

# Consumer Guide to Imaging Modalities

Benefits and Risks of Common  
Medical Imaging Procedures



RadSite™

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## Introduction

**W**hen a patient, family member or friend experiences a medical event, part of the diagnosis or treatment often involves getting a referral to get an x-ray or another type of imaging procedure by a radiologist or a radiology technician. Understanding what the procedure is, how it works, and how it can help the patient can be very confusing.

This Consumer Guide provides an introduction to the different imaging modalities, how they work, and the benefits and risks. Understanding each type of imaging modality is one step to ensure that each individual is informed and empowered—either as a patient or as the person providing guidance to a loved one. The primary goal is to ensure that the right individual is getting the right test at the right time. Patient safety also is critical and should be a central part of the decision-making process before, during and after each imaging procedure—as well as a clear understanding of the cumulative effects of the radiation from diagnostic imaging. This issue brief gives you important navigational markers to guide you to ask the right questions to ensure that the proper course of testing/imaging and diagnosis is being taken.

This guide should not be used as a source of medical advice and is for informational purposes only. In all cases, it is vital a licensed medical professional with the appropriate expertise is consulted. It is RadSite's hope that this overview helps you ask the right questions to make an informed decision, whether today or in the future.

This Consumer Guide will be updated from time-to-time, so please check back periodically at [www.radsitequality.com](http://www.radsitequality.com), and be sure to share this information.



**The primary goal is to ensure that the right individual is getting the right test at the right time.**

## Background

Since its inception in the early 1900s, the field of radiology has evolved from basic plain-film x-ray to advanced diagnostic imaging modalities that create three-dimensional cross sections of internal structures.<sup>1</sup> Each method encompasses specialized techniques designed for the imaging of certain body systems and provides its own set of risks and benefits. Diagnostic imaging has become a cornerstone of modern healthcare and continues to improve our quality of life by enhancing the diagnosis of diseases, increasing cancer survival rates reducing the need for invasive procedures, and furthering our understanding of the human body. Medical imaging touches almost every patient office visit, every hospital stay, and every surgery. Virtually every adult has undergone some form of medical imaging from a basic chest x-ray to the most complex Computed Tomography (CT) scan, Magnetic Resonance Imaging (MRI) evaluation, or Positron Emission Tomography (PET) study.

The first and oldest type of imaging uses x-rays with the radiation source located outside the patient. There are five primary x-ray imaging modalities:

- *Radiography* is also referred to as plain film x-ray and is the oldest form of medical imaging. This method began with screen-film techniques using methods similar to that of traditional photography and, like most cameras, has more recently become

largely digitalized. Both of these methods, screen-film and digital, project a beam of x-radiation through a patient's body to create an image that is captured on an image receptor typically located behind them.<sup>3, 4</sup>

- *Fluoroscopy* refers to the continuous acquisition of a sequence of x-ray images over time, creating a moving image of internal body functions that can be viewed in real-time like a movie.<sup>5, 6</sup>
- *Computed Tomography (CT)*, also referred to as a *CAT (computerized axial tomography) scan*, uses x-ray beams from various angles to produce cross-sectional images referred to as "slices," which may be reconstructed into two dimensional sections or three dimensional volumes of anatomic structures.<sup>9</sup>
- *Dual-emission X-ray Absorptiometry (DXA)* uses two different energies of ionizing radiation to measure a patient's bone mineral density.<sup>11</sup>
- *Mammography* uses low energy x-rays to specifically image breast tissue.<sup>12</sup>

A second type of medical imaging commonly referred to as nuclear medicine produces medical images by viewing a radioactive chemical or compound that has been introduced into the patient's body. The radioactive materials are known as radiotracers and are given to the patient orally (swallowed), by injection (through a needle into a vein), or by inhalation (breathing in the radioactive substance). The resulting radiation emitting from the radiotracer inside the patient's body is detected to produce images.

Nuclear medicine encompasses three main modalities:

- *Nuclear Medicine Planar Imaging*, through the use of *gamma cameras*, measures the uptake of the radiotracer throughout the body, allowing physicians to study organ function.



- *Positron Emission Tomography (PET)* frequently uses radiotracers to monitor the use of oxygen and glucose, allowing physicians to study organ function and metabolism.<sup>13</sup>
- *Single Photon Emission Computed Tomography (SPECT)* is a radiotracer detection method that uses technology similar to that of Computed Tomography (CT). However, unlike traditional CT where the x-ray beam is projected through the patient, SPECT acquires two dimensional slices of human anatomy by imaging the distribution of the radiotracer coming from inside the patient.<sup>14</sup>

Finally, there are those imaging modalities that do not use ionizing radiation:

- *Ultrasound* images are constructed by projecting high frequency sound waves into the body and using sonic echoes to create a real-time image of internal anatomy.<sup>15</sup>
- *Magnetic Resonance Imaging (MRI)* uses magnetic fields and radio frequency pulses to create 2D and 3D images with amazing clarity.<sup>16,17</sup>

Because ionizing radiation can potentially lead to cancer, there is always a certain level of risk associated with the use of methods that expose a patient to ionizing radiation. Additionally, contrast materials, sedation and other techniques can potentially cause harmful side effects. Poor quality imaging can also have an adverse effect by impairing the diagnostician's ability to interpret the imaging study, potentially leading to an incorrect or missed diagnosis. These risks are minimized when radiology equipment is operated by trained and licensed technologists and overseen by physicians trained in the appropriate and safe use of radiation for imaging.

RadSite has been evaluating radiology practices since 2005, and seeks to ensure that safe, high-quality imaging methods are followed in facilities throughout the U.S.<sup>2</sup> Through its various accreditation programs, RadSite recognizes facilities that exhibit a commitment to quality and safety in their imaging standards.

**Diagnostic imaging has become a cornerstone of modern healthcare and continues to improve our quality of life by enhancing the diagnosis of diseases, increasing cancer survival rates, and furthering our understanding of the human body.**



## Imaging Modality Types

The following modalities are those covered by RadSite accreditation programs. Each modality is described below in terms of the methods and technology used to generate the images, what common procedures and body systems are best suited for each use, and the relative risks and benefits of each technique.

### Radiography

Radiography is the first medical imaging technology used to visualize internal body structures, and remains the most commonly used modality today. X-rays were discovered in 1895 and used immediately for anatomic imaging. Radiography works by projecting a beam of ionizing radiation through a patient's body onto a photographic film or recording plate, and then developing or creating an image of the body part being evaluated.<sup>1</sup> Various parts of the body have different densities, and each part of the body allows a different degree of the ionizing radiation to pass

through it. Bones, the densest part of a patient's body, will block most of the ionizing radiation and appear white on the x-ray film. Soft tissues, such as muscles, tendons and organs, will appear as varying shades of grey, depending on their density. Empty air space will appear black.<sup>3</sup>

Radiography is used to image all parts of the body, but chest imaging is most frequent. Over 150 million chest x-rays are performed annually in the U.S., at a cost of over 11 billion dollars per year.<sup>18</sup> These images are typically produced from a postero-anterior (PA) view, with the x-ray beam entering the patient through the back, producing an image on the film cassette in front of the patient's chest. (This is done to minimize the size of the heart, and allow a better view of the lungs.) Alternatively, doctors may order lateral chest x-rays, in which a patient stands with their arms straight in the air so the x-ray beam passes through their side.<sup>3</sup> X-ray radiation can be applied to any part of a patient's body to view bones and diagnose abnormal growths, deteriorations and fractures, dislocated joints, and digestive problems within the gastrointestinal (GI) tract.

Radiography may provide patients with a lower-risk option for diagnostic imaging depending on the area of the body being evaluated, as compared, for example, to CT imaging. In general, x-ray imaging is relatively low in cost compared to other imaging modalities, subjects the patient to a lower dose of radiation, and is readily available in most locations. Although the relatively low cost and accessibility may be a benefit, this can potentially lead to inappropriate use with unnecessary radiation exposure and expense. In fact, x-ray imaging is not well-suited for all situations. It does not image soft tissue well, nor does it produce images of the same contrast resolution as newer techniques such as CT and MRI due to the overlapping of structures displayed on the standard x-ray film. Additionally, radiography uses ionizing radiation, and therefore has some increased cancer risk.<sup>3,4</sup>





## Fluoroscopy

Much like radiography, fluoroscopy projects a beam of ionizing radiation through a patient's body onto a fluorescent screen. Instead of producing a single x-ray image, however, a fluoroscopy imaging system also known as a fluoroscope uses a continuously repeating beam of ionizing radiation that creates a sequence of images on a monitor, allowing physicians to view the motion of internal body systems in real-time, like a movie. Patients can be given a contrast medium to help enhance the image of the areas of interest, such as a barium swallow or enema. The contrast medium is designed to be radio-opaque, causing the areas that absorb the contrast to be projected as white images against the darker, non-coated body systems around them.<sup>5,6</sup>

Fluoroscopy is commonly used to investigate suspected problems or diseases of the upper or lower GI tract. When imaging the upper GI tract, physicians

make use of ingested contrast to highlight abnormalities in the esophageal function, identify tumors, and diagnose other related health problems.<sup>5</sup> For the lower GI tract, the contrast agent is inserted into the patient's rectum, allowing doctors to identify digestive problems and locate potentially cancerous polyps.<sup>6</sup> Other uses for fluoroscopy procedures include imaging the uterus and fallopian tubes (hysterosalpingography),<sup>7</sup> as well as studying the motion of bones and joints (arthography).<sup>8</sup> Fluoroscopes can also be used during orthopedic surgery to guide the placement of implants, such as metal screws and bars used to repair bone injuries, as well as catheter placement in a cath lab.

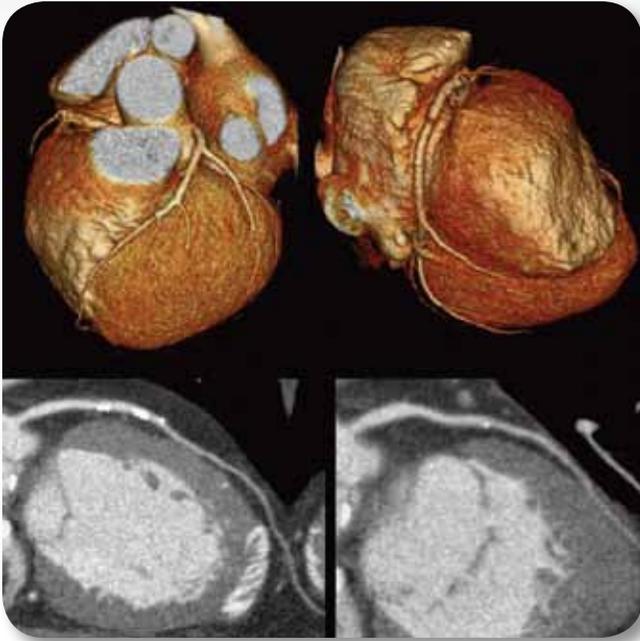
Unique from radiography, fluoroscopy allows physicians to view images of contrast agents flowing through the GI tract and other areas of the body in real-time. Unfortunately, because fluoroscopy involves taking several x-ray images in sequence to create a moving picture of a body function, the patient may be exposed to a greater dose of radiation than through regular radiography. Additionally, although reactions to barium are extremely uncommon, the use of contrast media can pose an additional risk to the patient and should be considered when weighing benefits versus risks.

## Computed Tomography (CT)

The Computed Tomography (CT) modality uses computers to combine x-ray data taken from multiple angles and locations to create cross-sectional images of particular areas within a patient's body. Breaking down the area of interest into digital "slices," CT scans allow physicians to non-invasively see into the human body, viewing highly-detailed images "slice by slice" to identify potential problems in bones, organs, and other bodily tissues.<sup>9</sup>

CT scans are particularly effective in examining the body for trauma, and are often utilized to diagnose muscle and bone disorders, cancer, and heart disease. Going beyond the diagnostic side of medicine, CT scans can be used to provide extra guidance during medical procedures, allowing doctors to accurately direct surgery, biopsies, and radiation therapy.

In many situations, CT imaging has reduced the need for more invasive procedures, such as biopsies or major exploratory surgeries. Unfortunately, CT scans do not come without risks. Outside of the potential allergic reaction from contrast materials, CT also uses



ionizing radiation with an associated cancer risk. The risk is proportional to the amount of radiation and to the life expectancy of the patient after exposure. Therefore, patients with multiple exams and young patients have a higher cancer incidence risk. The cancer risk for females from the same amount of radiation is greater than for males, especially at younger ages.<sup>10</sup> Additionally, CT exams may require a much higher amount of radiation than radiography due to the increased contrast resolution requirements. To place this risk in context, a CT scan of the entire body can subject the patient to the radiation equivalent of 2,000 chest x-rays.<sup>10</sup> Because of the relatively high doses of ionizing radiation produced by CT imaging systems, it is important to focus on appropriate use, and make sure that CT scans are not ordered under conditions that could be more appropriately handled with conservative treatment.

### DXA / Bone Densitometry

Dual-emission X-ray Absorptiometry, or DXA, is a form of x-ray imaging technology that is used to measure bone mineral density (BMD). To produce images, the DXA scanner sends out two separate x-ray beams with distinct energy levels, which are aimed at the bones being examined. One beam is absorbed mostly by bone and the other by soft tissue. By comparing the two images, soft tissue can be subtracted from the total, enabling doctors to estimate the mineral density of the patient's bones.<sup>11</sup>

The DXA scan is typically used to diagnose and monitor the onset or progression of osteoporosis, which causes bones to become thinner and more fragile due to the gradual deterioration of bone mass. DXA can also be useful in predicting the likelihood of developing fractures. These scanners come in two main classes: Central and Peripheral. Central DXA scanners are usually large, fixed machines in hospitals and physician's offices, and are used to measure bone density in the hip and lower spine. Peripheral DXA devices are small and portable, and are used to measure density in fingers, hands and feet.<sup>11</sup>

Even though DXA scanners use x-ray beams to generate images, the amount of radiation used is extremely small—only a fraction of a standard chest x-ray, and less radiation than one would receive



on a transcontinental airplane flight. While DXA scanners have a limited range of uses, they are relatively inexpensive, easily accessible, and pose very little radiation risk. Therefore, they are considered one of the best methods available for bone density measurement; unfortunately they do not offer the benefit of imaging other body systems.

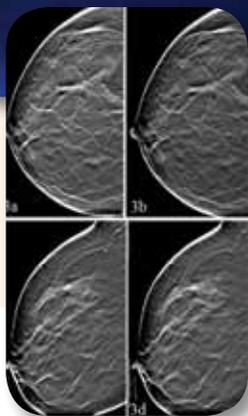
## Mammography

Through methodology similar to radiography, mammography uses low energy x-ray radiation to examine breasts for cancerous growths and tumors. In the examination, the breast is compressed to produce an even thickness of tissue, which improves image quality and reduces patient radiation dose. This prevents small abnormalities from being concealed, and ensures that all tissue can be fully visualized. Radiation is then focused on the breasts, with x-rays penetrating different densities of tissue in varying

amounts, highlighting dense abnormalities that may prove cancerous.<sup>12</sup> Considered to be one of the most effective methods available for diagnosing breast cancer, the American College of Radiology recommends annual mammography screenings of women over the age of 40.<sup>10</sup>

Typically, mammography is ordered to detect and diagnose breast abnormalities such as cancerous growths in women. Employed principally to locate tumors and assist in telling the difference between noncancerous (benign) and cancerous (malignant) diseases, mammograms can assist doctors in determining whether or not biopsy or surgery is necessary.<sup>12</sup>

Currently, mammography is the best screening tool for breast cancer detection. Since 1990, mammography has reduced the breast cancer death rate in the United States by 30 percent. Unfortunately, it is not a perfect imaging technique, with 5 to 15 percent of tests requiring further testing due to false positives.<sup>12</sup> As with all other diagnostic radiology involving ionizing radiation, there is an increased risk of cancer associated with the exam. However, special care is taken to use the smallest radiation dose possible while producing the clearest images for analysis.



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## Nuclear Medicine

Nuclear medicine works in a manner somewhat different than most other imaging modalities that involve the use of ionizing radiation. Rather than directing a beam of x-radiation through a patient, a radioactive material known as a radiotracer is positioned inside the body. The resulting radiation emitted by the radiotracer is used to analyze important body functions by monitoring the use of oxygen and glucose that has been labeled with the radiotracer, or by monitoring the distribution of the radiotracer within an area of interest. Because cells and tissues use oxygen and glucose to carry out their metabolic functions, the radiotracer will gather in areas of increased metabolic activity, allowing physicians to produce images of both the structure and function of organs and tissues within the body. Depending on the type of examination, the radiotracer is either swallowed, injected into a vein, or inhaled as a gas and eventually accumulates in the organ or the area of the body being examined.<sup>14</sup> Once inside the body, radiation is released from the radiotracer, which is then detected by either: (1) gamma cameras for both planar images and Single Photon Emission Computed Tomography (SPECT) acquisitions; or (2) Positron Emission Tomography (PET) scanners.



***Gamma Camera & Single Photon Emission Computed Tomography (SPECT):*** Gamma cameras work by measuring the gamma rays emitted by the radiotracer. As the radioactive isotope in the patient's body decays, it emits gamma rays, which are analyzed to produce computer-generated images. The gamma camera can produce two-dimensional planar images, or can be operated in SPECT mode to generate three-dimensional images of internal anatomy and metabolic function. While typically shown as cross-sectional slices through the body of the patient, the SPECT images can be arranged as needed to provide views desired by healthcare professionals.<sup>14</sup> SPECT can also be coupled with CT scanners for enhanced imaging.

***Positron Emission Tomography (PET):*** While gamma cameras monitor gamma radiation directly, PET scans measure annihilation photons resulting from positrons that are emitted by the radiotracer. These positrons travel a short distance and annihilate with electron-producing annihilation photons in roughly opposite directions. The PET scanner measures the coincident emissions of these "annihilation photons," allowing for higher resolution images that reveal the metabolic changes that occur in an organ or tissue. Today, PET scans are sometimes executed on machines that combine both PET/CT and/or PET/MRI technology. Scans produced by these imaging systems have been shown to provide more accurate results than the two of them separately.<sup>13</sup>

PET and SPECT are two of the most common forms of nuclear medicine and can be used for a wide variety of purposes, including the diagnosis of cancers, heart disease, and other abnormalities. They are especially useful for understanding the functional processes of internal organs and tissues, highlighting areas that may not be functioning properly due to cancer or illness.<sup>13, 14</sup>

For some diseases, nuclear medicine studies can identify medical problems at an earlier stage than other diagnostic tests. Nuclear medicine procedures often provide information unattainable by using other imaging techniques, because nuclear medicine

studies can provide information specifically about a body system's metabolic function. However, there are drawbacks to using this modality. While most other tests can be ordered and produced over short time periods, nuclear medicine has a longer preparation time than other modalities. Because it can take anywhere from a few minutes to several days for the radiotracer to accumulate in the part of the body being examined, the imaging itself may take up to several hours to perform. Nuclear medicine is not generally practical for emergency care or situations where immediate testing is required.

## Diagnostic Ultrasound

Diagnostic ultrasound, or sonography, is a non-invasive medical imaging modality that involves exposing the body to high-frequency sound waves, instead of ionizing radiation. A transducer produces images by sending sound waves into a patient's body, and receiving echoes back from various internal body structures. The images produced provide information about the size, shape and consistency of anatomical structures. Computer measurements assess variations in the returning sound, creating real-time images of the motion of internal organs.<sup>15</sup>

Ultrasound is routinely used to monitor the progression of pregnancy, but can also be used for a wide variety of other medical purposes. Doppler ultrasound, used for the imaging of blood vessels (angiography), measures the direction and speed of blood cells as they move through vessels in order to generate an image of the cardiovascular system. Ultrasound-guided breast biopsy, another common application of ultrasound technology, enables surgeons to watch their actions on a monitor while

they are removing tissue samples. Despite providing relatively poor resolution, ultrasound is still an effective method of detecting tumors throughout all areas of the body.<sup>15</sup>

Because ultrasound relies on the use of sound waves rather than ionizing radiation, there are no risks to the patient. The accuracy of the image produced however, relies heavily on the operator, and ultrasound images do not provide the same level of clarity that is produced by some of the advanced diagnostic imaging modalities such as MRI, CT, or nuclear medicine. Additionally, ultrasound equipment over ten years old without software and/or hardware upgrades has been proven to be less effective. Therefore equipment age and upkeep is important. Because of the absence of radiation risk, ultrasound should always be considered as a potential imaging option for soft tissue studies before resorting to modalities that carry a risk of inducing a malignancy.

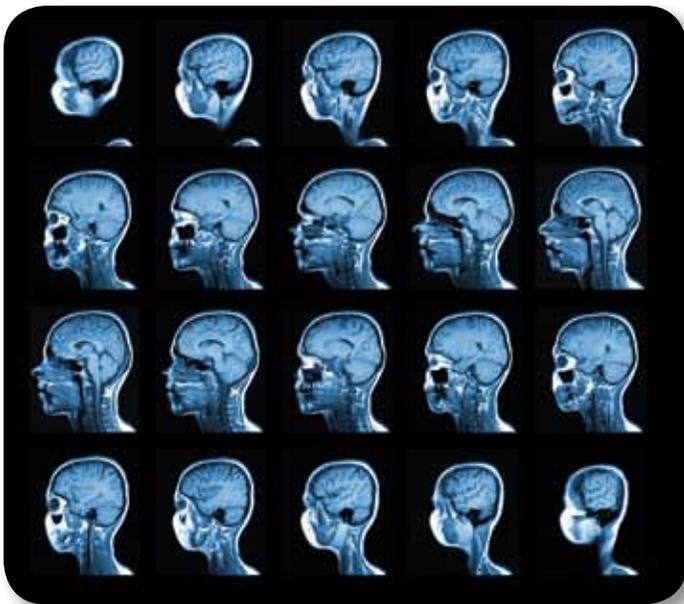


## Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) allows physicians to better visualize soft tissue without the use of ionizing radiation, therefore reducing the need for invasive surgeries and eliminating the risk of introducing a malignancy. MRI imaging systems work by creating a powerful magnetic field around the area of interest to align the water molecules in a patient's body. A radio frequency (RF) pulse is then applied, which alters the alignment of the water molecules, causing them to release a distinct energy signal. An RF antennae collects the emitted signals, which are analyzed to produce computer-generated two- or three-dimensional images of organs, tissue and bone, which can be studied from various angles and cross-sections.<sup>16</sup>

MRI provides very clear contrast between different types of soft tissue, making it one of the best techniques available for imaging soft tissue of the body. It is often used to detect tumors, diagnose heart and vascular disease, and search for abnormalities in muscles, organs, and the brain. One of the most useful features of MRI procedures is that they allow physicians to clearly differentiate between diseased tissues and healthy areas, without requiring a biopsy.<sup>16, 17</sup>

In addition to being an exceptionally safe test, when properly performed MRI examinations are also very thorough and effective, often identifying problems otherwise overlooked by other types of scans. While they typically cost more and may take more time to perform than other imaging studies, MRIs produce some of the highest soft tissue contrast resolution images possible, without exposing the patient to harmful ionizing radiation. As with any imaging modality however, potential risks exist. Because MRI procedures use a very strong magnet, metal implants such as surgical screws, and electronic devices such as pacemakers may pose a danger to the patient if they are placed in the magnetic field. Additionally, some MRI exams may utilize contrast agents, to which the patient may be allergic.

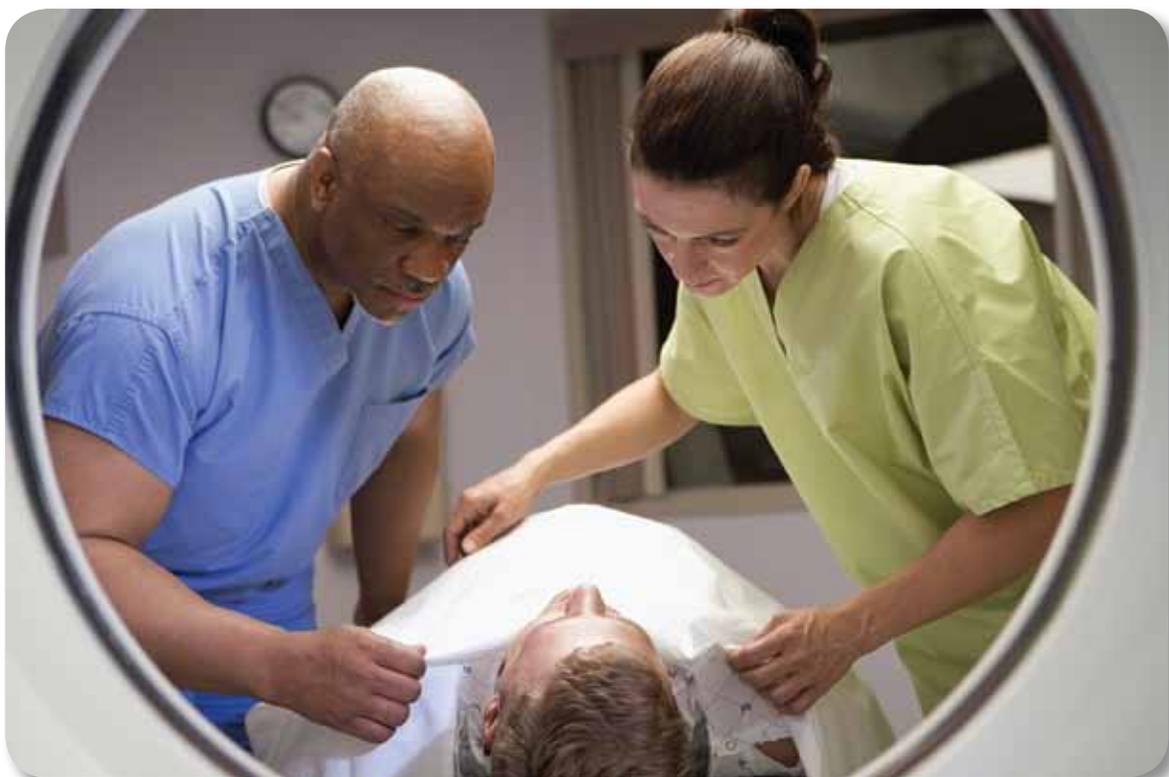


## Conclusion

While the various forms of imaging technology provide us with the tools to image anatomy and detect diseases in ways previously only imagined, there is also a great risk of over-radiation that can result from the inappropriate or unnecessary use of these procedures. Because of the potential risks associated with every procedure, it is important to be aware of what tests are appropriate and under what conditions. The decision to order diagnostic imaging should always be driven by medical best practice; weighing the potential benefit against the potential risk. Employing this risk/benefit analysis may deem imaging studies unnecessary until other medical options are explored. When an imaging study is considered beneficial, the quality of the image and the care taken to perform the study correctly are essential.

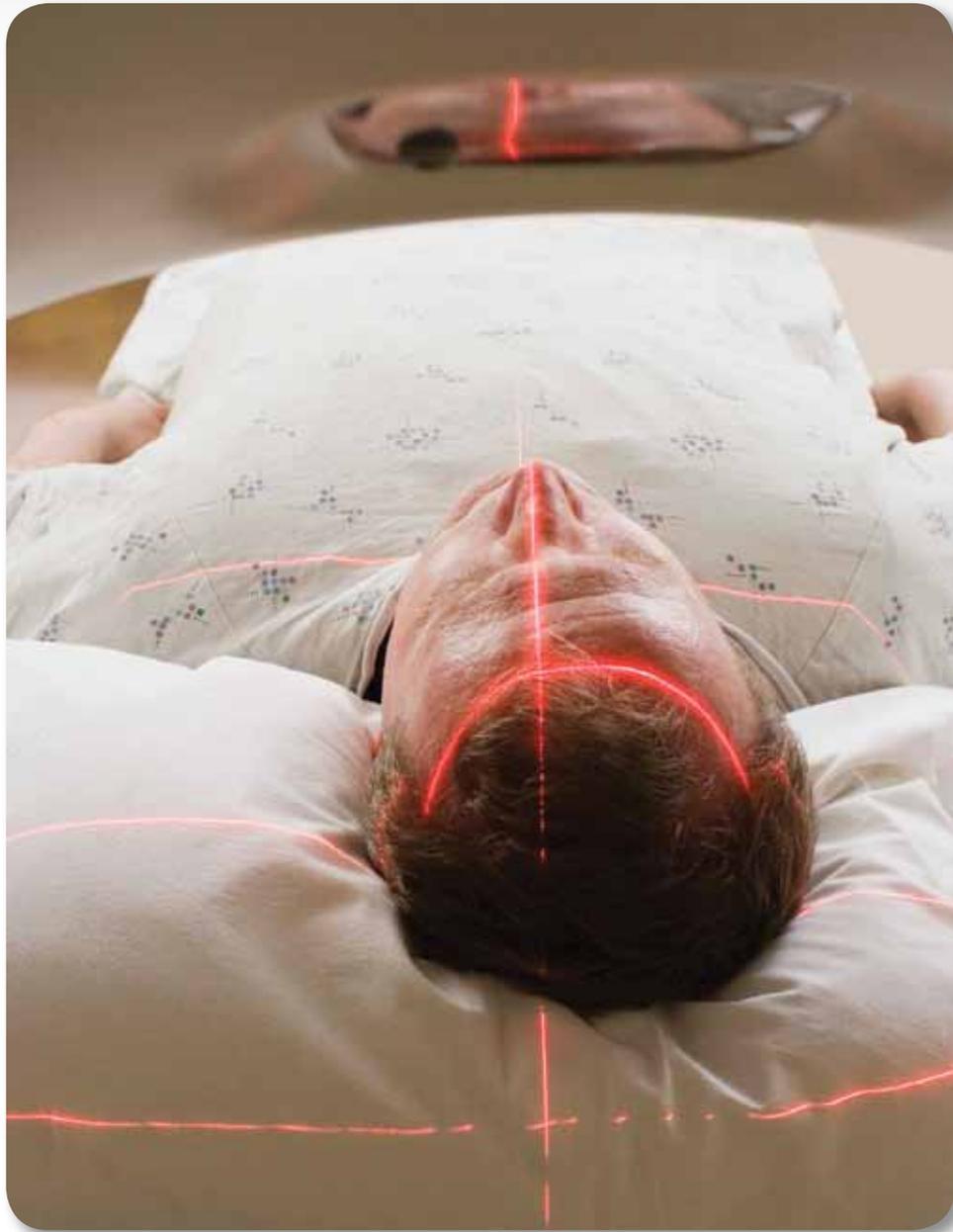
The overall approach to radiation safety is the concept of “as low as reasonably achievable,” or ALARA, with the goal of all imaging procedures being to keep the radiation dose as low as possible while providing a high-quality diagnostic image. Special care must be taken when imaging children, since radiation dose is amplified and cumulative over a lifetime. Finally, expert interpretation by a radiologist or highly trained specialist leads to a meaningful diagnosis that a clinician can use to determine a treatment plan, or rule out certain conditions.

This RadSite overview is intended to provide a general source of information to the public about the medical imaging modalities available, their appropriate use, and the risks/benefits of each. For more information, visit [www.RadSiteQuality.com](http://www.RadSiteQuality.com).



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## About RadSite™

Founded in 2005, RadSite's mission is to promote quality-based practices for imaging systems across the United States and its territories. RadSite has certified over 20,000 imaging facilities covering at about 50,000 imaging systems. RadSite's certification and accreditation programs help assess, track and report imaging trends in an effort to enhance imaging procedures and outcomes. RadSite also offers educational programs, publishes issue briefs, and underwrites research on a complimentary basis to raise awareness of patient safety issues and to promote best practices. The organization is governed by an independent board and committee system, which is open to a wide-range of volunteers to ensure transparency and accountability. RadSite is expanding its activities and resources to serve patients, providers, payers, government agencies, and other stakeholder groups. To learn more about RadSite, please visit our website at [www.RadSiteQuality.com](http://www.RadSiteQuality.com), or contact us at (855) 440-6001 or [info@radsitequality.com](mailto:info@radsitequality.com).

