to ionizing radiation as a human carcinogen: (1) studies of atomic bomb survivors; (2) studies of patients irradiated for diagnostic or therapeutic purposes; (3) occupational studies of workers exposed to radiation in healthcare, manufacturing, mining, or the various sectors of the nuclear power/nuclear weapons industries; and (4) environmental epidemiological studies of communities exposed to indoor radon and to radiation across the nuclear fuel cycle. For example:

- Many studies of atomic bomb survivors indicate that radiation dramatically increases the risk of leukemia (UNSCEAR, 2000);
- Studies of atomic bomb survivors (UNSCEAR, 2000; Wakeford, 2004), female radiologic technologists (Mohan et al., 2002), and patients with tuberculosis (Boice et al., 1991) or scoliosis (Morin-Doody et al., 2000), show increased risk of breast cancer.
- Childhood cancer studies link nuclear fallout from weapons testing with acute leukemias (Stevens et al., 1990). Contamination from the Chernobyl nuclear reactor accident is associated with increased thyroid cancers (Cardis et al., 2005). One meta-analysis suggested that living near nuclear facilities is associated with an increase in the risk of leukemia (Baker & Hoel, 2007).
- Studies of uranium miners show significantly increased risk of lung cancer from exposure to radon (Taeger et al., 2008; Boice et al., 2008).
- The largest study ever of nuclear workers linked low doses of radiation with a small increase in cancer risk (Cardis et al., 2005).

There is no “safe” dose of ionizing radiation. The National Research Council’s 2005 review of low-dose risk estimates concluded that there is no beneficial exposure to ionizing radiation—a small risk of cancer exists even at low doses and increases proportionally with each increase in dose (National Research Council, 2005). Radiation damage to genes is cumulative over a lifetime (Boice, 2001). Therefore, many low-dose exposures over time may have the same harmful effects as a single high-dose exposure. Any effort to prevent cancer must include reducing or eliminating unnecessary exposure to ionizing radiation whenever and wherever possible.

Non-Ionizing Radiation and Cancer

Mounting evidence suggests that chronic, low-level exposure to non-ionizing radiation from extremely low-frequency electromagnetic fields (ELF-EMF) and radiofrequency/microwave (RF) sources may increase the risk of cancer in children and adults. Hundreds of studies indicate that these exposures can damage DNA, modify gene expression, alter cellular function, and lead to cancer. Studies in human populations include exposure to RF from cellular and cordless phone use and exposure to ELF-EMF from the transmission and distribution of electrical power (Sage & Carpenter, 2009).

Extremely Low-Frequency Electromagnetic Fields (ELF-EMF)

The International Agency for Research on Cancer (IARC) classifies ELF-EMF as a Group 2B carcinogen (possible human carcinogen). This classification is based on more than 25 years of study examining the association between exposure to ELF-EMF and the risk of childhood leukemia. Key findings include the following:

- Two comprehensive meta-analyses using different pooling techniques reached the same conclusion: high and prolonged average levels of ELF-EMF exposure were linked with elevated risk of childhood leukemia (Ahlbom et al., 2000; Greenland et al., 2000). These studies defined high levels as above 4 milligauss [mG], which are very rare and affect fewer than 1% of children.
- Additional evidence suggests an increased risk of childhood leukemia following maternal occupational exposure to ELF-EMF during pregnancy (Infante-Rivard & Deadman, 2003).
- Men who work in electrical occupations have an elevated risk of breast cancer, even though the disease is rare among men (Milham, 2004; Erren, 2001; Weiss et al., 2005). Two studies in Sweden (Kliukiene et al., 2004; Feychting et al., 1998) found that women with both occupational and residential exposure to high-voltage power lines had a higher risk of breast cancer than those exposed only at home.
- The California Department of Health Services (2002) found that EMF increases the risk of adult brain tumors.

How ELF-EMF contributes to leukemia and other cancers is not completely understood. However, a new study from China suggests that genetic variability in DNA repair mechanisms may increase some children's susceptibility to leukemia when chronically exposed to ELF-EMF during prenatal development (Yang et al., 2008).

Radiofrequency Radiation (RF)

Cellular and cordless phone use has increased exponentially over the past ten years. Scientists have investigated the potential health effects of these devices and their supporting infrastructure only since about 1995. Even in this short time, results from the largest international cell phone studies conducted under the auspices of the World Health Organization (WHO) Interphone Study Group are showing an increased risk of malignant brain tumors (glioma). These aggressive tumors are found at twice the expected rate at only >10 years latency (the time between exposure and diagnosis of cancer) when phones are used predominantly on one side of the head (laterality) (Lahkola, et al., 2007). Normal latency for solid tumors is >20 years between exposure and diagnosis of cancer. Other examples follow:

- Studies in Sweden and other countries in which cellular/cordless phones have been used for years longer than in the United States also found a consistently elevated risk of acoustic neuroma (a tumor on the auditory nerve affecting hearing and balance) and glioma after >10 years of use when used primarily on one side of the head (Hardell et al., 2008; Hardell et al., 2007; Cardis, 2008).
- Meta-analyses of studies with appropriate latency (>10 years), degree of use and laterality all show nearly a doubling of brain tumor risk (Hardell et al., 2008; Kan et al., 2007).

Ionizing Radiation in Medicine

> In 2006 Americans were exposed to more than seven times as much ionizing radiation from medical procedures as was the case in the early 1980s.
> NCRP, 2009

Continued advances in medical imaging techniques are increasing the accuracy of diagnoses but they are also increasing radiation exposure. Evidence from Medicare populations show that trends for use of conventional radiography and fluoroscopy are declining. However, use of mammography, CT scans, and nuclear imaging is rising (Matino et al., 2003). Radiation safety experts around the world are concerned that overuse of high-tech scanning procedures will increase the population risk of cancer.
The International Atomic Energy Agency (IAEA) and other organizations are urging that radiation protection of patients be given increased attention by health professionals, manufacturers, trainers, and policymakers. The IAEA, together with the World Health Organization (WHO), UNSCEAR, and the International Commission on Radiological Protection are designing a multi-pronged approach to reduce radiation doses and create greater awareness on the part of the patient and of the physician ordering the imaging studies (IAEA, 2009).

IAEA and other experts are working with manufacturers and IT specialists to develop a Smart Card designed to measure the cumulative amount of radiation a person receives over a lifetime. Eventually radiation exposure data will be available on electronic health cards carried by people in many of the world's developed countries. Such a Smart Card would take the guesswork out of radiation exposure and perhaps would avoid overuse of radiation technologies.

Measuring Ionizing Radiation Exposure

The following table presents several methods used to measure and describe exposure to ionizing radiation.

Methods of Measuring Ionizing Radiation

Method	Conventional unit	SI unit
Radiation exposure	roentgen (R)	Coulombs per kilogram (C/kg)
Radiation dose	rad	Gray (Gy)
Equivalent dose	rem	Sievert (Sv)
Effective dose	Effective dose equivalent (Sv)	Sievert (Sv)
Computed tomography dose index		Milligray (mGy)
Dose length product		Milligray centimeter (mGy.cm)

1 Gy= 1J/kg, 1 rad =100 Gy, 10 mSv = 1 rem (1mSv = 100 mrem)
Source: Hui et al., 2009.

Radiation exposure, expressed in roentgens, is the concentration of radiation at a specific point in air and is the ionization produced in a specific volume of air. It does not indicate how much energy is absorbed by irradiated tissues (Hui et al., 2009).

Radiation dose, also called *absorbed dose*, is expressed in rads or grays, and describes the amount of energy absorbed per unit mass at a specific point. It does not consider the differing radiation sensitivity of organs. Therefore, the absorbed dose cannot be used to compare examinations in different parts of the body.

Equivalent dose is a modification of the absorbed dose that incorporates weighting factors to account for the different biologic effects of various sources of radiation. The equivalent dose is expressed as rems in conventional units and sieverts in SI units: 100 rem = 1 sievert.

Effective dose, also expressed in sieverts, considers where the radiation dose is being absorbed and estimates the whole-body dose that would be required to produce the same risk as the partial-body dose that was actually delivered in a localized radiologic procedure. This measurement allows comparisons with other types of radiation exposure, including natural background radiation.

CT scans are quantified in terms of dose index and dose length product. *CT dose index (CTDI)* represents the dose in a single slice and is expressed in milligray (mGy). *Dose length product (DLP)* is the product of the CTDI and the scan length, expressed in milligray centimeters (mGy.cm).

Average Annual Individual Exposure

Source	**Amount of exposure**
Natural sources (primarily radon)	300 millirem (3 millisieverts) [mSv]
Medical procedures	40 millirem (0.4 millisieverts) [mSv]
Commercial, industrial activities	20 millirem (0.2 millisieverts) [mSv]
Total	360 millirem (3.6 millisieverts) [mSv]

The Nuclear Regulatory Commission (NRC) establishes annual limits of radiation exposure from man-made sources for the public and for radiation workers in the United States. Maximum radiation exposure to individual members of the public is limited to 100 mrem (1mSv).

Occupational exposure of radiation workers is limited to 5,000 mrem (50 mSv). Specific annual limits apply for the following:

- Skin/extremity , 50 rem/yr
- Any internal organ, 50 rem/yr
- Lens of eye, 15 rem/yr
- Declared pregnant worker, 500 mrem/pregnancy, 50 mrem/month

Medical radiation is specifically excluded from the NRC limits, based on the assumption that the benefits greatly outweigh the risk for most medical applications (Hadley et al., 2006). However, documented cases of injury to patients and physicians resulting from procedures involving fluoroscopy and serial imaging indicate that this assumption not always valid. In 1994 the U.S. Food and Drug Administration (FDA) issued an advisory alerting healthcare facilities to the potential for radiation-induced burns to patients from fluoroscopic procedures (FDA, 1994).

As of 2006 the FDA had documented about a hundred cases of radiation-induced burns (Archer, 2006). Case histories of serious burn injuries to both patients and physicians have been documented in the literature; in addition, cataracts and serious hand injuries were seen in physicians who began using fluoroscopy in their practice.

Regulatory authority over the medical use of radioactive material and other sources of ionizing radiation (eg, x-ray machines, scanners) is shared among several government agencies at the federal, state, and local levels. Radioactive material is regulated by either the NRC or by an Agreement State (one of 35 states that have entered into an agreement with the NRC to regulate the use of certain radioactive materials). Agreement States issue licenses and currently regulate approximately 6,000 medical-use licensees, including university medical centers, hospitals, clinics, and physicians in private practice.

The NRC regulates the medical use of radioactive material in the 15 non-Agreement States, the District of Columbia, Puerto Rico, and various territories of the United States, totaling approximately 1,500 medical-use licensees. The NRC maintains jurisdiction nationwide in matters regarding the common defense and security of nuclear materials, such as enhanced security measures.

The FDA oversees approval of radiation-producing machines and radiopharmaceuticals for safety and efficacy; however, it does not **regulate** the use of the devices and radiopharmaceuticals that it approves. Radiation-producing machines, such as x-ray machines and linear accelerators that do not produce radioactive material are regulated by the states (NRC, 2008).

Medical Diagnostics Dose in rems*

Source	Dose
Chest x-ray (1 film)	0.01
Dental oral exam	0.16
Mammogram	0.25
Lumbosacral spine	0.32
PET scan	0.37
Bone (Tc-99m)	0.44
Cardiac (Tc-99m)	0.75
Cranial CT (MSAD)**	5.00
Barium contrast G-1	8.50
Fluoroscopy (2-min scan), spiral CT	3–10

*1 rem = 10 millisieverts (mSv)
**multiple scan average dose
Source: Office of Science, U.S. Department of Energy, 2005.

Computed Tomography (CT)

Medical imaging has undergone dramatic changes over the past several decades. Computed tomography (CT) has transformed diagnostic radiology by providing three-dimensional views of an organ or body region. Interventional radiology has expanded medical imaging beyond diagnosis into treatment of disease and disorders other than cancer. No longer the exclusive province of radiologists, interventional radiology has entered the practice of surgeons, cardiologists, gynecologists, and other non-radiologist physicians.

Although the use of medical radiation has grown exponentially, radiology education is under-emphasized in the curriculum of most medical schools (Tay et al., 2009). According to the Association of American Medical Colleges (Lewis & Shaffer, 2005), only 22% of American medical schools require radiology content, either integrated over the 4 years of medical school or as a 4-week stand-alone clerkship. Therefore, some physicians and surgeons who use radiologic procedures, particularly fluoroscopically guided interventions, may not have had the same training in radiation safety as those who chose radiology as a medical specialty. For example, cardiologists have been performing radiological procedures since 1990. Yet the first recommended guidelines for safer use of fluoroscopy by these practitioners were not published until 2004 (ACCF/AHA/HRS/SCAI, 2004).

These practitioners and their clinical staff are exposed to the highest radiation levels in diagnostic radiology. Research indicates that many cardiologists do not correctly evaluate the exposure dose, the environmental impact and the individual risk of radiologic procedures (Correia et al., 2005). This lack of awareness creates unnecessary risk to themselves, their patients, and staff.

Physicians, their patients, and the public are poorly informed about the inherent risk of radiation exposure, particularly CT scans, or about alternative imaging techniques such as MRI that carry less risk (Thomas et al., 2006; Rice et al., 2007). The soaring use of CT scans in medicine not only increases the cost of healthcare but also increases cancer risk, particularly in children and women, who are more vulnerable to damage from radiation. CT scans can deliver 100 to 1,000 times the radiation dose of traditional x-rays—exposure levels similar to the low-dose range found to increase cancer among atomic bomb survivors (Semelka et al., 2007). In a survey of pediatric surgeons, more than 75% of respondents underestimated the radiation dose from a CT scan as compared to a chest x-ray; generally, most of the surgeons did not discuss the potential risks of CT scan with their patients (Rice et al., 2007).

Public ignorance about the radiation risk of CT scans coupled with fear of undetected cancer led to aggressive direct-to-consumer marketing of self-referred whole-body CT scans, beginning in the late 1990s. The self-referred imaging industry promoted CT screening for cancer, cardiovascular disease, and other disorders using misinformation and unsubstantiated scientific claims, while ignoring uncertainties and risks associated with radiation exposure (Iles et al., 2004). Promotion of CT scans was so successful that a national telephone survey found that 85% of persons asked said they would prefer a free screening to receiving $1,000 in cash (Schwartz et al., 2004). They undoubtedly were unaware that the radiation dose from a single full body CT scan is comparable to the doses received by some of the Japanese atomic bomb survivors who had increased risk of cancers (Brenner, 2004).

Although some of these for-profit imaging centers have closed, other imaging centers have expanded into self-referred functional brain imaging using CT. Promotion of this service is directed to school-aged children who are performing poorly in school and to adults concerned about memory loss and Alzheimer's disease. Since this industry is not regulated by the FDA or other government agency, it is essential that nurses and other health professionals inform patients about the radiation risk involved in CT scanning.

Informed Consent

Research documenting lack of awareness concerning the cancer risk associated with medical radiation supports "a continued and compelling need for radiation safety education for health professionals and the public" (Brody et al., 2007). Referring physicians as well as those who perform radiological procedures need to inform patients fully about risks of these procedures, particularly in the case of CT scans, the major source of medical radiation exposure. Yet studies indicate that few patients are being adequately informed.

A survey by Yale researchers found that only 7% of patients said they were informed about the risks and benefits of CT scans, and only 3% reported being told about the increased lifetime cancer risk inherent in CT. Even emergency physicians, who frequently refer patients for CT, were largely unaware of the increased cancer risk. Most troubling, the majority of the radiologists performing CT scans considered radiation exposure of limited concern and did not know the dose of radiation involved in CT (Lee et al., 2004).

Another study of informed consent practices at academic medical centers found that radiologic technologists are more likely to inform patients about the risks of CT than are their physician counterparts. The researchers wrote: "Although most academic medical centers currently have guidelines for informed consent regarding CT, only a minority of institutions inform patients about possible radiation risks and alternatives to CT" (Lee et al., 2006).

Brenner and Hall (2007) suggest three ways to reduce the overall radiation dose from CT in the population:

1. Reduce the CT-related dose in individual patients.
2. Replace CT use, when practical, with ultrasonography or MRI.
3. Decrease the number of CT studies that are prescribed; use only when justified by medical need.

The authors conclude their article with these words: "…if it is true that about one-third of all CT scans are not justified by medical need, and it appears to be likely, perhaps 20 million adults and, crucially, more than 1 million children per year in the United States are being irradiated unnecessarily."

Pediatric CT Scans

> Until recently, the same CT-examination parameters were used for children and adults. In fact, a change in these parameters with a resultant reduction in dose, ranging from approximately 50% to 90%, has been shown to be satisfactory for a child's CT study.
> Brody et al., 2007

Children are at greatest risk of harm from CT scans because their cells are dividing more rapidly and they have more years ahead in which to develop cancer (NCI, 2008). For example, a dose of radiation in a child is ten times more likely to cause cancer compared to an equivalent dose in an adult (Brody et al., 2007). One widely debated study estimated that of 600,000 abdominal and head CT scans annually performed in children under the age of 15 years, 500 children might ultimately die from cancer attributable to the CT radiation (Brenner et al., 2001). According to the Society of Pediatric Radiology (2002), at least one-third of the 7 million childhood CT scans performed each year may be unnecessary or could be easily replaced by an alternative imaging technique such as MRI or ultrasound.

> The major growth area in CT use for children has been presurgical diagnosis of appendicitis, for which CT appears to be both accurate and cost-effective—though arguably no more so than ultrasonography in most cases.
>
> Brenner & Hall, 2007

CT scans in children may also harm the developing brain, diminishing cognitive abilities in adulthood. Scientists from Sweden's Karolinska Institute found that "intellectual development is adversely affected when the infant brain is exposed to ionizing radiation at doses equivalent to those from computed tomography of the skull" (Hall et al., 2004). The researchers studied men who had been exposed to low-dose ionizing radiation to treat cutaneous hemangioma (birthmark) before the age of 18 months and compared their performance on cognitive tests with a matched control group of unexposed men. The exposed group were more likely to underachieve educationally than the unexposed group. Similar effects were documented among children exposed in utero after the bombings of Hiroshima and Nagasaki (Schull & Otake, 1999) or treated with radiation for ringworm of the scalp (Ron et al., 1982). These studies suggest the need for caution in referring children for CT scans when MRI or ultrasound might be just as effective in evaluating minor head trauma in young children.

Parents are often unaware of the risks involved in CT scans and therefore may contribute to the demand for CT. A study by Larson et al (2007) found that only 13% of parents understood that CT scanning involved a potential cancer risk. This study also found that using a simple handout to inform parents about the risk and benefits of CT did not cause them to refuse the procedure. Informing parents about the risk is not only ethical but it builds trust between parents and care providers.

Clinical practice in medicine can be slow to change. Since Brenner and colleagues (2001) sounded the alarm about the cancer risk involved in pediatric CT, medical associations and government agencies have mounted an effort to better inform health professionals and the public. A 5-year followup Web-based survey of pediatric radiologists found that 84% of respondents had significantly reduced the peak kilovoltage and tube current settings, two principal parameters in determining radiation dose (Arch & Frush, 2009). Radiologists at Massachusetts General Hospital (MGH) in Boston reported that customizing pediatric CT protocols according to clinical indications, patient weight, and number of prior studies helped reduce pediatric CT radiation dose as much as 90% (Singh et al., 2009).

Image Gently Campaign

In 2007 the Alliance for Radiation Safety in Pediatric Imaging, a 33-member collaborative of medical societies, agencies, and regulatory groups, created the **Image Gently** campaign. This campaign offers downloadable educational materials for parents, including brochures and a medical imaging record for parents to track when and where imaging tests were performed. In addition, the campaign targets radiologists and technologists who work in predominantly adult hospital settings with the tools to comply with the ALARA principle, by reducing the exposure to As Low As Reasonably Achievable:

- Reduce or "child-size" the amount of radiation used.
- Scan only when necessary.
- Scan only the indicated region.
- Scan once; multiphase scanning in usually not necessary in children.

As patient and family advocates, nurses can help educate parents about the risks and benefits of procedures involving radiation, especially CT scanning. The Image Gently campaign advises parents to:

- **Talk with your child's physician**. Ask whether the imaging center to which they refer uses appropriate pediatric CT scanning techniques, and if an MRI or ultrasound test might be as useful for your child's situation.
- **Be your child's advocate**. Learn about ways health professionals can lower radiation dose in CT scans. Ask questions.
- **Be sure the imaging facility is using appropriately reduced radiation techniques**. Ask questions—it's your right to do so.
- **Check credentials**. Ask whether the facility has American College of Radiology accreditation, whether the CT technologists have the proper credentials, and if the person interpreting the studies is a board-certified radiologist or pediatric radiologist.

Prenatal Exposure to Radiation

> The developing embryo or fetus is particularly sensitive to radiation. If an examination that involves radiation exposure can be postponed or replaced with another study, this is always desirable. . . . Breast-feeding patients are of concern in nuclear medicine studies (diagnostic or therapeutic), because the compounds given to the mother may be taken up and excreted into the breast milk, and thus possibly ingested by the nursing infant.
>
> Health Physics Society, 2009

Ionizing radiation can cause both cancer and birth defects in the fetus. Although NCRP and the American College of Obstetricians and Gynecologists maintain that a cumulative effective dose to the fetus of less than 50 mSv (5 rem) is not associated with increased risk, the possibility of birth defects and/or childhood leukemia exists. Exposure during the second to eighth week of fetal life carries the greatest risk of birth defects, which include microcephaly, mental retardation, and growth retardation. Any prenatal exposure increases the risk of childhood leukemia (Lockwood et al., 2006).

Potential non-cancer health effects of prenatal radiation exposure

Acute radiation dose[1] to the embryo/fetus	**Time Post Conception**				
	Blastogenesis Up to 2 weeks	**Organogenesis** 2-7 weeks	**Fetogenesis**		
			8-15 weeks	16-25 weeks	26-38 weeks
<0.05 Gy (5 rads)[2]	Non-cancer health effects **not** detectable				
0.05-0.50 Gy (5-50 rads)	Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (non-cancer) health effects	Incidence of major malformations may increase slightly Growth retardation possible	Growth retardation possible Reduction in IQ possible (up to 15 points, depending on the dose) Incidence of severe mental retardation up to 20%, depending on dose.	**Non-cancer health effects unlikely**	
>0.50 Gy (50 rads)	Incidence of failure to implant will likely be large[3], depending on dose, but surviving embryos will probably have no significant (non-cancer) health effects	Incidence of miscarriage may increase, depending on dose. Substantial risk of major malformations such as neurological and motor deficiencies. Growth retardation likely.	Incidence of miscarriage probably will increase, depending on dose. Growth retardation likely. Reduction in IQ possible (>15 points, depending on dose). Incidence of major malformations will probably increase.	Incidence of miscarriage may increase, depending on dose. Growth retardation possible, depending on dose. Reduction in IQ possible, depending on dose. Severe mental retardation possible, depending on dose. Incidence of major malformations may increase	Incidence of miscarriage and neonatal death will probably increase, depending on dose.[3]

Source: CDC. Prenatal Radiation Exposure: A Fact Sheet for Physicians, 2006.

1 Acute dose: dose delivered in a short time (usually minutes). Fractionated or chronic doses: doses delivered over time. For fractionated or chronic doses the health effects to the fetus may differ from what is depicted here.

2 Both the gray (Gy) and the rad are units of absorbed dose and reflect the amount of energy deposited into a mass of tissue (1 Gy = 100 rads). In this document, the absorbed dose is that dose received by the entire fetus (whole-body fetal dose). The referenced absorbed dose levels in this document are assumed to be from beta, gamma, or x-radiation. Neutron or proton radiation produces many of the health effects described herein at lower absorbed dose levels.

3 A fetal dose of 1 Gy (100 rads) will likely kill 50% of the embryos. The dose necessary to kill 100% of human embryos or fetuses before 18 weeks' gestation is about 5 Gy (500 rads).

Estimated risk for cancer from prenatal radiation exposure

Radiation dose	Estimated childhood cancer incidence 1,2	Estimated lifetime 3 cancer incidence 4 (exposure at age 10)
No radiation exposure above background	0.3%	38%
0.00-0.05 Gy (0-5 rads)	0.3%-1%	38%-40%
0.05-0.50 Gy (5-50 rads)	1%-6%	40%-55%
>0.50 Gy (50 rads)	>6%	>55%

Source: Centers for Disease Control and Prevention. Prenatal Radiation Exposure: A Fact Sheet for Physicians, 2006.
1 Data published by the International Commission on Radiation Protection.
2 Childhood cancer mortality is roughly half of childhood cancer incidence.
3 The lifetime cancer risks from prenatal radiation exposure are not yet known. The lifetime risk estimates given are for Japanese males exposed at age 10 years from models published by the United Nations Scientific Committee on the Effects of Atomic Radiation.
4 Lifetime cancer mortality is roughly one third of lifetime cancer incidence.

To prevent prenatal exposure to her embryo/fetus, a nurse who becomes pregnant needs to advise her employer in writing about the pregnancy, including the estimated date of conception. The employer is required to monitor and record the occupational radiation dose, using an individual monitoring device (film badge) if it is likely that the nurse will receive, from external sources, a deep dose equivalent in excess of 0.1 rem (1mSv). The employer is also required to ensure that the occupational dose to an embryo/fetus does not exceed 50 mrem in any one month or that the total exposure during the entire pregnancy does not exceed 0.5 rem (5 mSv) (NRC, 1999).

> The core principle governing the use of ionizing radiation is ALARA (As Low As Reasonably Achievable). The ALARA principle recognizes that there is no magnitude of radiation exposure that is known to be completely safe.
>
> Hirshfeld et al., 2004

Radiation Safety Procedures

Reducing all radiation exposures to ALARA protects patients, physicians, and clinical staff. Three principal measures are fundamental to reaching this goal:

1. Minimize exposure time.
2. Increase the distance from the radiation source.
3. Shield whenever and wherever possible.

Scattered radiation results from the interaction of the x-ray beam and the patient, and is the principal source of unintended exposure to areas of the patient's body outside the field of the primary x-ray beam and to the staff. The amount of scatter increases with increases in the size of the x-ray field and the intensity of the x-ray beam as well as with the thickness of body parts being x-rayed. Therefore, more scatter is produced in obese patients. Reducing the patient dose also reduces scattered radiation exposure of the patient and clinical personnel.

Exposure to radiation in the emergency department and in intensive care can be high for both patients and staff due to widespread and sometimes repeated use of CT scans and, occasionally, fluoroscopy. Trauma team members and paramedical personnel can be exposed when initial imaging is done during resuscitation and while supporting patients during adjunct examinations. Trauma nurses receive a greater amount of radiation per film than residents and emergency physicians because they are generally closer to the irradiated field during resuscitations and radiologic examinations, drawing blood, administering medications, inserting catheters, and so on (Hui et al., 2009).

Researchers reported that in a series of critically ill trauma patients at the University of Pennsylvania, the average number of studies per patient was 70.1 and the cumulative effective radiation dose per patient was 106 mSv. CT scans accounted for less than 10% of the imaging studies but for two-thirds of the radiation dose (Kim et al., 2004).

There is growing concern that emergency physicians fail to consistently follow established guidelines for ordering CT scans. One recent study found that the number of whole chest **multi-detector CT (MDCT)** for suspected pulmonary embolism (PE) was increasing while the number of positive studies was decreasing. Current practice protocols suggest that patients with a low clinical suspicion for PE should be screened with D-dimer* testing before having a scan. However, the researchers reported that MCDT was performed in 7% of patients who later were found to have negative D-dimer results, which should have ruled out the need for a scan. They also reported that 42% of the patients studied had a positive D-dimer test and did not have a scan although protocols indicated that they should have (Corwin et al., 2009). Negative D-dimer results eliminate the need for a scan.

*D-dimer is one of the fibrin degradation products generated during clotting, and concentrations are higher in pulmonary embolism, deep-vein thrombosis, and disseminated intravascular coalition (DIC). Normal concentrations rule out the likelihood of a clotting event.

Whole-chest MDCT can expedite the evaluation of low-risk patients with chest pain and perhaps reduce the length of hospital stay, but concern about radiation dose may limit referrals for the test. However, researchers at the University of Washington found that using whole-chest MDCT combined with prospective ECG triggering could reduce radiation dose by 71%, with no loss of image quality. Prospective ECG triggering enables the CT scanner to monitor the ECG signal of several heart beats in real time and turn on the radiation beam only during alternate beats, whereas MDCT with retrospective ECG gating turns on the radiation beam throughout several beats, thereby delivering more radiation (May et al., 2009).

Computed tomography angiography (CCTA) is rapidly becoming the method of choice for diagnosing coronary artery disease but radiation dose from the procedure is a concern. This concern led Michigan physicians to test a best practices model for dose reduction in a large, multi-facility collaborative study that included both small community hospitals and large academic medical centers. The best practices model included minimized scan range, use of beta-blockers to control heart rate and heart rate variability; maximizing use of electrocardiographic-gated tube current modulation; narrowing the acquisition window at low, stable heart rates, and decreasing scan voltage in normal-weight individuals. The study found that implementing the best practices model reduced the dosage by half without affecting image quality (Raff et al., 2009).

Innovations in imaging technology offer unparalleled advantages in diagnosis and treatment. However, physicians who refer patients for these procedures and operators who perform the procedures need to strive continually to reduce the radiation dose to ALARA. As Raff and colleagues emphasized, "it is impossible to improve practice without monitoring radiation doses, and a dose recording and review process has been recommended in published guidelines."

Dosimetry

Dosimetry is the measurement of cumulative radiation dose to an individual, using a dosimeter. Healthcare workers whose activities routinely expose them to ionizing radiation (more than 500 millirem over one year) are provided with a body badge (also called a film badge) or a ring badge. These badges are exchanged at regular intervals determined by the facility's radiation safety program. Badges for pregnant health professionals are exchanged each month. The radiation safety officer (RSO) is responsible for maintaining employee radiation exposure records.

Badges should be worn so that the front of the dosimeter faces toward the radiation source. Body badges are issued with a plastic badge holder, which is retained and reused when badges are exchanged. Only the badge is exchanged.

Ring badges should be worn so that the label faces out from the side of the hand most likely to be exposed to radiation. Ring badges are used for persons handling radioactive materials or by physicians performing interventional radiologic procedures in which their hands are exposed to the radiation beam. Ring badges should be worn under radiation attenuation gloves to avoid contamination of the badge.

Usage guidelines:

- Dosimetry badges should not be shared or borrowed. Each badge should be worn only by the designated person.
- Do not intentionally expose badges to radiation. Intentional tampering with badges is a very serious offense.
- If your badge becomes contaminated, notify the RSO and request a replacement.
- Never wear your badge when you have a medical x-ray or other radiologic procedure. Your badge should only document occupational dose, not medical dose.
- Do not use your badge at another institution. If you work at more than one facility, each facility should issue a badge for use on its premises.
- Store your badges at work in a safe place, away from sources of radiation and away from sources of heat. Leaving your badge in your car on a hot summer day could lead to an inaccurate reading.
- Lost, damaged or contaminated badges should be immediately returned to the RSO for replacement.

Keeping Your Distance

Distance from any radiation source drastically reduces the exposure. For example, a simulation study (using dosimeters but no personnel) of exposures to an orthopedic surgical team during a fluoroscopically assisted procedure found that those working 24 inches or less from the beam received significant radiation exposure, whereas those working 36 inches or more from the beam received an extremely low amount of radiation (Mehlman & DiPasquale, 1997). Therefore, nurses should maintain the greatest distance possible from any radiation source that is consistent with effective patient care.

Nurses who care for patients receiving nuclear medicine therapy, usually radioactive iodine- (I-131) should put on shoe covers and protective gloves before entering the patient's room. Time in the room should be minimized without seeming rushed. Standard Precautions should be followed when handling blood and other body fluids, especially urine. All trash, linens, and food trays should be left in the room. Uneaten food and drink should be flushed down the toilet whenever possible to avoid spoilage during the mandatory 3-month holding period. Nurses should not eat, drink, smoke, or apply cosmetics in a room where radioactive materials are present.

Before leaving the room, gloves and shoe covers should be removed and placed in the trash box inside the room. Hands should be washed after leaving the room. Portable shields may help reduce exposure. However, according to Duke University, wearing of lead aprons in this situation is minimally effective, except during prolonged procedures at close proximity to the patient, such as a difficult blood draw.

Shielding

Maximal shielding of patients and staff is an essential component of radiation safety. Although shielding is not required by law, it has become standard practice in most healthcare facilities in the United States. Devices such as lead aprons, thyroid shields, and protective eyewear are widely used. Radiation-attenuating gloves reduce the radiation dose to physicians whose hands are at risk during fluoroscopy procedures as well as to nurses and nuclear medicine workers who handle radioactive materials. Table-side lead drapes and portable lead panels also reduce exposure to scattered radiation.

Although lead has long been the preferred shield against radiation, its weight makes lead less desirable for some types of shielding. Innovations in lead-free protective materials have expanded the choices in protective personal equipment (PPE) for physicians, nurses, and other radiation personnel. These newer materials may not offer the same dose reduction as leaded materials; however, the lighter weight makes them more practical for physicians and others. For example, one simulation study used tungsten antimony shielding in the form of a lightweight polymer sheet, which reduced the maximum dose to the patient by more than 90% (Neeman et al., 2006). The choice of materials depends in part on the energy range of the exposure. As McCaffrey and colleagues (2007) wrote, "A single material or combination cannot provide [optimal] shielding for all energy ranges."

New Safety Standards Needed

> The current lack of uniform educational standards nationwide for operators of radiologic equipment poses a hazard to the public.
> American Society of Radiologic Technologists, 2008

In the United States there are no standardized guidelines for informing patients about the risks associated with radiation exposure from diagnostic imaging. In the European Union, however, physicians who refer patients for any radiologic examination are required to provide sufficient medical data to justify the exam. The EU also requires that the CT dosage be included in the patient's electronic imaging records (European Commission, 2003, 1997).

Although medical imaging technologies have evolved rapidly over the past fifty years, federal radiation protection standards have not kept pace. Many of these standards are based on average lifetime exposure or on a hypothetical adult caucasian male, 20 to 30 years old, weighing 154 pounds—the so-called reference man. As discussed earlier, children's bodies are not the same as those of adult men in their response to ionizing radiation. Women, particularly pregnant women and their developing fetuses, are also more radiosensitive than their male counterparts. Based on these facts, a broad coalition of scientists, physicians, health advocates, and women's groups have called for stricter standards that would protect those most vulnerable to harm from radiation (IEER, 2006).

> A radiologic technologist is typically the first, and may be the only, healthcare professional to interact with a patient presenting for a radiologic procedure. To respond to patients' imaging-related questions, technologists need to be familiar with all components of the particular examinations, including not only the technical aspects but also the associated radiation dose and risk. Furthermore, it may be a technologist who recognizes that a duplicate or questionably indicated examination has been ordered for a patient or that a patient has undergone multiple similar examinations. An alert technologist should notify the radiologist in such a case and thereby possibly avoid exposing the patient to unnecessary radiation. (American College of Radiology, 2007)

Current standards within the U.S. healthcare system fail to ensure that medical radiation exposure meets the ALARA standard. For example, seven states have no licensure or regulatory provision for radiologic technologists and six more regulate only partially (ASRT, 2008). Most states have only recommended quality assurance (QA) standards—if they have standards at all. Moreover, many medical and dental offices do not perform the tests required to ensure that the standards are maintained.

Legislation to establish federal educational standards for operators of radiologic equipment has been introduced in each session of Congress for the past ten years but has never been signed into law. The Consistency, Accuracy, Responsibility, and Excellence in Medical Imaging and Radiation Therapy (CARE bill [HR583 and S1042]) passed the U.S. House of Representatives in June 2008 but the Senate failed to act on the bill. Interestingly, the CARE bill excluded x-ray, fluoroscopy, ultrasound, and radiation therapy. As of June 29, 2009, the bill had not been reintroduced in the Congress.

Non-Ionizing Radiation

Everyone in the developed world has been exposed to extremely low-frequency electromagnetic fields (ELF-EMF) since electricity transformed modern life. Research evidence has shown that exposure to ELF-EMF is not entirely benign, and in fact can increase the risk of cancer. As mentioned earlier, ELF-EMF is associated with increased risk of childhood leukemia (Greenland et al., 2000) as well as breast cancer in both men and women (Erren, 2001).

The wireless revolution, which reached the United States in the 1990s and quickly made cell phones must-have devices, dramatically increased exposure to radiofrequency/microwave radiation (RF). Exposure to RF is ubiquitous in daily life, including the workplace. The exponential growth of wireless technologies has increased the ambient levels of RF exposure ten-fold since the mid 1970s (Frei et al., 2009). A growing body of scientific evidence suggests that the convenience afforded by wireless technologies may come at a high price to human health.

Wireless in the Healthcare Workplace

Hospitals and other healthcare facilities are adopting wireless technologies, not only for communication but also for information collection and storage, and for inventory control. Portable wireless devices used by hospital visitors and personnel—cellular phones, pagers, personal data assistants (PDAs), and wireless notebook computers—add another layer of RF exposure. Together, these exposures can compound the physiologic stress of an already challenging work environment (Blank-Goodman, 2009, 2004) that includes exposure to chemicals, noise, and possibly shift work effects, fatigue, and psychological stress. This combination of stressors may affect the health of nurses and patients.

To minimize or avoid the effects of RF, nurses can choose alternatives to wireless such as wired or cable communications and data transmission. They can also:

- Advocate for designated cell phone areas (such as areas for smoking) removed from patient rooms and visitor waiting areas.
- Keep required wireless electronic communication or recording devices turned OFF until ready to use, and turn them OFF as soon as finished using.
- Carry devices away from the body when turned ON.
- Keep their distance from cell phones and pagers—use a wired earpiece, not a wireless one, or use the speaker phone feature.
- Advocate against Wi-Fi networks because of chronic exposure to patients and staff.
- Advocate for measurement surveys of RF and ELF-EMF exposures and advocate for wired alternatives to wireless technologies.

Staying wired protects nurses’ work environment and patients’ healing environment.

Wireless communication systems are not the only troubling source of chronic RF exposure for personnel and for patients. **Radiofrequency identification (RFID) systems** are gaining popularity for tracking medical equipment, avoiding drug counterfeiting, and monitoring the quality of blood products. These "smart" chips are touted as improving patient safety and reducing medical errors. However, researchers in The Netherlands reported that their simulation study (performed without patients) revealed potential hazards in RFID systems. They found that RFID technology can interfere with critical care equipment such as ventilators, medication pumps, and dialysis machines, with potentially fatal effects (van der Togt et al., 2008). Electromagnetic interference (EMI) occurred in about 1 in 3 of the tests when RFID scanners were placed within 1 foot of the medical equipment. One in 5 of those malfunctions would have seriously harmed patients. Careful testing is essential before implementing wireless systems and devices near critically ill patients.

Patients with implanted devices such as defibrillators, pacemakers, or neurostimulators (used in surgical deep-brain stimulation for Parkinson's disease) are also at risk for harm from RF exposure. The EMI emitted by wireless technologies can stop or otherwise disrupt function of implanted devices. One woman with Parkinson's who has two implanted neurostimulators recounted her experience:

> This happened to me this past winter during a visit to the emergency room. A nurse used a wireless scanner to scan an RFID tag on the pain medication she was giving me. Within minutes, my Parkinson's motor symptoms reappeared. I suspected the scanner but couldn't be sure that I had been "turned off" until I left the hospital. Sure enough, one of my neurostimulators was off.
>
> This phenomenon is hardly limited to hospitals, although it is the most ironic place for it to happen. My deep-brain stimulation system has been turned off by security systems, theft-detection equipment, and other electronic devices. The Federal Communications Commission has been letting industry set guidelines and voluntary programs since 1982. It's time for Congressional hearings, I think! (Christensen, 2008)

EMI effects of wireless technologies on implanted devices suggests the possibility of similar effects on natural neural networks. Humans are bioelectrical beings whose hearts and brains are regulated by internal bioelectrical signals.

Studies have shown that ELF-EMF exposure can affect the nervous system in ill patients. Critically ill or premature newborns placed in isolettes prior to 1994 were often exposed to very high levels of ELF-EMF from the motors of heating units directly under the baby (Paul et al., 1994). This paper documented that nurses were also being exposed to high ELF-EMF from these units. Redesign of the units greatly reduced or eliminated these emissions. Recently, however, Italian scientists found that even the very low EMF still emitted by incubators can disrupt development of the nervous system and can decrease heart rate variability in newborns (Bellieni et al., 2008).

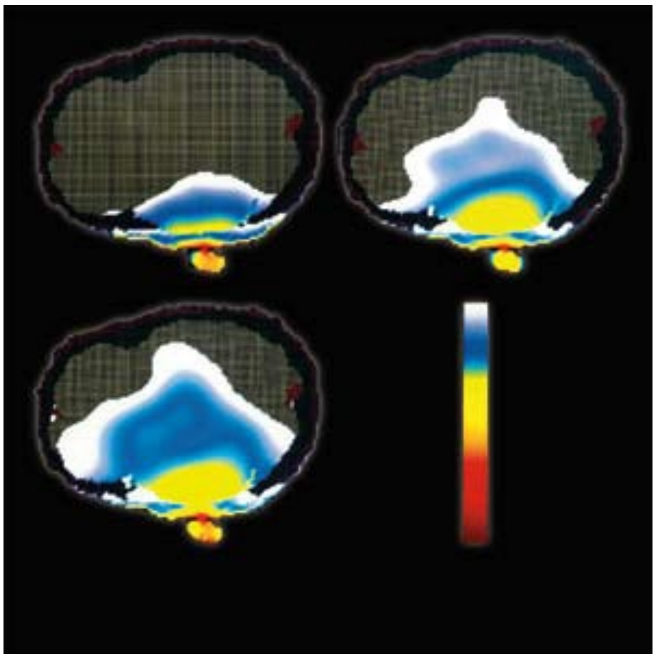
Youngest at Highest Risk

As with ionizing radiation or any other environmental exposure, the youngest are at highest risk of harm, and RF is no exception, especially when youngsters are ill (WHO, 2005). Wireless environments, especially in the ICU and NICU, may have serious effects on these fragile young patients.

Cellular Phones

Now at 4 billion and counting, cellular telephones and the towers and antennas that transmit their signals have intensified the RF environment more than any other single device. There is international concern about the effects of cellular phone use by children under age 10 because their small heads and thin skulls allow RF radiation to penetrate deeper into their brains (Gandhi et al., 1996). French scientists found that children absorb twice the RF from cell phone use as adults do (Wiart et al., 2008), which may increase their risk of brain cancer as young adults.

Energy Deposition for a Cellular Telephone



Energy deposition for a cellular telephone is measured at 835 MHz; radiated power = 600 mW (right). Source: Gandhi et al., 1996. Copyright © 1996 IEEE. Reprinted with permission.

Concern about the long-term effects of cell phone use by children led an international panel of physicians and scientists to endorse an Appeal in Relation to the Use of Mobile Phones. The Appeal included an analysis of research and ten precautionary measures (Collaborative for Health and the Environment, 2008). The governments of Germany (Lower House of the German Parliament, 2007), France (Ministry of Health, Youth, Sports and Associations, 2008), Austria (Fleming, 2008) and the United Kingdom (Sample, 2007), the European Environment Agency (EEA, 2007), and the Russian National Committee on Non-Ionizing Radiation Protection (Mobilefunk-EMF-Omega-News, 2008) have cautioned the public to reduce wireless exposures and warned against cell phone use by children. Meanwhile, in the United States, the telecommunications industry continues to deny any evidence of health effects.

Exposure to RF and ELF-EMF radiation are only two among many environmental exposures nurses encounter every day in the workplace, in the home, and in the world at large. The mix includes dozens if not hundreds of chemicals and other types of radiation. All these exposures have the potential to interact with one's own body burden of agricultural and industrial chemicals that were accumulated over decades. For example, oncology nurses who work with chemotherapy drugs such as Adriamycin, a known carcinogen, are also exposed to RF and ELF-EMF within the healthcare facility and at home. Mixtures matter; A meta-analysis of 65 studies on the combined effects of chemical carcinogens and RF exposure provides compelling evidence that the hazard is worse with both exposures when compared to either exposure alone (Juutilainen et al., 2006).

Regulation of Non-Ionizing Radiation

As with ionizing radiation, regulatory standards have not kept pace with changing technologies. Existing safety standards for non-ionizing radiation are inadequate to protect public health. The standards are based on acute exposure and on thermal effects alone. This outdated, erroneous concept assumes that unless EMF exposure is strong enough to heat human tissue within 30 minutes, it is safe. Moreover, there are no federal standards for EMF exposure based on long-term, chronic exposure or on non-thermal effects (NTE), which are the most common types of exposure and the most likely to cause human health effects, including cancer. The existence of NTE was documented in 1986 by the National Council of Radiation Protection and Measurements but has been ignored ever since by researchers and by national and international standard-setting agencies (Blackman, 2009).

Existing U.S. standards for ELF-EMF are set at 904 milligauss even though more than two decades of science show that cancer risk begins to increase at only 2 milligauss (Ahlbom et al., 2000). Standards for personal wireless devices such as cell phones also are based solely on absorbed heat, measured by a unit called the Specific Absorption Rate (SAR). The U.S. standard for cell phones is 1.6 watts per kilogram (W/kg], which is not sufficiently protective, given evidence that health effects may occur at lower levels (Eberhardt et al., 2008).

As epidemiologist John Goldsmith wrote (1995),

> There are strong political and economic reasons for wanting there to be no health effect of RF/MW exposure, just as there are strong public health reasons for more accurately portraying the risks. Those of us who intend to speak for public health must be ready for opposition that is nominally but not truly scientific.

Two powerful forces continue to obstruct public policy changes that will set biologically based exposure standards for non-ionizing radiation—standards that acknowledge the growing scientific evidence of risk. Those two forces are economics and politics, and they protect the status quo. Modern societies depend on the use of electricity and radiofrequency communications. Any restrictions on use of these technologies could have significant economic consequences. Electric utility and telecommunications industries wield extraordinary political influence, and even support a major portion of the research on health effects of EMF.

Financial support for EMF research can affect if and how that research is reported to the public. Swiss researchers analyzed cell phone studies and found that the source of research funding affected the reporting of the results. Studies funded by industry were least likely to report a statistically significant result (Huss et al., 2007).

The telecommunications industry is lobbying hard to expand the role of wireless throughout the healthcare system. On June 24, 2009, CTIA–The Wireless Association hosted a Washington, D.C. "technology and policy forum on health solutions for America's chronic care crisis." This forum suggested that remote wireless monitoring of people with chronic illness such as diabetes, congestive heart failure, and COPD could save more than $21 billion annually, while improving access to care, eliminating healthcare disparities, making healthcare more affordable, and resolving epidemics (Business Wire, 2009). This wireless wonder may be coming soon to a facility near you. Are you ready?

Resources

American Academy of Pediatrics
www.aap.org

American College of Radiology
www.acr.org
BioInitiative Report
www.bioinitiative.org

Collaborative for Health and the Environment
www.healthandenvironment.org

Environmental Protection Agency
Citizen's Guide to Radon
http://www.epa.gov/radon/pdfs/citizensguide.pdf

Food & Drug Administration
www.fda.gov

Image Gently campaign
www.imagegently.org

Microwave News
www.microwavenews.com

Radiologic Society of North America
www.rsna.org

American College of Radiology and the
Radiology Society of North America
www.radiologyinfo.org

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(Post Test begins on next page)

Post Test

Use the Answer Sheet following the test to record your answers.

1. Radiation exposure:
   a. Is no problem for nurses because are trained to protect themselves.
   b. Usually causes tumor development within 5 years of the exposure.
   c. Is more dangerous to children because of their rapidly dividing cells and longer lifespans during which cancer may develop.
   d. Is more likely to cause cancer in adults because of existing medical conditions, weakened immune systems, and shorter lifespans.

2. Any form of radiation with enough energy to detach electrons from atoms is called:
   a. An electromagnetic field.
   b. Ionizing radiation.
   c. Non-ionizing radiation.
   d. Radiofrequency/microwave radiation.

3. Exposure to medical radiation:
   a. Accounts for nearly half of the total ionizing radiation exposure of the U.S. population.
   b. Has been significantly reduced in recent years due to decreased use of CT scans.
   c. Accounts for most of the non-ionizing radiation exposure in the United States.
   d. Can be dangerous because of the release of radon gas during x-rays and CT scans.

4. Low-level radiation without enough energy to detach electrons from their orbits around atoms is called:
   a. Ionizing radiation.
   b. Alpha particles.
   c. Beta particles.
   d. Non-ionizing radiation.

5. Radiation exposure that can alter the DNA, proliferation, and interactions of neighboring cells is called:
   a. Mutation.
   b. The "bystander effect."
   c. Chromosomal change.
   d. Direct mutagenesis.

6. Repeated exposure to low levels of ionizing radiation:
   a. Has been shown to be safe in studies of female radiologic technicians.
   b. Causes cumulative damage to genes over a lifetime.
   c. Must be kept at or below the safe dose level to prevent gene damage.
   d. Has fewer harmful effects than a single high-dose exposure.

7. Results from recent cell phone studies by the World Health Organization have shown:
   a. No increased risk of brain cancer caused by cell phone usage.
   b. An increased risk of lymphoma caused by exposure to cell phone radiation.
   c. Nearly a doubling of brain tumor risk after >10 years when phones are used mostly on one side of the head.
   d. Increased rates of hearing loss due to cell phone radiation when phones are used mostly on one side of the head.

8. Fluoroscopy:
   a. Gives off no radiation and is considered the safest of the imaging techniques.
   b. Involves only brief exposure to radiation for the physician and patient.
   c. May involve lengthy exposure to the radiation beam for both patient and operator.
   d. Is no longer used due to many cases of radiation burns to both patients and physicians.

9. A single full-body CT scan has a radiation dose comparable to the doses received by some Japanese atomic bomb survivors who had increased risk of cancers.
   a. True
   b. False

10. Ultrasonography and MRI:
   a. Should be used in place of CT scans when practical.
   b. Expose patients and operators to more radiation than CT scans.
   c. Should never be used in place of CT scans.
   d. Have caused radiation burns in many patients.

11. CT scans in children:
   a. Are less likely to cause cancer than in adults because of their rapidly dividing cells and longer life spans.
   b. Should use the same radiation dose as in adults to achieve good results.
   c. Should always be used instead of MRI or ultrasonography to decrease radiation exposure.
   d. May be customized to use radiation amounts based on clinical indications, patient weight, and number of prior studies.

12. Prenatal exposure to radiation:
   a. During the second to eighth week of fetal life carries the highest risk of birth defects.
   b. Has not been proven to increase the risk of childhood leukemia.
   c. May cause severe mental retardation during the last weeks of gestation.
   d. Is not considered a risk for a developing fetus because it is protected by the mother's body.

13. ALARA (As Low As Reasonably Achievable) includes all of the following as goals, except:
    a. Minimize exposure time.
    b. Increase the distance from the radiation source.
    c. Shield whenever and wherever possible.
    d. Mandatory yearly cancer screening for x-ray technicians.

14. The principle cause of unintended radiation exposure to medical staff is:
    a. CT scans.
    b. Scattered radiation.
    c. Fluoroscopy.
    d. Use of wireless technology such as bar code scanners.

15. In order to reduce the use of CT scans, patients with a low clinical suspicion of pulmonary embolus should first be screened with:
    a. D-dimer test.
    b. Fluoroscopy.
    c. Ultrasound.
    d. Lactate test.

16. Healthcare workers exposed to radiation:
    a. Should always wear dosimetry badges, even during their own medical x-rays, to determine their total radiation dose over time.
    b. Should use the same dosimetry badge everywhere if they have more than one job.
    c. Must wear body badges when handling radioactive materials.
    d. Must exchange their dosimetry badges each month if they are pregnant.

17. Keeping your distance from any radiation source:
    a. Does not reduce exposure because of scatter.
    b. Drastically reduces exposure.
    c. Does not reduce exposure because radiation beams can travel great distances.
    d. Is not necessary because the radiation beam is directed at the patient.

18. Many federal radiation protection standards are based on:
    a. A hypothetical Caucasian male called "reference man."
    b. The amount of scatter produced by CT scanners.
    c. Regulations used by the European Union.
    d. Average yearly radiation exposure.

19. Extremely low-frequency electromagnetic fields (ELF-EMF):
    a. Are a dangerous type of radiation emitted by CT scans.
    b. Have never been shown to increase the risk of cancer.
    c. Are radiation given off by cell phones.
    d. Are produced when electrical power is transmitted and distributed.

20. The use of wireless technology and scanners:
    a. Has been shown to be a safe way to track medications and reduce medical errors in hospitals.
    b. Is not allowed in hospitals because of interference with implanted patient devices such as defibrillators.
    c. Can disrupt function of implanted devices such as pacemakers and neurostimulators due to electromagnetic interference.
    d. Has greatly reduced the amount of radiation exposure to both patients and nurses.

21. Exposure to RF radiation emitted by cell phones:
    a. May increase the risk of brain cancer in children because of the high levels of absorbed radiation.
    b. Should be reduced in children according to the U.S. telecommunications industry.
    c. Is safe because it is not strong enough to heat body tissue within 30 minutes.
    d. Has decreased over the last decade due to advances in wireless technology.

22. Existing U.S. standards for radiation exposure:
    a. Are set at 904 milligauss for ELF-EMF, which science has shown is the threshold level for cancer risk.
    b. Are 1.6 watts per kilogram for personal wireless devices, although evidence shows that health effects may occur at lower levels.
    c. Are based on long-term chronic exposure effects which are the most common types of exposure.
    d. Have been updated yearly to reflect rapidly changing technology.

(Answer Sheet on next page)

Answer Sheet

Radiation Exposure in the Clinical Settings

Name (Please print your name): ____
Date: ___________________

Passing score is 80%

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______
11. ______
12. ______
13. ______
14. ______
15. ______
16. ______
17. ______
18. ______
19. ______
20. ______
21. ______
22. ______

Course Evaluation

Please use this scale for your course evaluation. Items with asterisks (*) are required.

- 5 = Strongly agree
- 4 = Agree
- 3 = Neutral
- 2 = Disagree
- 1 = Strongly disagree

*1. Upon completion of the course, I was able to:

a. Identify both natural and manmade sources of radiation in the United States.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

b. Describe the mechanisms and effects of ionizing and non-ionizing radiation related to cancer.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

c. Explain why exposure to non-ionizing radiation from extremely low-frequency electromagnetic fields and radiofrequency/microwave sources may increase the risk of cancer in children and adults.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

d. State the types of ionizing radiation used in medicine and discuss their potential for overuse.

.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

e. Discuss potential hazards from extremely low-frequency electromagnetic fields and radiofrequency radiation (non-ionizing radiation).

.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

f. Summarize radiation safety procedures for both patients and healthcare workers.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

*2. The course was written in a way that facilitated my learning.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

*3. This course was free from commercial bias.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

*4. The course met my continuing education needs.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

*5. The material presented was supported by evidence.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

*6. The author avoided the use of anecdotal information as the main source of material.

❑ 5 ❑ 4 ❑ 3 ❑ 2 ❑ 1

*7. The course was free of product promotion.

❑ Yes ❑ No**

** If you answered no, please answer #8.

8. Was product promotion the sole purpose of the presentation?

❑ Yes ❑ No

* 9. It took me 60 minutes per contact hour to complete the course, test, and evaluation.

❑ Yes ❑ No**

** If your answer was no, how long did it take? ______________________________

10. My professional educational level is (check one):

Nursing

❑ Nurse Aide ❑ LVN/LPN ❑ RN (diploma) ❑ RN (AD)

❑ BSN ❑ MSN ❑ Nurse Practitioner / Advanced Practice Nurse

❑ PhD / DNSc

Therapy

❑ OT Aide ❑ COTA ❑ OT ❑ MOT ❑ OTD

❑ PT Aide ❑ PTA ❑ PT ❑ MPT ❑ MSPT ❑ DPT ❑ PhD

Other (please specify): ____________________________________

11. I heard about ATrain Education from:

❑ Search engine
❑ Government or Board website
❑ Friend
❑ Other ______________________
❑ Advertisement
❑ Returning customer
❑ Publication (Magazine, etc.)

12. I found the ATrainCEU.com website easy to use:

❑ Yes ❑ No

13. Comments or suggestions (optional): ________________________________

____

____

(Registration on next page)

Registration Information

Please answer all of the following questions (*required).

* Name: ____

* Address: ____

* City: _________________________________State:______ Zip: ________

* Phone: ____

* Professional Designation: ______________________________

* License Number and State: _____________________________

Please e-mail my certificate: ❑ Yes ❑ No

Email (required if you want your certificate sent by email): ____________________

(Note: If you request an email certificate we will not send a copy of your certificate by US Mail.)

Payment Options

This course is free of charge. If you want to order a printed certificate, the charge is $5.00.

Credit card information:

Name ____

Address (if different from above): _________________________

City: ____________________________________State:____ Zip: ________

Card type: ❑ Visa ❑ MC ❑ American Express ❑ Discover

Card number ______________________________ CVS # __________

Expiration date ____________________________________

Test Completion and Mailing Instructions

1. Complete all forms:
   - ❑ Answer Sheet
   - ❑ Evaluation Learning Activity
   - ❑ Registration Form (this page)

2. If you order a printed certificate and are not paying by credit card, prepare a check for $5.00 made out to ATrain Education, Inc. There is no charge for the class if you only want an electronic certificate.

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