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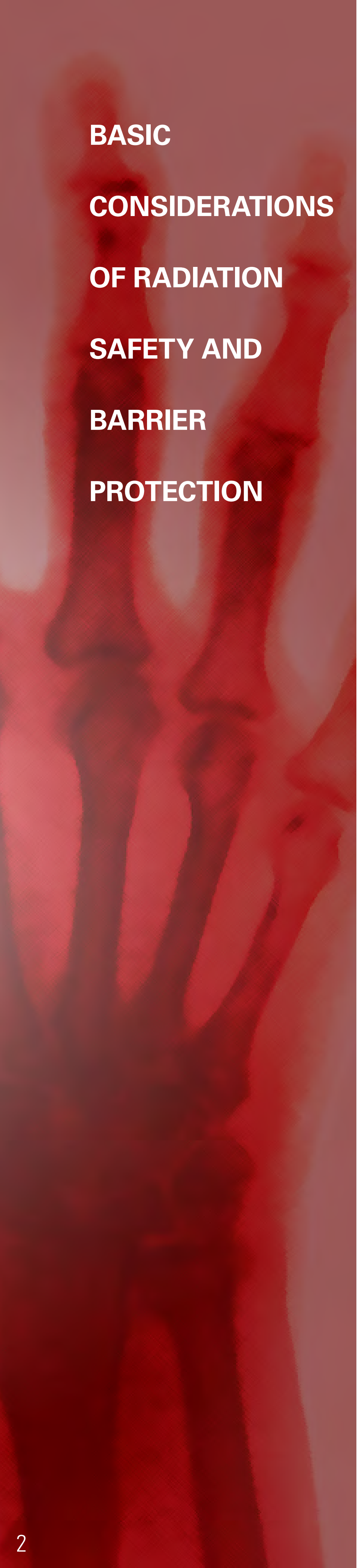
A SELF STUDY GUIDE

BASIC CONSIDERATIONS OF RADIATION SAFETY AND BARRIER PROTECTION

Registered Nurses



BASIC CONSIDERATIONS OF RADIATION SAFETY AND BARRIER PROTECTION

OVERVIEW

This educational module examines the basic knowledge of the safety issues associated with radiographic risk and to present strategies to avert adverse reactions. Be an informed and protected healthcare worker (HCW) by understanding the latest information from the FDA, OSHA and NIOSH for radiology protection.

LEARNING OBJECTIVES

Upon completion of this educational activity, the learner should be able to:

1. Explain the history of medical diagnostic imaging.
2. Describe the biological effects of x-rays.
3. Explain safety principles for using x-rays.
4. Differentiate between the three categories of radiation used in medicine.
5. Discuss regulations related to radiation exposure.
6. Discuss the monitoring of radiation exposure.

INTENDED AUDIENCE

The information contained in this self-study guidebook is intended for use by healthcare professionals who are responsible for or involved in the following activities related to this topic:

- Educating healthcare workers.
- Establishing institutional or departmental policies and procedures.
- Decision-making responsibilities for hand-barrier products.
- Maintaining regulatory compliance with agencies such as OSHA, ADA and CDC.
- Managing employee health and infection control services.

INSTRUCTIONS

Ansell is a Recognized Provider of continuing education by the California Board of Registered Nursing, provider #CEP 15538 and the Australian College of Perioperative Nurses (ACORN). This course has been accredited for 2 (two) contact hours. Obtaining full credit for this offering depends on completion of the self-study materials on-line as directed below.

Approval refers to recognition of educational activities only and does not imply endorsement of any product or company displayed in any form during the educational activity.

To receive contact hours for this program, please go to the “Program Tests” area and complete the post-test. You will receive your certificate via email.

AN 85% PASSING SCORE IS REQUIRED FOR SUCCESSFUL COMPLETION
Any learner who does not successfully complete the post-test will be notified and given an opportunity to resubmit for certification.

For more information about our educational programs or hand-barrier-related topics, please contact Ansell Healthcare Educational Services by e-mail at edu@ansellhealthcare.com

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As employees of Ansell Mrs. Ouellet, Mrs. Richardson, Mrs. Taylor and Ms. Werner have declared an affiliation that could be perceived as posing a potential conflict of interest with development of this self-study module. This module will include discussion of commercial products referenced in generic terms only.

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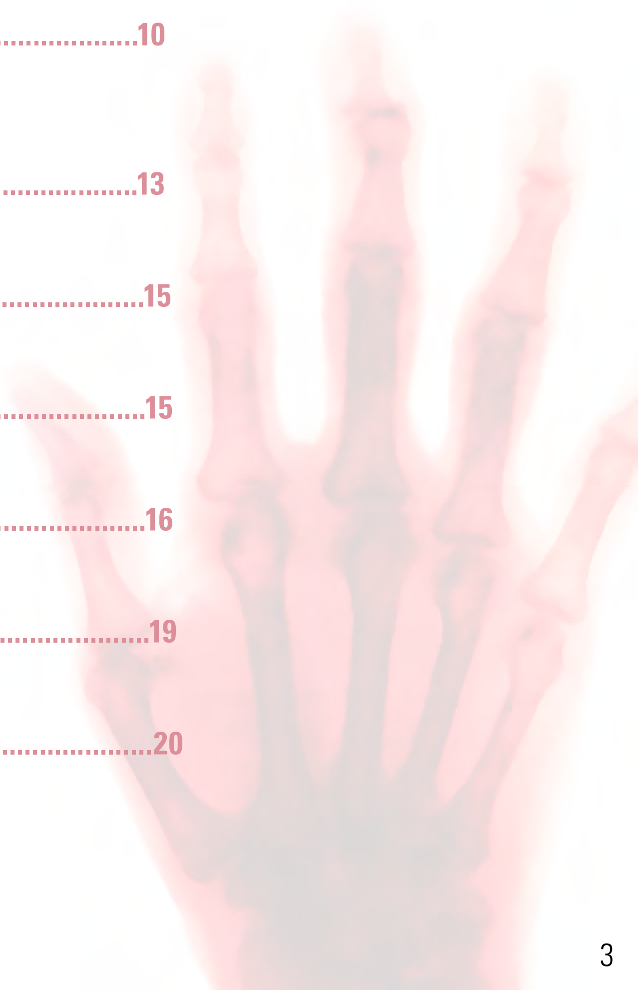
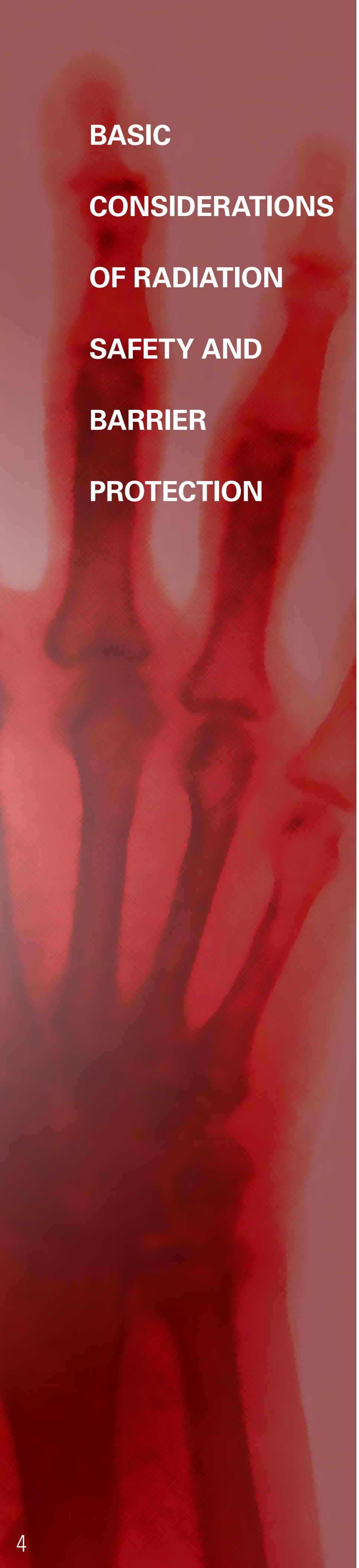




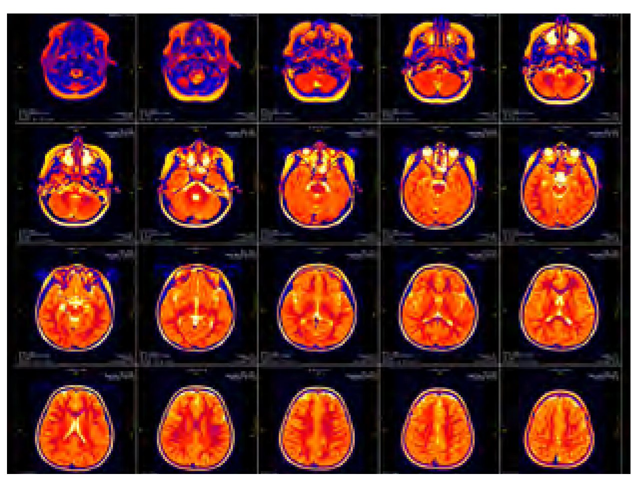
BASIC CONSIDERATIONS OF RADIATION SAFETY AND BARRIER PROTECTION

INTRODUCTION

From the ancient Greeks, who initially believed that all matter was made up of atoms, to the splitting of the atom in the first half of this century, radiation has long been a source of curiosity for scientists and students alike. This curiosity has led to many scientific discoveries, leaving us with a nuclear legacy of both risks and benefits. On November 8, 1895, Wilhelm Röntgen discovered x-rays. Within one year of his discovery, physicians were using x-rays for diagnosis and as a new way of gathering evidence to protect themselves against malpractice claims. X-rays opened the door to a range of new procedures that were considered to be the most technologically advanced diagnostic tools available. Many believed this new ability to non-invasively "see inside the body" was miraculous and realized that x-rays gave great promise to the sick. Thus, the medical world embraced these mysterious invisible rays with great enthusiasm. However, almost immediately after their discovery, it became clear that x-rays could cause serious medical problems. Some physicians received burns that would not heal, requiring amputation of their fingers. Others developed fatal cancers of the skin, blood, and bone.

Although the information offered in this study guide is fundamental, it is the goal of this educational program to heighten awareness of radiation safety and the employment of radiation protection practices.

The information provided in this educational offering is intended to enhance the understanding of healthcare personnel as it relates to safety and barrier protection in a radiological situation. Participants should consult their individual institutions, member organizations, and/or qualified physicians for specific recommendations, policies, or protocols related to radiological equipment and its use.



UNDERSTANDING RADIOLOGY

Radiology is the use of ionizing radiation for medical diagnosis, particularly the use of x-rays in medical radiography or fluoroscopy. In general, the term "radiology" refers to medical imaging techniques that employ advanced computers and other complex equipment enabling doctors to see inside a patient's body. At present, it is estimated that 30-50% of critical decisions in medical approaches are affected by x-ray examination.[1] Using the x-ray as a diagnostic tool requires appropriate and accurate knowledge about its advantages, as well the negative biological effects that can occur when x-rays are used improperly or without approved protection measures. Warnings regarding the excessive use of these radiations and instructions proposed for safe application of these technologies are based on the recommendations of the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP).[2] According to a 2009 report by the NCRP the U.S. population's total exposure to ionizing radiation has nearly doubled over the past decade. NCRP estimates that 17 million interventional fluoroscopy were performed in the United States in 2006 and authors anticipate that these types of procedures will grow in their number.[3]

X-RAY PROPERTIES

X-rays, invisible electromagnetic radiation, pass through the body without creating a sensation. As x-rays pass through matter, there is enough energy to remove electrons from atoms. This creates ionized atoms and free radicals (atoms with an unpaired electron in the outer shell), which in turn can produce harmful biological effects.

In clinical settings, a current passing through a negatively charged, electrically heated filament called a cathode generates x-rays. This produces electrons that are accelerated via high voltage (kilovolt peak: kVp) through an x-ray tube toward the positive electrode (the anode). Energy attained by the electrons is converted to x-radiation as a result of the electron-anode interaction.

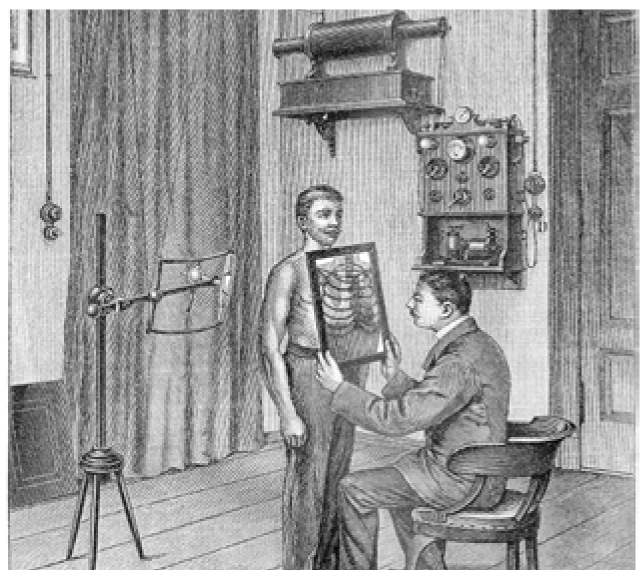
RADIATION SOURCES

Primary radiation is a type of radiation used for medical diagnosis or treatment; it is referred to as "the useful beam." Secondary radiation is made up of leakage radiation, which comes from the x-ray tube housing assembly. Another source of secondary radiation is called scatter radiation. Scatter radiation results when the useful beam intercepts an object so that some x-rays pass through while others are dispersed or reflected. During medical procedures, the patient is the primary scattering object. The degree of scatter increases with increasing tissue density.

HISTORY OF MEDICAL DIAGNOSTIC IMAGING AND PROTECTION

X-rays were discovered in 1895 by Professor Röntgen. Radiology began as a medical sub-specialty in the early 1900s. The development of radiology grew at a brisk pace, and was an integral part of diagnostic medicine during World War II. The advent of the digital computer and new imaging modalities such as ultrasound and magnetic resonance imaging (MRI) have combined to create an explosion of diagnostic imaging techniques in the past 25 years.

For the first 50 years of radiology, an examination involved focusing x-rays through the body part of interest and directly



onto a single piece of film housed inside a special cassette. In the earliest days, a head x-ray could require up to 11 minutes of exposure time. Today, x-ray images are taken in milliseconds, and the x-ray dose is as little as 2% of what was used for an 11-minute head exam over 100 years ago.

Scientists truly began to make advances in the study of atomic structure and radiation in the latter part of the 19th century. They soon learned that radiation was not only a source of energy that could be used for medical purposes, but that it could also be a potential threat to human health if not handled properly. After x-rays were discovered in 1895, medical doctors immediately saw the potential benefits and began experimenting with "The Ray" using homemade equipment. Just three weeks after the discovery of x-rays was announced, the first of many experimenters complained that their hands had received painful x-ray burns. In fact, early pioneers in radiation research died from radiation-induced illnesses due to overexposure. Thomas Edison's assistant died from a radiation-induced tumor as a result of too much x-ray exposure. Madame Marie Curie, who discovered radium and polonium, eventually died at the age of 67 from leukemia. We now know that radiation poisoning and a lifetime of exposure to radioactive materials can cause leukemia. French physicist Antoine Henri Becquerel, discoverer of natural radioactivity, carried a piece of radium in his vest pocket and suffered a severe radiation-induced burn. Indeed, the early pioneers in the discovery of radiation and radioactive materials were very often martyrs to the cause!

SAFETY REGULATIONS TO REDUCE RADIATION EXPOSURE

In 1915, the British Röntgen Society organized an effort to provide protection to people from overexposure to x-rays. By 1922, American organizations adopted these protection guidelines as well. Radiation awareness and education continued to grow throughout the 1920s and 30s to address radiation protection in the United States.

In 1970, Congress created the Environmental Protection Agency (EPA) and radiation protection became a part of the EPA's responsibility. Today, EPA's Radiation Protection Division (RPD) is responsible for protecting the environment and the health of the public from undue exposure to radiation. This is accomplished by setting safety standards and guidelines. Now, organizations that deal with ionizing radiation must meet these standards to comply with the law. Ionizing radiation includes x-rays, gamma rays, alpha particles, and beta particles. Non-ionizing radiation includes radio waves, microwaves, light, and heat. The term "radiation" as used in this educational program is generally assumed to mean ionizing radiation, unless otherwise specified.

The Food and Drug Administration's (FDA) Center for Devices and Radiological Health is responsible for ensuring the safety and effectiveness of x-ray emitting medical devices. Their mission is to eliminate unnecessary human exposure to man-made radiation created by certain medical, occupational, and consumer products.

SKIN BURNS FROM RADIATION EXPOSURE IMAGE

Prompted by growing evidence of radiation-induced cancers and severe skin reactions, government agencies instituted regulations on the design and use of x-ray equipment. In 1992, the FDA began receiving reports of radiation-induced injuries to the skin of patients who had undergone extensive fluoroscopically guided interventional procedures. Injuries varied in severity from erythema to tissue necrosis requiring skin grafting. These injuries occurred after a variety of interventional procedures, including cardiac catheter ablation, catheter placement for chemotherapy, transjugular intrahepatic portosystemic shunt replacement, coronary angioplasty, renal angioplasty, multiple hepatic or biliary procedures (angioplasty), stent placement and biopsy, and percutaneous cholangiography followed by multiple embolization procedures.[4,5]

In 1994, as injury reports continued to rise, the FDA determined that many physicians performing these procedures might not fully realize the magnitude of the skin doses that can result from long, complicated interventional procedures. A public health advisory was issued to alert the radiologic community of this concern and to suggest actions designed to reduce the potential for radiation-induced skin injuries to patients. These actions included establishing standard protocols for screening and monitoring radiation dose rates, as well as modifying protocols and recording information on exposure. In 1995, the FDA recommended that all medical facilities record absorbed radiation doses in the records of all patients who received radiation procedures. This enabled the monitoring of patients to ensure their combined doses of absorbed radiation did not exceed 1 gray, the limit deemed safe by the FDA. In addition, the FDA also required the monitoring and recording of procedures with the potential for long exposure time, including cardiac ablation, vascular embolization, and percutaneous endovascular reconstruction.[6]

CATEGORIES OF RADIATION IN MEDICINE

Today, three broad categories of radiation are used in medicine. The most intense in terms of radiation exposure to the patient is radiation therapy. Radiation therapy involves a tumoricidal dosage that is highly focused on neoplastic tissues in an attempt to cure or control local growth or disease. Patients who undergo radiation therapy typically receive the highest doses of radiation exposure, although all efforts are made to minimize the potential for untoward reactions in the surrounding healthy tissue. A second category, called diagnostic radiology, is used in determining or confirming healthcare disorders such as bone fractures, or other maladies such as pneumonia. To the general public, diagnostic x-rays are a principal source

of exposure to potentially carcinogenic man-made ionizing radiations. The last category encompasses the high-dose fluoroscopically guided interventional procedures such as angioplasty and stent replacement. These procedures involve a single dose of low-energy x-rays with limited variation in the direction of applications. Patients undergoing fluoroscopically or fluorographically guided interventional procedures absorb much larger doses from ionizing radiation than patients having diagnostic procedures.

Some clinicians believe that the high doses reported in the interventional literature actually under-represent exposure time for many long, complex cases.[7]

SAFETY PRINCIPLES

The medical profession has taken many steps to protect patients and medical personnel from the risks of radiation. There are three fundamental principles of radiation protection:

Minimal time of exposure – Minimizing the duration of exposure directly reduces radiation dose. Simply put, if the amount of time spent near a radiation source is reduced, the amount of radiation exposure received will also decrease. A common analogy: if you spend a lot of time at the beach, you will be exposed to the sun and ultimately get sunburn. If you spend less time in the sun and more time in the shade, your sunburn will be much less severe. This is similar to the way radiation exposure works.

Maximum distance from the radiation beam – When the working distance from a radiation source is increased by a factor of two, the dose received from that source will be reduced by a factor of four. Therefore, a person or object 40 feet from a radiation source will receive 1/4 of the exposure than that of a person 20 feet from the source. Compare this to an outdoor concert, and think of the radiation as the music emanating from the speakers. A person sitting directly in front of the speaker may suffer some permanent hearing damage. A person 50 yards from the stage will most likely be exposed to music of average intensity. And a person in a park across the street may not even hear the concert. Radiation exposure is similar: the closer you are to the source, the greater your chances are for damaging your body.

USING PLEXIGLAS AS A BARRIER AGAINST BETA PARTICLES REDUCES RADIATION EXPOSURE

Use of all possible shielding – Shielding is the use of any material to reduce the intensity of the radiation by absorption or reflection. Increasing the shielding around a radiation source decreases the exposure. Example: if you stand in the rain without an umbrella, you will get wet. But, if you use an umbrella as a shield, you will remain dry and protected. Also, think of complete coverage and optimum protection by incorporating boots, raincoat, hat, and a larger umbrella. This is similar to radiation shielding in which the specific shielding material and thickness depends on the amount and type of radiation involved. Employing Plexiglas for beta particles and lead for x-rays and gamma rays is an effective way to reduce radiation exposure. Shielding is gauged by the amount of protection that reduces exposure from a radiation source by one-half. This is termed the half-value layer (HVL), which is dependent on both the energy of the radiation and the atomic number of the absorbing material. While this exact terminology may not be of clinical relevance, it is important because it is part of the lexicon that describes the interaction of x-rays with shielding materials.

ALARA is an acronym for "As Low As Reasonably Achievable." This is a radiation safety principle for minimizing radiation doses by employing all reasonable methods. ALARA is a regulatory requirement for all radiation safety programs. It is the core of any radiation protection program and a mindset of professional excellence. One can never have "zero" radiation exposure due to naturally occurring radioactivity that surrounds us – cosmic rays, the sun, natural isotopes in our body, etc. Therefore, it is best to add nothing to this background dose.

The ALARA approach used by the U.S. Nuclear Regulatory Commission (NRC) assumes that any exposure to ionizing radiation carries some risk. The risk is assumed to be linear, so as one's exposure increases, so does the risk of adverse health effects. Instead of operating at or just below permissible exposure limits, one must stay as far below the exposure limits as possible. This affords a wider margin of safety, because should a control malfunction or fail, one's exposure level may rise yet still remain below the acceptable level.

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RADIATION EXPOSURE

Both large and small doses of radiation can cause cellular damage. The extent of the damage depends upon the total amount of energy absorbed, the time period and dose rate of the exposure, and the particular organs exposed.[8]

By damaging the genetic material (DNA) contained in the body's cells, radiation can cause cancer. Damage to genetic material in reproductive cells can cause genetic mutations that can be passed on to future generations. In rare occurrences where there is a large amount of radiation exposure, sickness or even death can occur in a limited amount of hours or days.[9]

One study found that the death rate from brain cancer in radiologists was almost three times that of other medical specialists who did not use radiation.[10]

Radiation is potentially harmful, and exposure to it should be monitored and controlled. No unnecessary exposure should be allowed.[11] Evan C. Lipsitz, MD, Assistant Professor of Surgery, Montefiore Medical Center, New York, Division of Vascular Surgery, says "We should remember that radiation exposure

is cumulative over one's lifetime and that the effects are permanent. And, reducing fluoroscopy time, increasing distance from the source, and using adequate protection with monitoring are the basic methods of reducing exposure."[12]

POSSIBLE BIOLOGICAL EFFECTS

Biological effects of radiation can be separated into two categories: Deterministic effects and stochastic effects. Deterministic effects are those for which a minimum number of cells must be affected above a threshold before a biological response is seen. Cataracts or radiation-induced erythema and necrosis are examples of deterministic radiation effects. As the dose increases above the threshold, the likelihood of seeing the effect and the severity of the effect increases. If the dose is sufficient, there is a 100% certainty the effect will be induced.[13]

Many radiation-induced effects occur when change in a single cell is sufficient to initiate biological processes such as the development of cancer. These effects are called stochastic and no known threshold dose exists. The likelihood of inducing the effect increases with dose and may differ among individuals. Such radiation risks include cancers of the blood, bone, lung, parotid gland, and other organs, including the skin. The first cancer thought to be caused by exposure to x-rays was a skin cancer case diagnosed in 1902 – seven years after Röntgen's discovery. Again, early radiologists were not aware of the risks associated with exposure to x-rays, and many accumulated very high radiation doses in a short time.[14]

If fluoroscopic doses are sufficiently high to include deterministic effects, skin effects are one of the earliest and most frequently observed signs. Skin exposed to ultraviolet radiation is more sensitive to x-rays. This is because fluoroscopic x-rays are attenuated rapidly in tissue. The dose is maximized at the point where the radiation beams enter the skin. The skin is also rendered susceptible to radiation effects because basal cells of the epidermis divide rapidly. Rapidly dividing stem cell populations contain "new" skin cells, and these immature cells are typically more sensitive to radiation than mature cells. The most common forms of cancer on the hands and arms are squamous cell carcinomas, while basal cell carcinomas are more likely to occur on the head and neck. Radiogenic skin cancer is frequently associated with chronic dermatitis, sometimes only observable at the microscopic level.

As GT Nahass writes in the Journal of the American Academy of Dermatology (1997), since the signs of acute radiodermatitis clear spontaneously, cases with mild symptoms may go unrecognized and untreated. The long-term consequences of acute radiodermatitis often appear months to years later. Radiation leukemia generally develops 10-15 years after exposure, but may occur as early as two years or as late as 25 years. The latent period for radiogenic skin cancer ranges from 4 to 40+ years, with squamous cell and basal cell carcinomas being the main associated cancer types.

DOSE LIMITS AND MONITORING

Since radiation dose is cumulative, the NRC and state regulatory agencies mandate the use of wearable radiation monitors (film badges) while performing fluoroscopic procedures. These devices respond to radiation exposure by eliciting a signal that indicates an estimate of the accumulated exposure over a period of time.

The International Commission on Radiological Protection (ICRP) sets effective radiation dose limits. Effective dose is a concept proposed by the ICRP to relate the risk from partial-body radiation dose to that from an equivalent whole-body dose. The ICRP suggests that approximately 37% of the total skin surface not shielded by a lead apron is present in the arms, lower legs, hands, and feet, with skin of the hands and forearms most likely to receive a higher radiation dose than the skin areas measured by the dosimeter (radiation monitor) placed over the collar of the lead apron.[15] If the monitor is worn under the apron, the dose to the head and neck will be unknown, and this is unacceptable. Unfortunately, there is no precise way of determining how much exposure one has had without diligently wearing some form of monitor. Practitioners with significant exposure – such as in the cardiac catheterization laboratory – wear monitors inside the lead apron, external monitors, and ring monitors on the fingers. However, if fluoroscopy is only being used sporadically, a pocket dosimeter may offer ample monitoring.

DOSE LIMITS FOR ADULT WORKERS

- 2,000 millirem (20 mSv) per year averaged over a five-year period – not to exceed 5,000 millirem or 50 mSv in any one year.[16]
- 15,000 millirem (150 mSv) per year to the lens of the eye.[17]
- 50,000 millirem (150 mSv) per year to the skin or to any extremities – hands, forearms or feet, and ankles.[18]
- The annual effective whole-body dose limit for physicians is 50 mSv.[19]

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Scatter radiation is a major concern for individuals in a fluoroscopy suite. Scatter can come from any direction and can increase when imaging denser tissues. Since the main source of scatter radiation is from both the imaging equipment and the patient, standing as far away as possible from the imaging unit and the patient will reduce one's exposure. However, as soon as the x-ray switch is disengaged, x-rays cease to exist in the room and neither the machine nor the patient are sources of scatter radiation.

PROTECTIVE SHIELDING

There is no law mandating the use of shielding devices commonly used in practice today (i.e., lead aprons, radiation attenuation gloves, thyroid shields, or protective eyewear). However, using these devices has become a standard and essential part of functioning in a fluoroscopic environment, even for individuals receiving less than 50 mSv per year. Protective apparel is particularly important during mobile C-arm fluoroscopy or portable radiography since the control console is not positioned behind fixed protective barriers. When using fixed units, personnel may leave the room while screening runs are obtained. Because this is not possible with portable radiography systems, drapes and aprons made of lead-impregnated vinyl are the primary protective barriers against stray radiation. Well-placed drapes can provide medical staff some additional protection by reducing radiation scatter.[20] "Wrap-around" lead aprons are useful when there is a great amount of time spent turned away from the patient for protection of the back of the body. Legs located near the x-ray tube must be shielded as well.

AORN writes in their standards of practice, "Whenever possible, shielding should be employed to provide attenuation of the radiation being delivered to personnel potentially exposed.

Types of shielding available to personnel include but are not limited to:

- Walls, windows, control booths and doors
- Mobile rigid shields on wheels for transport to various areas
- Ceiling-suspended transparent barriers
- Flexible aprons (e.g., wrap-arounds, open backs), vests skirts, thyroid shields, gloves and
- Lead safety eyeglasses with side shields."[21]

AST states that, "Surgical technologists should utilize protective lead lined gloves, aprons, thyroid collars and glasses to minimize exposure to radiation."[22]

Pregnant women may continue to work in fluoroscopic areas, but they should wear an extra radiation monitor at the level of the abdomen underneath the lead apron. This serves as a monitor for the dose to the conceptus. Specially designed lead maternity aprons are also available to provide added protection.

USE AND CARE OF X-RAY APRONS

1. Cleaning
If your x-ray apron is dirty from blood or other bodily fluids, you should clean it as soon as possible. Using cold water and mild detergent, carefully wipe down your x-ray apron. Do not use bleach or any harsh chemicals, this can deteriorate and perhaps alter the effectiveness of protection. Do not autoclave, dry-clean or machine launder x-ray aprons.

2. Storage
Don't fold, crease, drape, or sit down tightly on your x-ray aprons. Safely hang on a lead apron rack, hanger or equivalent storage unit. Storing aprons correctly can increase the life cycle of your x-ray aprons.

3. Inspection
It's recommended that lead aprons are to be checked fluoroscopically at least once a year to uphold standard performance. Checking x-ray aprons as often as possible is always best practice, the slightest crack can render the apron damaged.

4. Disposal
Each apron that contains lead must be properly disposed. You can do this by contacting a hazardous waste disposal service who can properly discard lead material. Alternatively, all non-lead aprons can be disposed of in the regular garbage disposal. There is no need to contact a disposal service for non-lead aprons.

Reference: http://blog.universalmedicalinc.com/how-to-care-for-your-x-ray-apron/

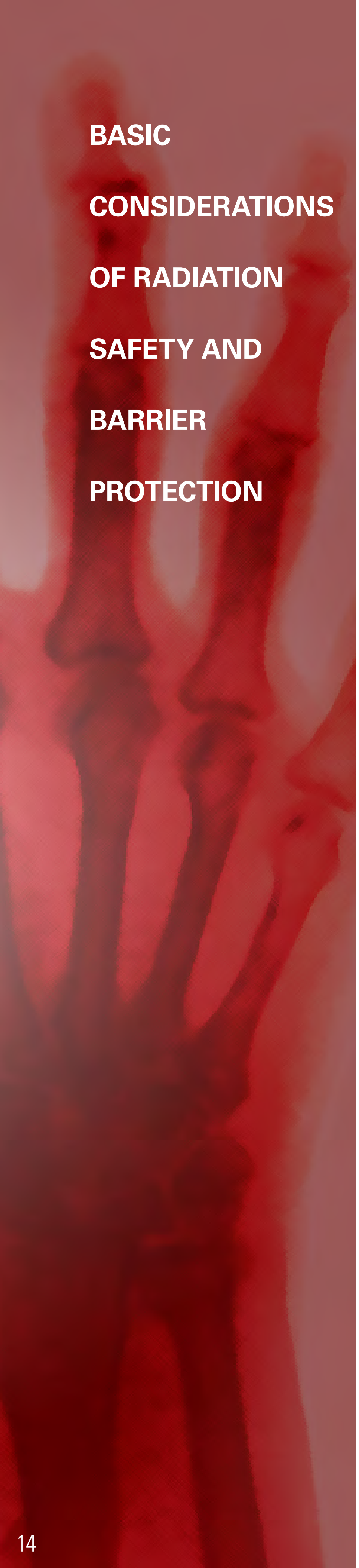
HAND PROTECTION FROM RADIATION EXPOSURE

During specific procedures, interventional radiologists, pain service physicians, and GI physicians may receive some of the highest doses of radiation of any medical personnel. Chronic irradiation of the hands is a principal radiation safety concern for any physician involved in the broad spectrum of high-dose fluoroscopically guided interventional procedures.[17]

As previously stated, fluoroscopically guided interventional procedures differ from other forms of radiation since medical personnel cannot move behind a shield and must stay in the room when x-ray exposure occurs. Because of the manipulation needed in these types of procedures, physicians' hands must be in close proximity to the scanning plane. Despite the use of devices such as needle holders (which are designed to reduce exposure to hands), many of these procedures are very complicated and force the physician to place his or her hands directly in the radiation beam for a limited amount of time.

Even when direct exposure can be avoided, the level of exposure due to scatter can be very high during interventional procedures. Stay as far away from the X-ray beam as possible. Use tubing extensions or needle holders so that your hands are away from the exposed field. Never place your hands in the X-ray beam.[23] Radiation exposure to hands is often the most significant factor in terms of overall radiation risk for physicians who perform the growing number of interventional procedures.[24] Most surprising, hands are the part of the body for which interventional radiologists are least likely to wear protective garments.[25]

Because exposure from fluoroscopy is not trivial, concern over radiation exposure has convinced some physicians to wear sterile x-ray attenuating surgical gloves. Wagner and



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Mulhern believe it is necessary to include protection from both forward-scattered x-rays as well as secondary electrons.[21] However, physicians should realize that these **gloves are not likely to protect hands if placed fully into the fluoroscopy beam.** When placed fully in the x-ray field, gloves add to the attenuation of the beam. This reduces image brightness, producing a large amount of scatter radiation from the gloves that irradiates the hand. Therefore, **physicians must not be lured into a false sense of security and mistakenly rely on gloves as their principal means of protection during fluoroscopy.**

If the physician's hand is exposed to the direct beam, the mean dose reaches 120 mSv per procedure. Thus, on the basis of the annual dose limit of 500 mSv for the hands as set by ICRP, a physician could only perform four (4) CT fluoroscopy- guided procedures per year to remain within occupational exposure limits. Kato found that by using a biopsy needle holder, allowing the physician to place his/her hands 4 cm from the direct beam, exposure would drop to 1.5 mSv per procedure, thus enabling the physician to perform up to 330 procedures per year.[26]

Monitoring for physicians is both a short-and long-term process. Theoretically, physicians should calculate the exposure incurred in various procedures performed. Physicians should then determine the number of procedures he or she can perform in one year, based on the cumulative occupational dose limits as determined by the ICRP.

Protective hand gear can be relied on only to protect against radiation outside the field of view of the equipment's automatic brightness control. Double-gloving with conventional latex surgical gloves provides only 1% attenuation. Specialized radiation protection gloves can reduce scattered radiation to the hands by as much as 59% at 60 kVp. Again, it must be stressed to keep hands out of the beam as much as possible. If the image of one's fingers or hands appears on the monitor, they are being directly exposed. Hands should always be pulled back from the imaged area unless physical control is required for patient care.

Today's radiation protection gloves are less bulky and can be used effectively under surgical gloves for interventional procedures, diagnostic heart catheterizations, coronary angioplasties, pain management, orthopedic surgery, urology, or in other situations where exposure to radiation is high. These gloves shield hands from the harmful exposure to scattered radiation and are powder-free to reduce any risk of powder-related complications. Some manufacturers offer latex-free and/or lead-free bismuth oxide attenuating specialty gloves. Per unit weight, bismuth oxide provides approximately the same radiation protection as lead, but it has the clear advantage of much lower toxicity*.

*Always check with the manufacturer for attenuating capabilities and specific performance characteristics. Radiation protection gloves can be disposed of in the same manner as surgical or medical examination gloves if:

- There is a possibility of induced radioactivity or contamination with radioactive isotopes. The EPA has developed toxicity characteristics to regulate wastes likely to leach hazardous concentrations through a landfill into groundwater. Lead falls under toxicity characteristic and must not leach more than 5mg/liter, according to the 40 Code of Federal Regulations 261.24.
- There is no possibility of radioactive contamination. If burned, the bismuth oxide radiation attenuation additive will become part of the small amount of ash that forms when any medical glove is burned. If they are landfilled, they will degrade along with any other gloves in the group and contribute micronutrients to the soil.

COMPLIANCE

To date, neither the FDA nor the Occupational Safety and Health Administration (OSHA) mandates radiation protection for healthcare professionals. It is acknowledged that the National Institute for Occupational Safety and Health (NIOSH) guidelines state that no part of the body should be directly exposed to radiation. If there is a danger of exposing a body part, appropriate protection must be used. "Lead aprons, gloves, and goggles should be worn by workers located in the direct field or in areas where radiation levels from scattering are high." However, based on glove wearing and other protective items compliance data, any definitive legislation in the United States would certainly require a strong educational approach. Until such regulations are in place, it is imperative to provide all healthcare professionals with information and education, especially as it relates to hand injuries resulting from exposure to scattered and secondary radiation.

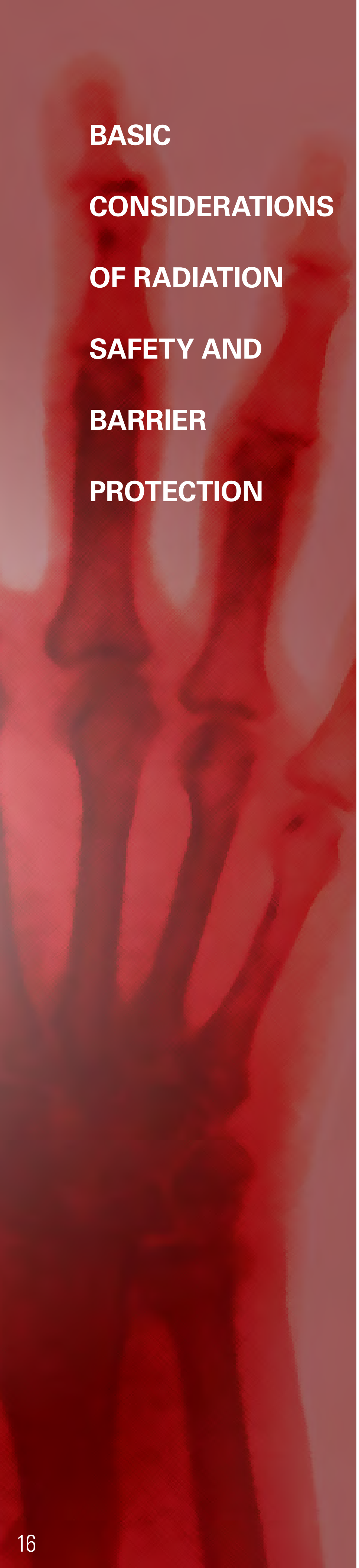
Although many physicians and interventionalists are aware of and concerned about the risks to their health, many focus foremost on the patient and the task at hand; focus is placed secondly on the cumulative exposure procedures during a time period; and lastly on their own protection.

It was noted in a study by Marx et al. that nearly half the respondents rarely or never wore their mandatory radiation badges; that 73% rarely or never wore lead glasses; and 83% rarely or never wore gloves. Lipsitz concluded that "there can be significant complacency even among the population of physicians who are at the most risk and who have had substantial training in radiation and physics."[12]

MOVING FORWARD

Clearly, when x-rays first came into use, there were many injuries and even deaths due to radiation exposure. Once it was determined that the amount of radiation involved in x-rays could be controlled, they became much safer procedures. Today, radiation protection is an integral component of any radiology department. The main principles of radiation protection are to provide adequate protection from undue exposure of radiation to personnel directly or indirectly involved with radiation, without unduly limiting the benefits of radiation exposure. Regular ongoing educational programs and reviews form a necessary part of the responsibilities of healthcare institutions. The application of simple radiation rules will allow healthcare professionals to minimize exposure as much as possible. Applying such rules may also help to improve the protection of other medical staff that are less familiar with radiation protection protocols.

Prudence dictates that anyone using or operating x-ray equipment should be trained in its safe and proper operation, and operators should know the biological hazards associated with its use. Should there be any questions regarding personal protection, safety of a particular fluoroscopic suite, x-ray equipment, or how to obtain additional information, a medical physicist or Radiation Safety Officer should be consulted. Also, the reader may find useful a comprehensive and detailed text by Wagner and Archer that further expands upon the information provided in this study guide.[21]



GLOSSARY

ABSORBED DOSE
The concentration of energy deposited locally in tissue and an important measure of the potential for biological effects. Absorbed dose is measured in units of gray (Gy_t) or milligray (mGy_t) where the subscript “t” specifies the dose as being in tissue.

ALPHA RADIATION
High-energy radiation that comes from radioactive atoms when broken apart.

ATTENUATE
To become thin, weak, or fine. Reduced or weakened, as in strength, value, or virulence. To reduce in force, value, amount, or degree; weaken.

ATTENUATION
The process by which the number of particles or photons entering a body of matter is reduced by absorption and scattering.

BACKGROUND RADIATION
Unavoidable radiation that occurs all around us. The typically quoted average individual exposure from background radiation is 360 millirems per year.

BETA RADIATION
High-speed electrons that come from radioactive atoms when broken apart.

CUMULATIVE DOSE
The total dose resulting from repeated exposures of ionizing radiation to the same portion of the body, or to the whole body, over a period of time.

DETERMINISTIC EFFECT
Health effects of radiation; the severity of which varies with the dose and for which a threshold is believed to exist. Deterministic effects generally result from the receipt of a relatively high dose over a short period of time. (Formerly called non-stochastic effect.)

DOSIMETER
A small portable instrument such as a film badge, thermoluminescent, or pocket dosimeter for measuring and recording the total accumulated dose of ionizing radiation.

EFFECTIVE DOSE
The dose averaged over the entire body.

FLUOROSCOPY
The momentary production and display of serial x-ray images for the purpose of observing real-time motion of internal anatomic structures. Fluoroscopy can deliver much larger doses of radiation than conventional x-rays.

GAMMA RAYS
Electromagnetic waves or photons emitted from the nucleus (center) of an atom that are of a very short wavelength and very high frequency, similar to x-rays.

GENETIC EFFECTS
Effects from some agent that are seen in the offspring of the individual who received the agent. The agent must be encountered pre-conception.

GRID
A flat plate device that improves image contrast by selectively shielding the image intensifier from scattered x-rays.

GRAY (GY)
The new international system (SI) unit of radiation dose expressed in terms of absorbed energy per unit mass of tissue. The gray is the unit of absorbed dose and has replaced the rad. 1 gray = 1 Joule/kilogram, and also equals 100 rad.

HIGH VOLTAGE
Tube voltage controls x-ray energy. High voltage is expressed as kilovolt peak (kVp) and usually ranges from around 60 to approximately 125 kVp. The kVp affects the penetration and the intensity of x-rays.

HVL
Half-value layer of x-ray beams (the thickness of a material required to attenuate a raw x-ray beam intensity by a factor of 2). Aluminum is usually the material used to measure HVL. Ionizing radiation: Radiation that can ionize and is especially dangerous to living tissues. Examples are gamma rays and neutrons.

JOULE
A unit of energy.

KVP
Stands for kilovoltage peak and is the power and strength of the x-ray beam (quality of the x-rays). This is the highest voltage (measured in thousands of volts) that will be produced by the x-ray machine during an exposure. kVp controls the penetrating strength of an x-ray beam (beam quality). Whenever an exposure is made, the x-rays must be strong enough to adequately penetrate through the area of interest. The higher the kVp, the more likely the x-ray beam will be able to penetrate through thicker or denser material. Most x-rays used in medical imaging are between 50 and 120 kVp (50,000 to 120,000 volts). Higher kVp settings produce more scatter radiation.

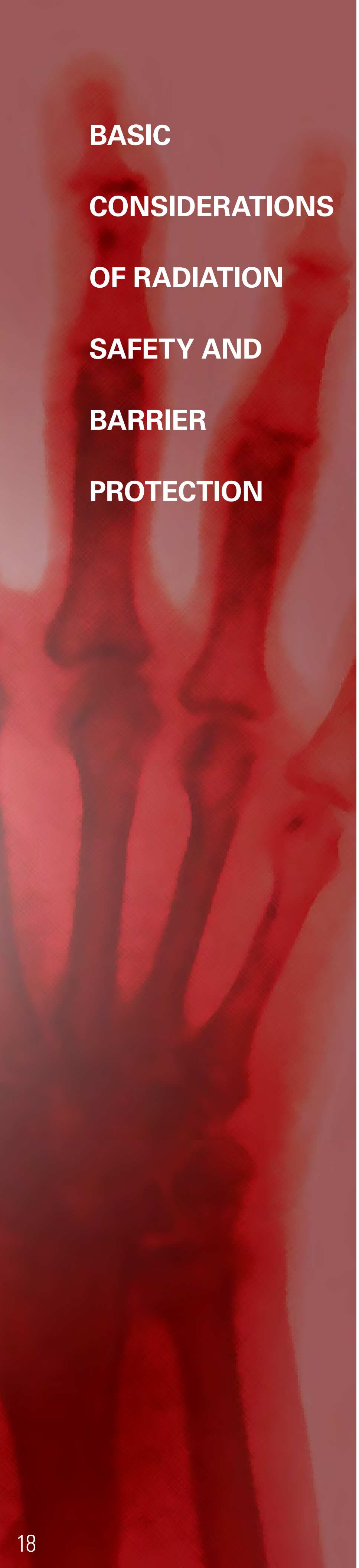
MSV
The scientific unit of measurement for radiation dose commonly referred to as the effective dose. We are exposed to radiation from natural sources all the time. The average person in the U.S. receives an effective dose of about 3 mSv per year from naturally occurring radioactive materials and cosmic radiation from outer space. These natural background doses vary throughout the country.

NON-STOCHASTIC EFFECT
Effects that can be related directly to the dose received. The effect is more severe with a higher dose; i.e., the burn gets worse as the dose increases. It typically has a threshold below which the effect will not occur. A skin burn from radiation is a non-stochastic effect. (This term has been replaced with deterministic effect.)

PHOTON
A quantum or packet of energy emitted in the form of electromagnetic radiation. X-rays and gamma rays are examples of photons.

RAD
Radiation absorbed dose – a measure of the quantity of energy absorbed from ionizing radiation. The rad has been replaced by the gray in the SI system of units (100 rad = 1 gray).

RADIATION
Energy given off by the nucleus of an atom in the form of particles or rays.



BASIC CONSIDERATIONS OF RADIATION SAFETY AND BARRIER PROTECTION

REM

Röntgen equivalent man – a measurement for how dangerous or potentially harmful radiation is to living tissue. Not all radiation has the same biological effect, even for the same amount of absorbed dose.

SCATTERED RADIATION

Radiation that, during its passage through a substance, has been changed in direction. It is a form of secondary radiation. When x-rays interact in a patient, many are scattered in random directions from the exposed volume of the patient. (These scattered x rays are the principal source of radiation exposure to personnel during fluoroscopy.)

SIEVERT

The international system (SI) unit for dose equivalent equal to 1 joule/kilogram. The Sievert has replaced the rem. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. One Sievert is equal to 100 rem.

SOMATIC EFFECTS

Effects from some agent, like radiation, that are seen in the individual who receives the agent.

STOCHASTIC EFFECT

An effect that occurs on a random basis, with its effect being independent of the size of dose. The effect typically has no threshold and is based on probabilities, with the chances of seeing the effect increasing with dose. In the context of radiation protection, the main stochastic effect is cancer.

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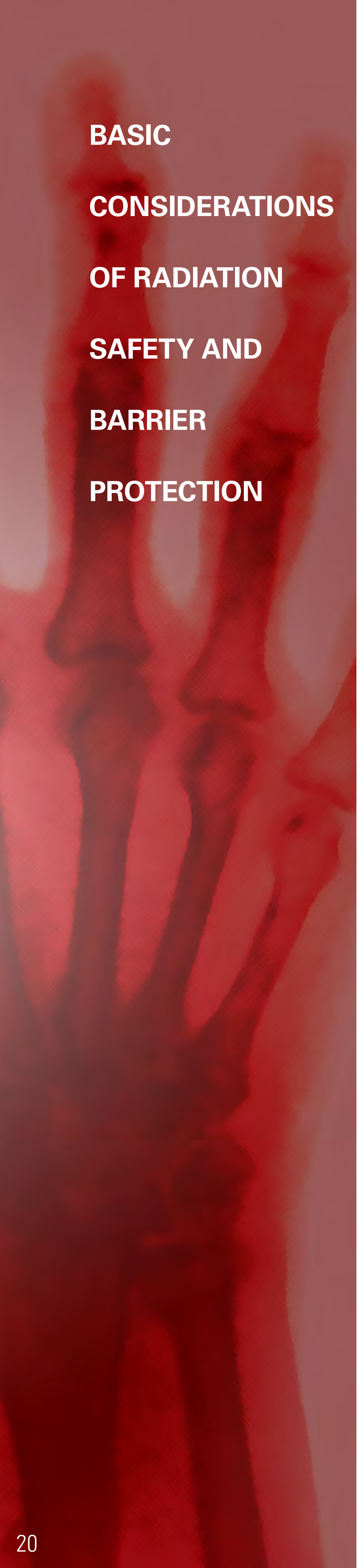

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