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Imaging Professions in the U.S.
An Overview as of 2004

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PREFACE

The field of medical imaging has changed dramatically over the past quarter century. It has been transformed from essentially a single medical specialty (radiology) dealing with static x-ray images used exclusively for diagnostic purposes, into a field with multiple imaging technologies that include cross-sectional and three-dimensional images, dynamic images of physiological processes, and a growing number of therapeutic treatments.

This report is an introduction to this dynamic field and the workforce that supports it. In addition to introducing some of the important imaging technologies and processes, it also presents basic data on the several health professions that comprise the field. The report is not meant to be a definitive discussion of the field of medical imaging, but rather an introduction and overview that can help planners and policy makers to understand the dimensions of the field and the kinds of transformations to expect in the future.

A glossary of terminology is provided in Appendix B to help those not familiar with the names and labels of the proliferating array of imaging tools and technologies. In addition, a bibliography is provided at the end of the report for readers interested in finding our more about the field of medical imaging.

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EXECUTIVE SUMMARY

Medical professionals providing imaging services are likely to be in high demand in both the near term and in the foreseeable future. Increasingly capable technology, promising research related to molecular biology and the human genome, and the development of rational therapies and treatments delivered using molecular imaging techniques suggest that demand for expert imaging professionals will continue to grow for the foreseeable future.

Although imaging technologies and professionals are likely to become a larger share of the total health care system, it is unlikely that this expansion will be simply more business as usual. The competencies required of professionals working in imaging are almost certain to change—perhaps dramatically—as the technologies evolve, applications of imaging techniques to different body systems become more sophisticated, and as the skills required by imaging professionals are defined more precisely.

The current practice of radiology requires expertise in all imaging modalities and in all body systems. Maintaining expertise in all areas of radiology will be an increasingly difficult challenge for imaging professionals in the future, as imaging tools and techniques increase in capability and make disease processes at the cellular level more discernible. As a result of this evolution in imaging technology, some imaging professionals may become generalists, gatekeepers to more specialized diagnostic studies and treatment applications performed by smaller cadres of imaging specialists trained in the latest tools and techniques.

As the number of imaging modalities increases, the source materials diversify, and the images generated become more detailed and precise, the skills and knowledge required to interpret and understand the resulting images will increase dramatically. This is likely to encourage sub-specialization in a number of related medical fields, promoting the integration of imaging protocols into many medical specialties. While it is conceivable that imaging professionals/ radiologists might sub-specialize in a particular organ or body system, it is also possible that expansion of imaging will create subspecialties in imaging in other fields of medicine such as neurology, cardiology, oncology, and endocrinology.

The continued evolution in imaging will require substantial resources devoted to research and development in a number of scientific fields including molecular biology, radiochemistry, health and medical physics, and computer science. It will also require academic medical researchers with an interest in advancing the science of imaging. In an environment where resources are becoming more limited and in which demand for health care services by an aging population may necessitate some rationing of health resources, continued development of high cost imaging technologies may slow.

It is apparent that modern imaging technologies in the hands of competent professionals have the capacity to improve health outcomes for patients with many types of illnesses and injuries. Earlier diagnosis of disease, ongoing monitoring of treatment protocols, and therapeutic applications in imaging have improved the prognosis for patients in many medical disciplines. The important contributions of imaging to quality health care are increasingly apparent and its place in the health care landscape seems secure.

A. Scope of this Report

This report is a preliminary analysis of existing data about imaging professions in the U.S. It is designed to provide an introduction to this increasingly important specialty area to interested planners and policy makers at the national, state, and local levels.

The report provides a variety of different kinds of information about the key professionals in the imaging workforce, physicians, and technologists. It also identifies some of the key organizations across the U.S. involved in promoting and monitoring the various professions. The report is not meant to be an exhaustive or definitive discussion of medical imaging, but rather an introduction and overview that can help interested planners and policy makers to understand the dimension of the field and the kinds of transformations to expect in the future. It also provides a useful bibliography of reports, articles, and data sources that readers can tap into themselves for additional information and insights.

B. Key Findings

The next several pages present the key findings and conclusions of this report, based on the discussion in the body of the report. They are not meant to be exhaustive, but rather to suggest to planners and policy makers the key trends and issues expected to be faced by those designing health care programs and making resource allocation decisions in health care in the future. The findings and conclusions are presented in several broad categories that reflect the structure of the body of the report.

1. Imaging Technologies

Much of the impetus for developing new imaging modalities is driven by rapidly evolving imaging technologies. Some of the important trends are summarized below.

- Imaging modalities, coupled with advances in science, are transforming the paradigm of diagnostic imaging and imaging treatment protocols for patients. Equally important, the evolution of imaging technologies will continue for many years into the future.
- Today, imaging technologies are substantially more diverse and more capable than they were even a decade ago. "Open source" imaging, which involves cameras that detect emissions from patients who have received one of a number of radioactive agents, is an increasingly important supplement to traditional "closed source" imaging, like x-rays, which involves images created by detecting radioactivity that has been transmitted through the patient by the camera.
- Contemporary imaging equipment uses computing technologies capable of eliminating background noise, correcting attenuation, and calibrating dosage of radioactive exposure to enhance patient safety. Complex algorithms integrate images obtained at brief time intervals (as short as a second) to produce three-dimensional images that significantly enhance our understanding of anatomy and function in the human body.
- The newest generation of imaging equipment called PET (positron emission tomography) technology is an open-source application with considerable capability. The rotating gamma camera detects thousands of gamma ray emissions per second from a patient who has ingested a radiotracer. The rate of metabolism of the radiotracer is different in diseased tissue and healthy tissue, permitting disease processes and progression (actual anatomic function) to be measured by these cameras in real time. This application will not only improve diagnosis but will permit new protocols in radiopharmaceutical therapy.
- Not only is the technology for creating the images evolving but the images themselves are also different. PET technology and SPECT (single photon emission computed tomography) permit three-dimensional imaging of all or part of the human body using

algorithms that reconstruct the various views obtained by the camera. These images are substantially different from images obtained from planar imaging where the camera remains in a fixed position. Both PET and SPECT are being fused with CT technology to permit the combination of cross sectional anatomic imaging with functional imaging permitting improved diagnosis and treatment.

- Applications of a variety of new technologies are expanding dramatically as discoveries in molecular biology continue. An example of current research in molecular science is the use of radiotracers attached to stem cells called "reporter genes". "Reporter genes" follow the progress of the stem cells through the body. Imaging technology is used to determine whether these reporters reach their ultimate destination. The growth of the stems cells can also be monitored over time using imaging to find these reporter genes.
- An important feature of some of the new imaging modalities, besides expanded capability, is the use of source materials that are not radioactive. Magnetic resonance imaging (using magnetism and radio waves), sonography (using sound waves), optical imaging and luminescence (using light waves) are examples of technologies that use neither open-source nor closed-source radioactivity to produce images.

2. The Imaging Workforce

Although this report discusses "imaging professionals," it is important to note the caveat that data are currently available only for "traditional" imaging professionals. Thus, the information presented in this report focuses primarily on diagnostic radiologists, radiologists, and nuclear medicine physicians, and radiologic technologists and nuclear medicine technologists. Several observations about these professionals are offered below.

Imaging Physicians

- Over 30,000 imaging physicians were practicing in the U.S. in 2003. This represented only 4% of physicians practicing in the U.S.
- Radiologic physicians are distributed across the U.S. with a high occurrence of these specialists in the Northeast. The Southwest has many fewer radiologic physicians per 100,000 population than other areas of the country.

- Radiologic residents are also distributed widely across the U.S. The highest concentration of residents per million population is in the Northeast and the North Central areas of the country with few to no residency programs in the Northern Plains.
- The number of physicians in each of the major imaging specialties (radiology and diagnostic radiology, nuclear medicine, radiation oncology) has generally increased since 1980.
- The number of new entrants to diagnostic radiology has remained fairly constant over the last decade with a slight dip around 2000. This suggests a fairly stable supply of diagnostic radiologists for the near future. However, the actual supply will depend heavily on the number of physicians in the age cohorts over 55 that retire or depart the profession in the coming decade.
- The percentage of imaging specialists who are female has increased in all imaging specialty areas, although the increase among nuclear medicine physicians has been smaller than for radiology, diagnostic radiology, and radiation oncology.
- The percentage of imaging specialists who are international medical graduates (IMGs) has declined substantially in all radiology specialties except nuclear medicine since 1985. The declining percent of IMGs suggests an increasing interest among U.S. medical graduates in the field.
- Demand for images is presently driven in large part by the increasing capabilities of imaging technologies. As capabilities increase and applications to a number of body systems are perfected, demand is expected to increase further in the future.
- Both the growth rate of the population and the aging of the population affect demand for imaging services. Over the last decade, there has been a 4.5% annual increase in the number of procedures performed by radiologists with a concomitant annual increase in complexity of 1.75%.
- This growth has generated a 6% increase in imaging relative value units billed annually. However, there has only been a 1.5% annual growth in the number of radiologists over the same period. These figures, reflecting increased utilization, have led to projection of a deficit of 10,000 to 15,000 radiologists by the year 2015.

- Federal regulation of radioactive substances is an important issue for imaging professionals. The Food and Drug Administration and Atomic Energy Commission in particular impose stringent requirements on the practice of nuclear medicine, which can have a significant impact on the future supply and demand for imaging services in the U.S.
- As imaging technologies become more capable, specialists other than traditional imaging physicians are using imaging in their day-to-day medical practices. The proliferation of imaging technologies in outpatient settings like physician offices and clinics and the use of imaging technology by other specialties such as cardiologists and oncologists could potentially suppress demand for traditional imaging professionals, particularly if economic incentives remain high.

Imaging Technologists

- The number of radiologic procedures provided to patients is large and growing. Over 300 million imaging procedures are provided annually to seven out of ten Americans
- The technologists who operate the various imaging equipment are an important part of the workforce providing imaging services. Radiologic technologists working in any or all of the multiple radiology modalities are among the largest group of allied health professions in the U.S. numbering a quarter of a million professionals. Radiologic technologists are trained and certified in three primary modalities: radiology; radiation therapy; nuclear medicine; and beginning in January of 2006, sonography.
- The Bureau of Labor Statistics indicates that there are approximately 250,000 jobs for imaging technologists in the U.S. Technologists work in general and medical surgical hospitals, other hospitals, offices of physicians, outpatient care centers, and medical and diagnostic laboratories as well as a variety of other health settings. The average mean annual salary varies by specialty, with nuclear medicine technologists having the highest average salaries at over $61,000 per year.
- Technologists may have multiple certifications. In 2005, there were approximately 258,000 certified imaging technologists in the U.S. holding over 350,000 certifications in a range of specialty areas.

- Education programs for technologists vary in content and in length. They include one-year certificate programs, two-year certificate and associate degree programs, and four-year bachelor’s programs. Generally, radiologic technologist education programs are two-year certificate/associate degree programs, while radiation therapy and nuclear medicine education are generally bachelor’s degree programs.
- The majority of states require licensure for radiologic technologists, but there is wide variation in who is required to be licensed. In some states all technologists must be licensed, in some radiologic technologists must be licensed, but not nuclear medicine technologists, and in some others only technologists using specific modalities like mammography must be licensed. A Federal bill (the CARE bill) has been proposed which is expected to redress this variation.
- The Bureau of Labor Statistics anticipates employment growth for all imaging technologists. Demand for imaging technologists is expected to increase faster than average through the year 2012. This increased demand will be driven by several factors: the aging of the population; increased demand for diagnostic imaging and therapeutic applications of imaging technology; the need to replace departing and retiring workers in the field; and technological innovation that will increase demand.
- It has become common practice for health care providers to contract with radiologic group practices not directly employed by the provider to interpret studies. As a result, a single radiologic physician group might conceivably read and interpret studies for a number of health care institutions. This practice is supported by computer systems that permit interpretation of images at a distance from the site of acquisition. Technologists, however, must be on-site with the machines to provide services directly to patients. Therefore, their pattern of employment is somewhat independent of the physicians with whom they work.

I. INTRODUCTION

The area of medicine known as radiology has progressed over a generation from a limited diagnostic specialty to an area of medicine now viewed as having both significant diagnostic and therapeutic capabilities. Much of this change has occurred because of improved technology and innovative applications that have expanded the capability of imaging professionals. These enhanced capabilities have increased demand for services and thus, demand for professionals who operate the machines and interpret the outputs.

As evidence of growth in imaging, the Medicare Payment Advisory Commission (MedPAC) reported that the highest growth in volume in physician services reported in 2001 was in the imaging sector. The Commission observed a 20% increase in nuclear medicine, CT, and MRI procedures from the previous year. In 2002, the MedPAC reported that imaging services represented 25% of all Medicare payments for hospital outpatient services. This was second only to payments for outpatient procedures (49%) [Mitka, 2005].

This expansion of imaging services has not occurred without some growing pains. Health care providers are concerned about the high costs of imaging equipment and the availability of capable and competent professionals to provide imaging services. The imaging professions are concerned with competency standards and basic and continuing education for currently practicing and new physicians and technologists who work with these new modalities. The government is concerned about use of imaging technology by a variety of non-imaging professionals, as well as about self-referral, marketing directly to patients, defensive medicine, medical liability, repetition of studies, and regulation of the quality of imaging equipment [Mitka, 2005]. As imaging technologies proliferate in the future, these concerns will only grow.

The overview that follows introduces the two key elements of modern imaging specialties: the technologies and the professionals that use them.

II. IMAGING TECHNOLOGIES

Historically, radiologists offered basic X-ray and fluoroscopy services to patients using a limited number of machines capable of producing two-dimensional images. This original imaging equipment used film technology that required development, handling, and storage and was not always capable of producing high-resolution images.

In contrast, digital images produced by a number of different imaging modalities are virtual, real time images of excellent quality and resolution. In facilities with appropriate computing and data transmission capabilities, these images are instantly available to authorized users both in real time and from digital archives. Generally, the newer imaging applications are not intrusive to patients while still providing detailed information about anatomy and function. Imaging studies are, therefore, replacing intrusive diagnostic procedures in many areas of medicine. Exploratory surgery is an example of the type of procedure that might be avoided through use of some of the newer imaging technologies. Demand for diagnostic imaging has increased substantially precisely because of its ability to describe disease in a much less invasive manner than traditional techniques [Mitka, 2005].

In the past, many of the studies performed by radiologists produced two-dimensional, planar images such as X-rays, but contemporary CT and MRI machines provide cross-sectional, three-dimensional images. Radiologists often image a patient through use of “closed-source” applications in which the physical source of the radioactive material creating the image is contained in the machine. Radiologists are trained to use closed-source X-ray modalities like mammography as well as cross-sectional modalities like CT (also closed-source) and MRI, and other non-radioactive, closed-source modalities like sonography.

“Open-source” means the radioactive material is not contained in the machine but is found in a radiotracer administered to the patient. The radioactive material selected depends on the kind of imaging study being performed. Although some imaging in radiology requires the patient to ingest a contrast agent (i.e., a barium study), most studies require only the passive participation of a patient. Nuclear medicine physicians generally provide “open source” imaging. However, radiologists and other medical specialists may also provide these services.

Radioactive materials known as radiotracers or radiopharmaceuticals are injected into, ingested, or inhaled by patients (or animals in research). Then the patient is imaged by gamma cameras that collect, respond to, and record the radioactive emissions from the body. The particular anatomical area being studied determines the type of media and/or radionuclide that is used. Gamma cameras detect emissions, locate the ingested material, and produce images that describe the location, degree of absorption and metabolic rate of the substance. These studies are used extensively to study disease process and to evaluate efficacy of treatment protocols.

Today, imaging media and the applications for imaging technology are substantially more diverse and more capable than they were even a decade ago. An in-depth discussion of all the latest imaging technologies and applications is beyond the scope of this paper, but it is important to understand that capable imaging modalities, coupled with advances in science, are changing the paradigm of diagnostic imaging and imaging treatment protocols for patients, and will continue to do so for many years into the future. The following section describes some of the scientific advances in imaging.

A. Alternative Source Materials

An important feature of the new imaging modalities besides expanded capability is the use of source materials that are not radioactive. Magnetic resonance imaging (using magnetism and radio waves), sonography (using sound waves), optical imaging and luminescence (using light waves) are examples of technologies that use neither open nor closed-source radioactivity to produce images. Although radioactive material is still a significant medium in imaging, research and development of a variety of modalities has enhanced and broadened the options for studies available to patients using other physical source material.

B. Advances in Computing Science and Imaging Equipment

Developments in computing have led to change in the imaging environment. The enhanced capability of imaging modalities is remarkable. Contemporary imaging equipment uses computing technology that is capable of eliminating background noise, correcting attenuation, and calibrating dosage of radioactive exposure to enhance patient safety. Complex algorithms integrate images obtained at brief time intervals (as short as a second) to produce three-dimensional images that significantly enhance our understanding of anatomy and function in the human body.

Digital images are now stored in powerful archiving systems. Digital archives also increase the availability of images to referring and other specialty physicians by increasing access across interoperable computing networks. Computer aided detection and diagnosis equipment is now being tested and implemented in radiology practices to supplement/augment the interpretation of radiologists, particularly in mammography. This technology is designed to improve detection of disease and ultimately to enhance both the sensitivity and specificity of the studies that are performed.

C. PET Technology *(Or Modern Technologies)*

The newest generation of imaging equipment called PET (positron emission tomography) technology is an open-source application with considerable capability. A patient receives a radioactive substance known as a radiotracer or radiopharmaceutical by injection or ingestion and is then positioned under a rotating gamma camera. Gamma cameras detect thousands of gamma ray emissions per second as the body metabolizes the radiotracer. The rate of metabolism of the radiotracer in diseased tissue varies from the metabolism in healthy tissue permitting disease process and progression (actual anatomic function) to be measured by these cameras in real time. This technology and SPECT (single photon emission computed tomography), permit three-dimensional imaging of all or part of the human body using algorithms that reconstruct the various views obtained by the camera. The images that are produced are substantially different from images obtained from planar imaging where the camera remains in a fixed position.

Although these technologies are relatively new, they have been widely embraced in a number of areas of medicines for their important capability to monitor and measure anatomical function. Market experts site high sales of this equipment to a variety of providers including many outpatient clinics and physician offices [IMV, 2003]. The use of PET increased by 35.6% in 2002 and is expected to continue to increase over the near future [European Association for Nuclear Medicine].

A second generation of this technology has been introduced to the market and is creating a new paradigm in imaging. These new machines, called PET/CT or SPECT/CT, combine the capability of PET or SPECT technology to image function with the capability of CT technology to view anatomy. The anatomical and functional information that is provided is critical to diagnosis of disease and evaluation of treatment protocols. Although this technology is often used for diagnosis, fusion hardware and software technology is increasingly being used for therapeutic applications. Eventually widespread use of fused images in advanced radio-immunotherapy for a wide range of body systems is expected as applications in molecular imaging progress.

The potential expanded applications for these technologies to several areas of medicine have piqued interest in learning its use from a number of medical specialties. Chief among the specialties embracing PET technology are cardiologists who view this modality as a perfect partner to practice in cardiology. Cardiac perfusion studies use less intrusive means than typical interventional studies making these nuclear studies the preference of doctors and patients alike. These studies using SPECT and PET are now widely performed as the gold standard in cardiac diagnostics. Applications in oncology are also expanding as it becomes obvious that these technologies provide significant opportunity to monitor efficacy of cancer treatment protocols.

D. New Applications

Applications for imaging protocols are expanding as discoveries in molecular biology continue. The use of radiotracers attached to stem cells, called “reporter genes,” is being investigated by researchers working to develop stem cell therapies [Carrington, 2005]. By tagging precursor cells that are injected in the body, researchers can follow the progress of those cells through imaging to determine whether they reach their ultimate destination and to monitor the growth of the cells over time. This work is somewhat limited by the short half-life of available radiotracers but research suggests that this is a promising technique in gene therapy and in immunotherapy for a number of areas of medicine including applications in treating cancer and acute myocardial infarction [Carrington, 2005].

Imaging is also being used in pharmaceutical research with transgenic mice. Although present FDA protocols for approval of new pharmaceuticals favor endpoint research in which tissue is dissected and examined, optical imaging and nuclear medicine imaging show promise for advancing pharmaceutical research and even speeding the drug development process [Ward, 2005]. Use of imaging applications in pharmaceutical research permits longitudinal studies of mice through multiple concurrent imaging studies showing the actual effects of the pharmaceutical on a mouse in real time. Radiotracers have no biological effect on the subject so any changes that occur can be directly attributed to the pharmaceutical in testing. Use of imaging in pharmaceutical research is gaining interest particularly because it is both more efficient (use of fewer expensive transgenic mice) and also more ethical (reduces the number of animals that must die during research).

III. THE IMAGING WORKFORCE

As a result of the variety of advances in imaging technology and applications, using the terms radiologist and radiologic technologist in a current discussion of imaging professionals and modalities is too limiting. To appropriately discuss the prevailing imaging technology and embrace the broader professions working in the field, the term "imaging professionals" is used in this paper. This is a more accurate description of these workers and points to the variety of backgrounds and training programs that are possessed by the physicians, technologists, and scientists using imaging technology.

> **Imaging physicians** are the key health professionals responsible for the application of imaging procedures for patients needing diagnostic and therapeutic services. Typically, patients are referred to them by primary care or specialist physicians requiring x-rays or other images to help diagnose injury or illness. The one role reserved for the physicians in all kinds of imaging studies is the interpretation of the image in a clinical context and the diagnosis of the problem under scrutiny.
>
> **Imaging technologists**—including radiologic technologists, nuclear medicine technologists, and others—have emerged in recent years as essential helpers of physicians. They are especially important in the process of capturing the images with the appropriate cameras and technologies. They unburden the physicians of the time consuming and technical tasks of prepping patients, actually capturing the images, and preparing and labeling the images for subsequent interpretation and storage.
>
> **Imaging scientists**, though seldom actually involved in regular clinical work, are a critical component of the imaging workforce. They are involved in such tasks as calibrating and certifying imaging equipment, conducting research to extend the utility of existing imaging tools to new applications, and providing technical support in situations where creative clinical work is being performed by the physicians and technologists.

A. Imaging Physicians

Although discussing workforce requires us to use the broader term "imaging professional," we must also mention the very practical caveat that the data available on imaging professionals is focused on those who traditionally reside in that category. Therefore, the information presented in this report will focus primarily on diagnostic radiologists, radiologists, and nuclear medicine physicians, radiologic technologists, and nuclear medicine technologists. (Radiologist and diagnostic radiologist as terms are used interchangeably in this paper. Certification in radiology by the American Board of Radiology ended in 1996 and diagnostic radiology is now the available certification). Information about other professions using these modalities, especially cardiologists and oncologists, is still quite limited since their more extensive use of imaging technology has been quite recent. They are therefore, omitted from the following data analysis. Their impact on imaging, however, should not be ignored. Stakeholders in the imaging environment are struggling to understand this phenomenon and to evaluate these trends.

1. Current Practice

The American Medical Association collects data from physicians on their medical specialties. The data for the year 2003 indicates that there were over 30,000 imaging professionals practicing in the United States (Table 1).

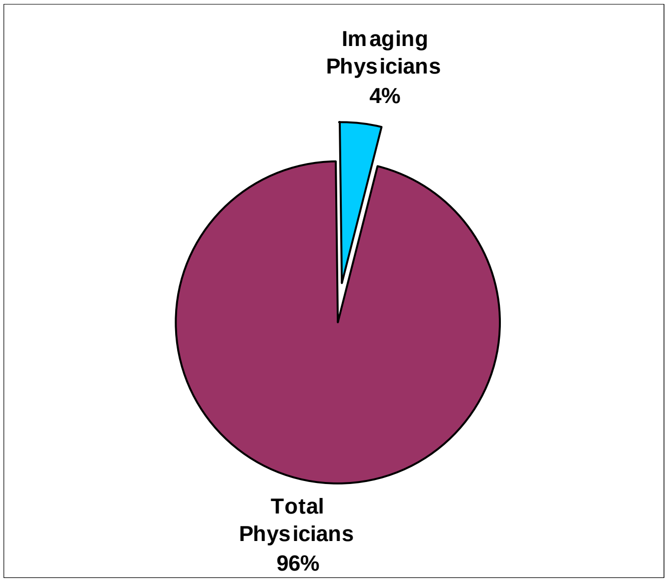
Table 1. Numbers of Physicians Specializing in Imaging, 2003

Imaging Specialists, United States, 2003	Total Physicians
Abdominal Radiology	2
Diagnostic Radiology	23,345
Endovascular Surgical Neuroradiology	1
Musculoskeletal Radiology	25
Neurology/Diagnostic Radiology/Neuroradiology	19
Neuroradiology	1,360
Nuclear Medicine	1,481
Nuclear Radiology	143
Pediatric Radiology	635
Radiation Oncology	4,272
Radiological Physics	1
Radiology	5,492
Vascular and Interventional Radiology	1,285
Total Imaging Professionals	**38,061**
Total Physicians, U.S., 2003	**871,535**

Source: AMA, 2005

As a proportion of all physicians in the U.S., the number of physicians who describe themselves as imaging specialists is a small proportion of physicians practicing in the U.S. (Figure 1).

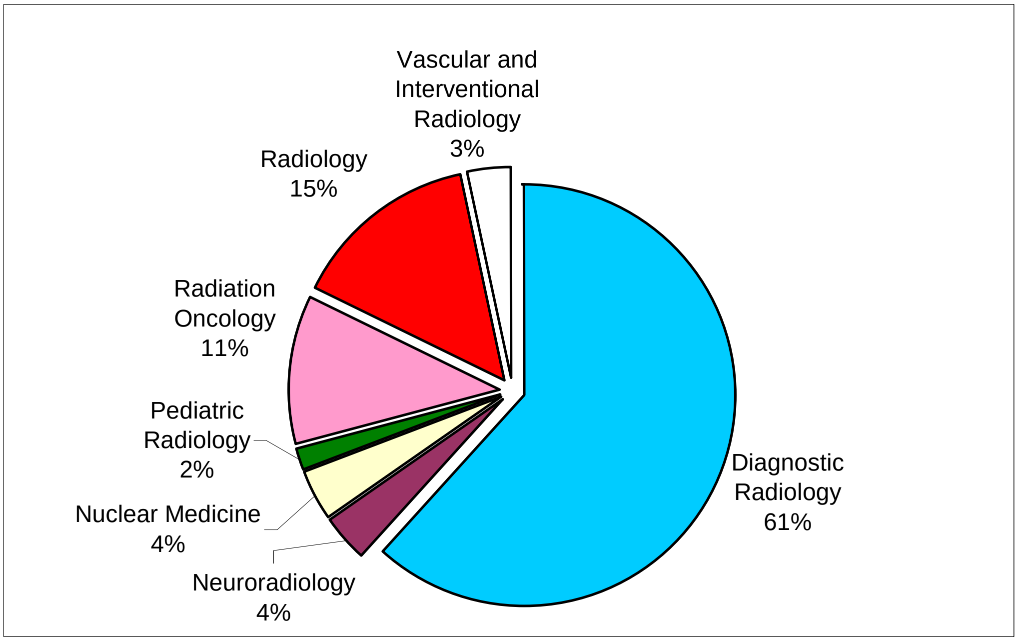
Figure 1. Imaging Physicians as a Proportion of All Physicians, U.S., 2003



Source: AMA, 2005

Physicians in traditional imaging specialties work in a number of fields. Figure 2 shows the proportion of physicians in each of the most established imaging specialties.

Figure 2. Specialties of Imaging Physicians, U.S., 2003

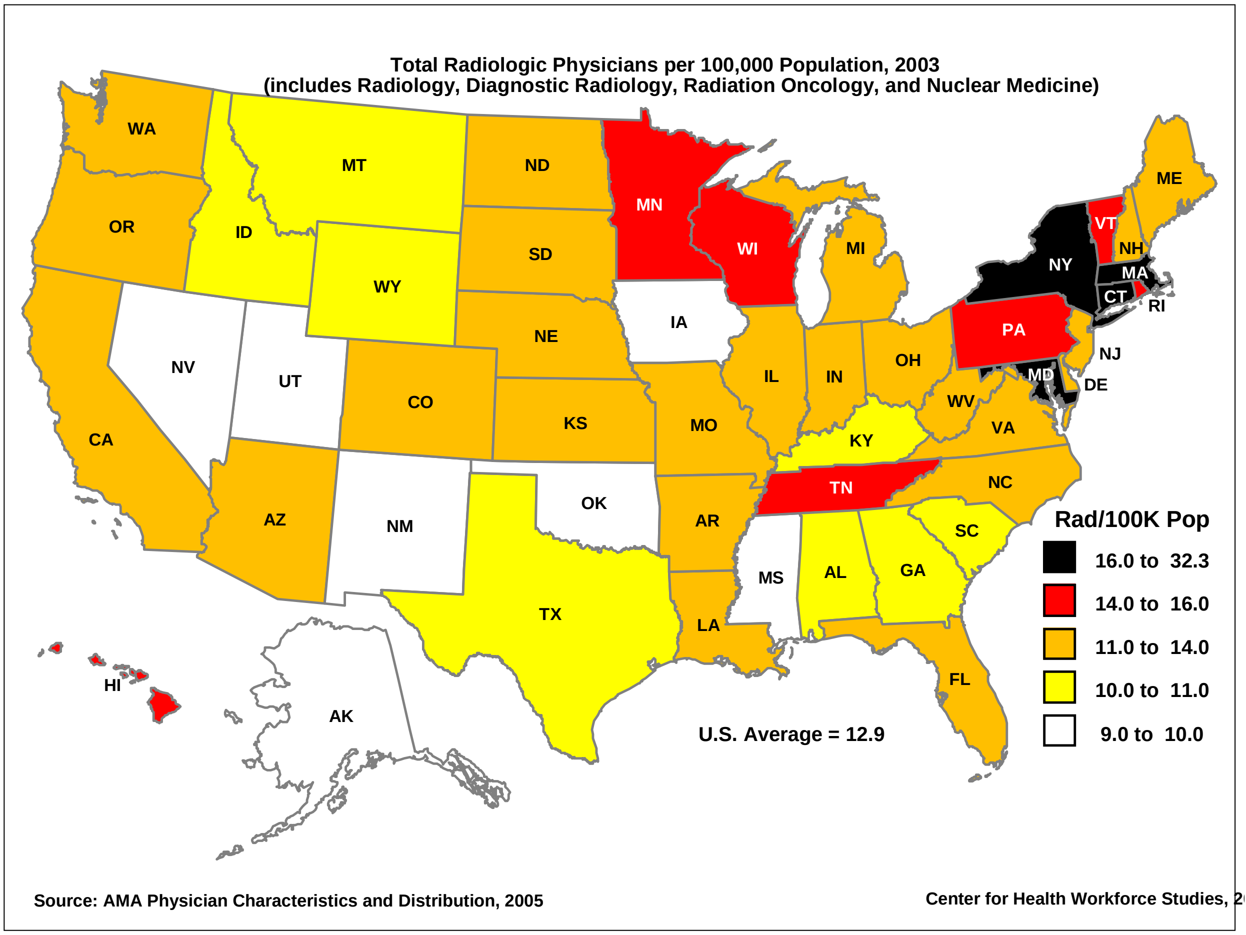


Source: AMA, 2005

2. Geographic Location of Radiologic Physicians

The location of radiologic physicians varies across the U.S. with a high occurrence of these specialists in the Northeast. The Southwest has many fewer radiologic physicians per 100,000 population than other areas of the country.

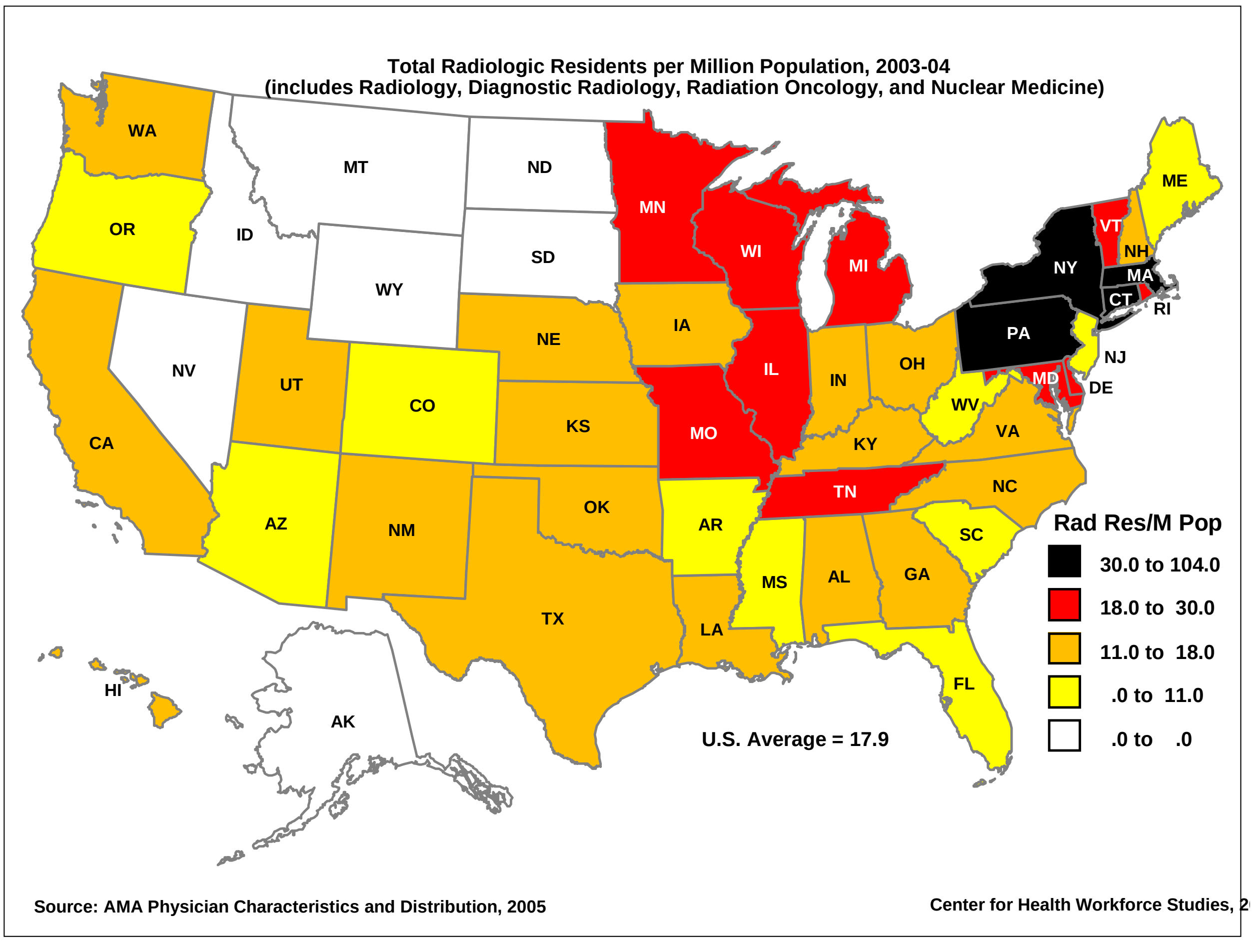
Figure 3. Total Radiologic Physicians per 100,000 Population in the Fifty States, 2003



In 1999, the American College of Radiology survey found that there were 4,400 radiology practices in the U.S., 85% of which were private non-academic practices. 43% of those practices served only hospitals and 39% were located in non-metropolitan or rural areas. Although 87% of multiradiologist private practices were owned by the members of the group, 66% of academic multiradiologist practices were owned by outsiders [Cypel, 2003]. This may reflect important differences in business models between clinical practice and academic medicine.

Figure 4 shows that the location of radiologic residents in graduate medical training also varies widely across the U.S. The highest concentration of residents per million population is in the Northeast and the North Central areas of the country with few to no residency programs in the Northern Plains. The location of residency programs varies somewhat from the location of practicing physicians suggesting that, although residents remain in major training states like New York, Massachusetts, Pennsylvania, Minnesota, and Wisconsin, they also locate to states with few or no training programs like North Dakota, Sought Dakota, and Montana. Appendix A in this report contains a detailed list by state of residency programs in radiologic specialties as listed by the Accreditation Council for Graduate Medical Education (ACGME). The appendix provides the number of programs in each state along with the number of available residencies and the filled positions for each specialty.

Figure 4. Total Radiologic Residents per Million Population in the Fifty States, 2003-04

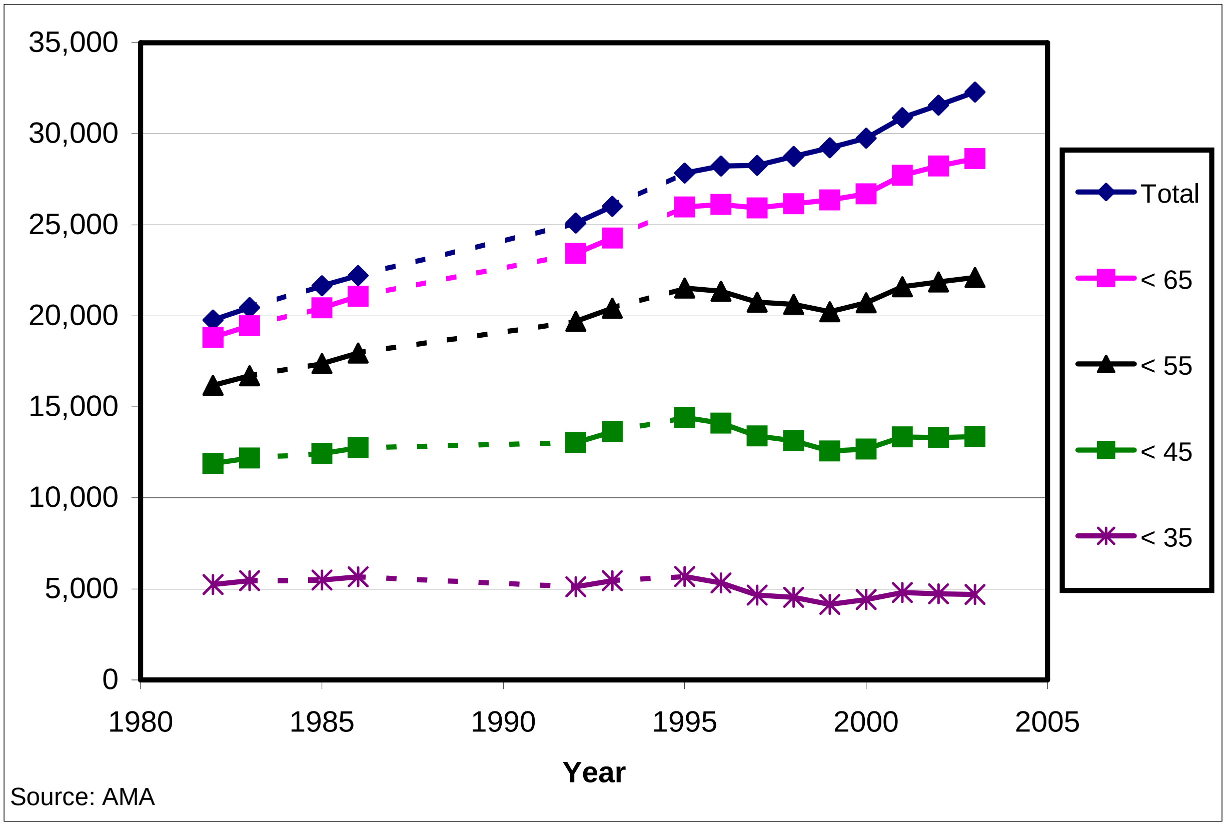


These charts are not comprehensive in that they do not include information about other physician specialties, like nuclear cardiology, that provide imaging services instrumental to delivery of care to patients in their specialties. In fact, the number of physicians actually providing imaging services is known to be much higher than that suggested by these data. For instance, many orthopedists routinely provide X-rays as part of their diagnostic services to patients. The number of cardiologists providing interventional studies has recently increased dramatically, as evidenced by the fact that the Certification Council in Nuclear Cardiology has certified 4,000 physicians in this subspecialty of cardiology since 1996 [CNBC, 2005].

The number of physicians in each of the major specialty areas of radiology has varied over time. Figures 5, 6, 7, and 8 show the number of physicians in each of four imaging specialties (radiology and diagnostic radiology, nuclear medicine, radiation oncology, and all four combined) by age group from 1982 to 2003. In each of the following charts, the space or gap between two lines represents the number of physicians in the radiologic specialty in the corresponding age group while each line on the graph represents the total number of physicians in the field who are younger than the corresponding age in the key.

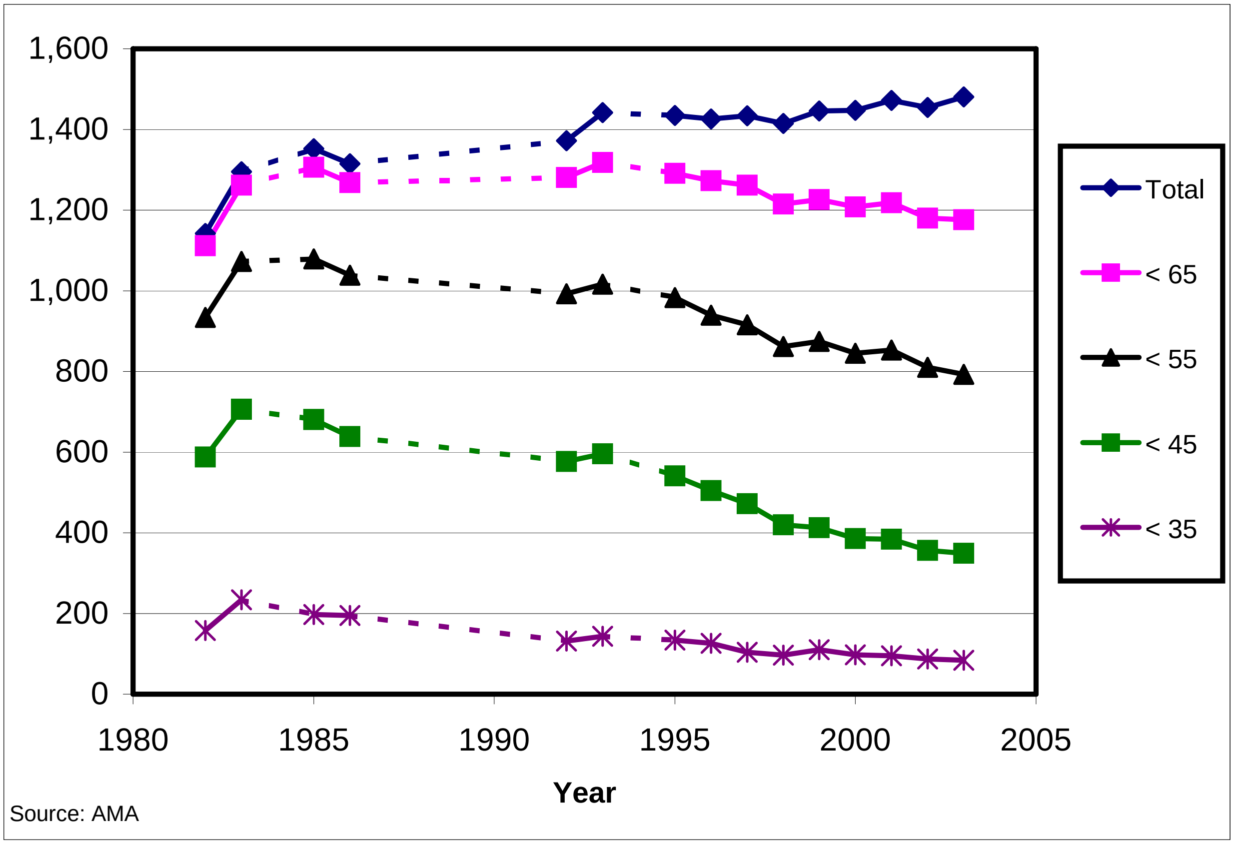
The number of new entrants to diagnostic radiology has remained fairly constant over the last decade with a slight dip around 2000. Figure 5 suggests a fairly stable supply of diagnostic radiologists for the near future. However, supply will depend on the number of physicians in the age cohorts over 55 that retire or depart the profession in the coming decade.

Figure 5. Number of Physicians in Radiology Plus Diagnostic Radiology in the U.S., by Age Group, 1982 to 2003



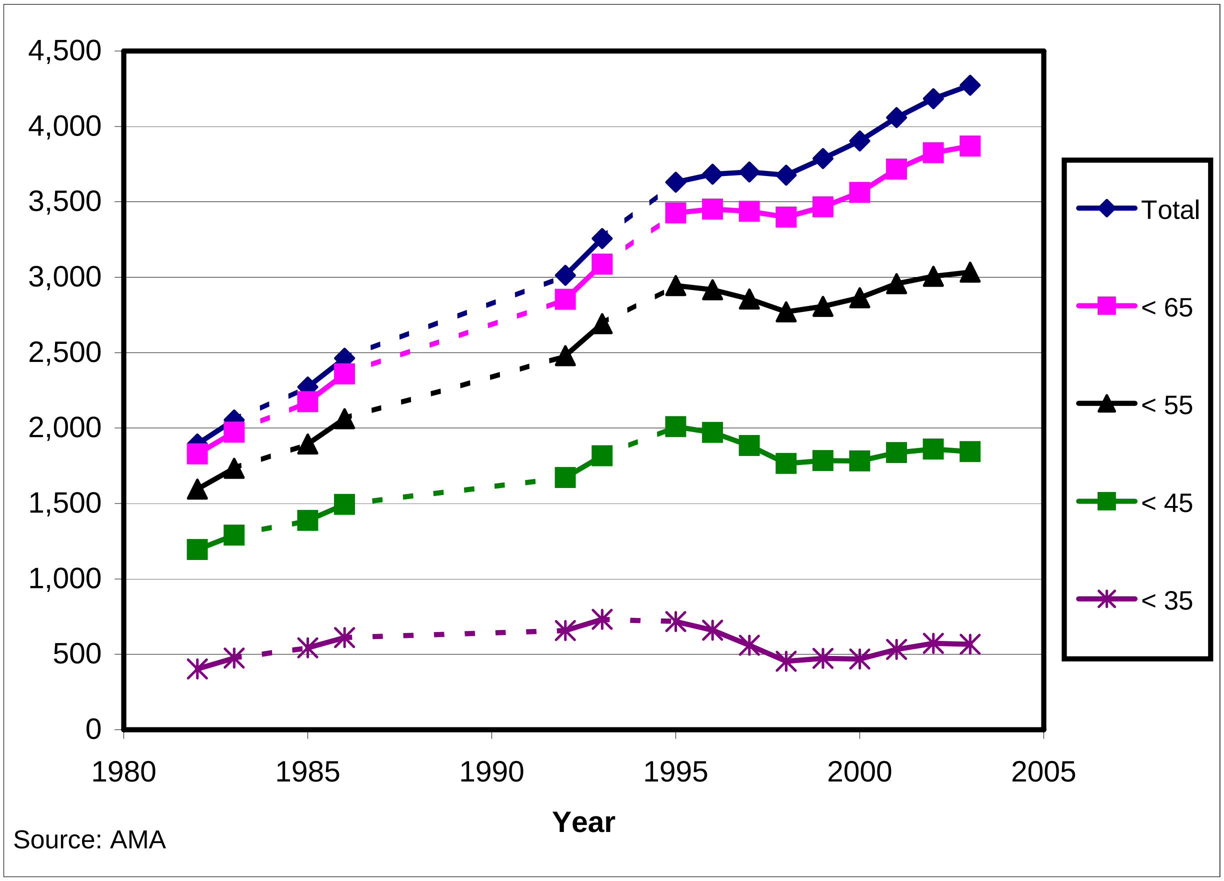
There has been a decline in both the number of new entrants under 35 and in the age cohort under 45 in the specialty field of nuclear medicine (Figure 6). Overall supply of physicians in nuclear medicine has been bolstered by the number of physicians practicing in the specialty that are over the age of 45. Retirements and departures from the profession over the coming decade could have a significant effect on the supply of nuclear medicine specialists working in the field.

Figure 6. Number of Physicians in Nuclear Medicine in the U.S., by Age Group, 1982 to 2003



New entrants to the field of radiation oncology have leveled since 1995 (Figure 7). A large number of practicing radiation oncologists are between the ages of 35 and 55 suggesting a fairly stable supply of radiation oncologists even with departures over the coming decade.

Figure 7. Number of Physicians in Radiation Oncology in the U.S. by Age Group, 1982 to 2003



Overall, the number of physicians working in all specialties in radiology has increased over the last 25 years (Figure 8). However the number of physicians in the age cohorts over 55 is substantially higher than those in the age cohort less than 35 who are new entrants to the field suggesting that the rate of retirement or departure of older radiologists could have an impact on supply of radiologists in the coming two decades.

Figure 8. Numbers of Physicians in All Major Radiologic Specialties in the U.S., by Age Group, 1982 to 2003

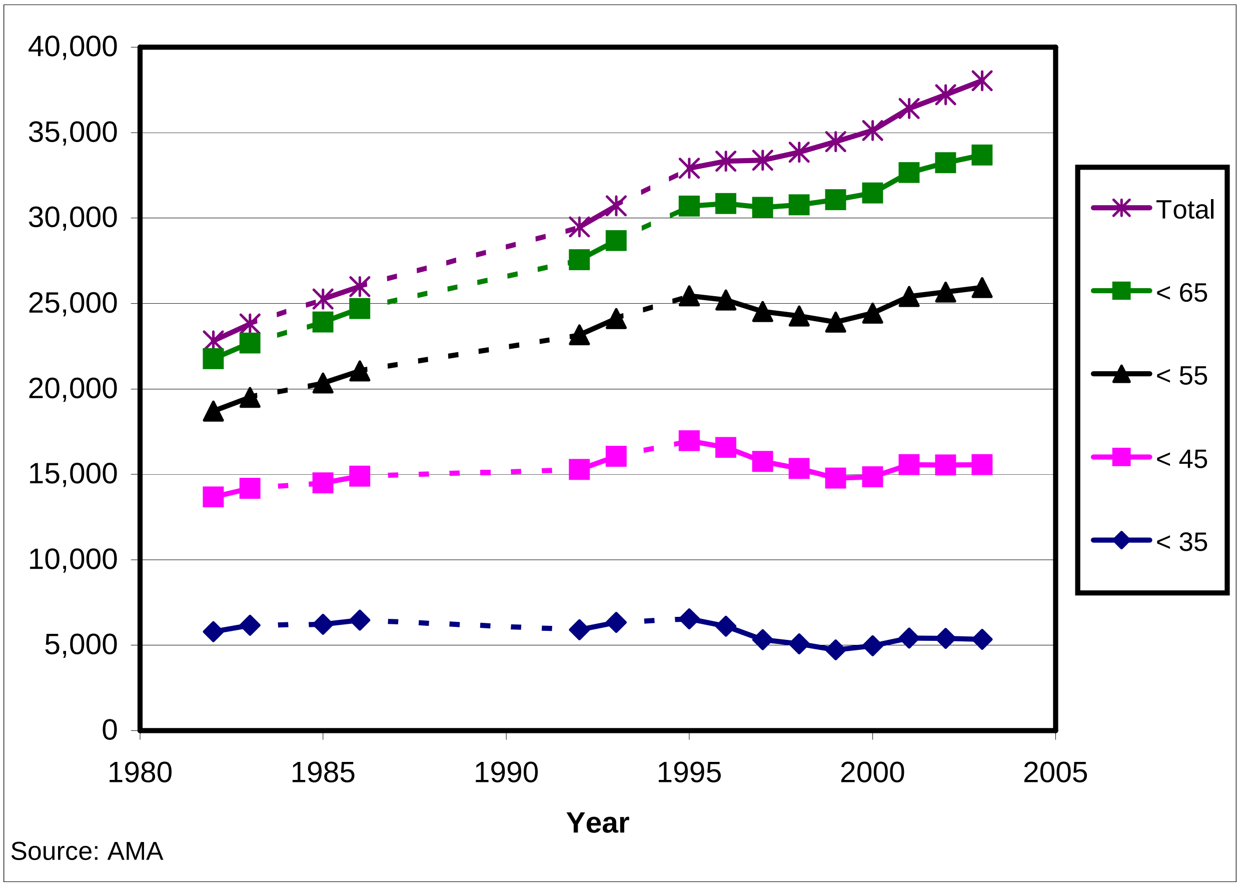


Figure 9 shows that the percent of imaging specialists who are female has increased in all imaging specialty areas. There has been a smaller increase in the percent female among nuclear medicine physicians than for radiology, diagnostic radiology, and radiation oncology. The percent of female physicians in radiology specialties has been steadily increasing in all specialties except radiology since 2000. This is most probably explained by the fact that board certification in radiology is no longer available.

Figure 9. Percent Female of Selected Radiologic Specialties, in the U.S., 1982 - 2003

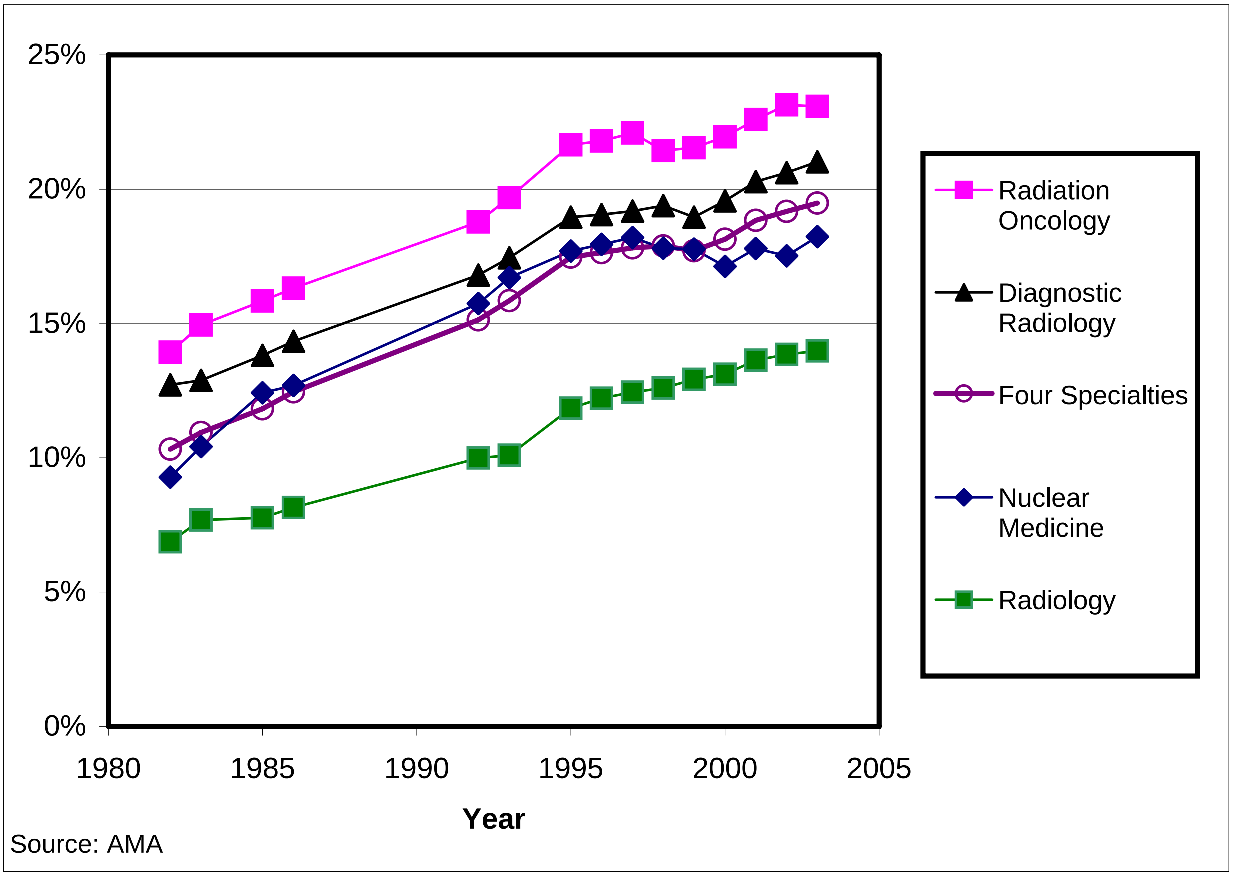
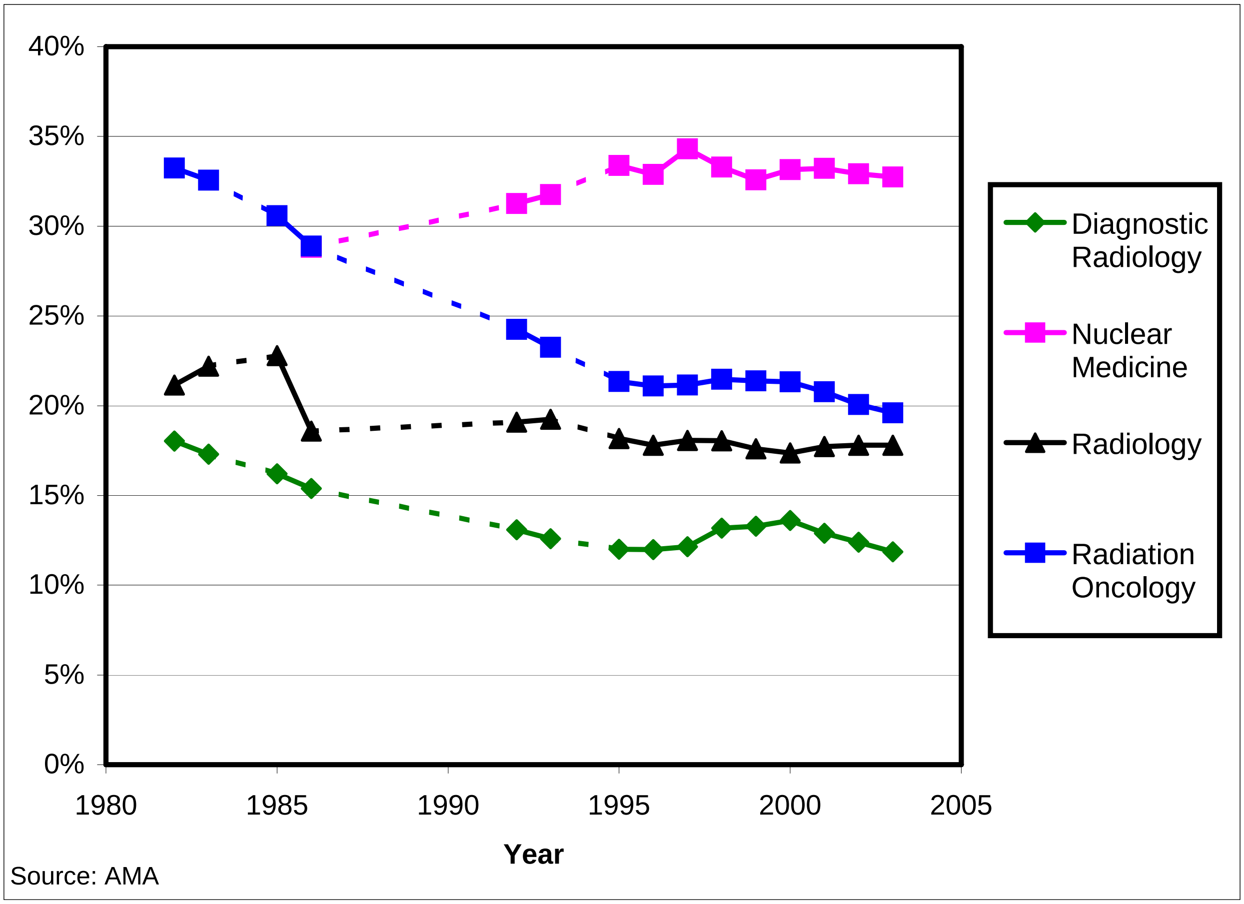


Figure 10 shows that the percent of international medical graduates (IMGs) entering the various radiology specialties has declined substantially since 1985 in all specialties except nuclear medicine where the percent has remained relatively stable. The high percent of IMGs in nuclear medicine suggests a lack of interest among U.S. medical graduates in the field. IMGs may also have more opportunities in nuclear medicine in their nation of origin than U.S. medical graduates, since the specialty experiences less governmental regulation in other countries.

Figure 10. Percent IMGs of Selected Radiologic Specialties in the U.S., 1982 to 2003



3. Training and Certification of Imaging Professionals

Radiologists, Radiation Oncologists and Nuclear Medicine Physicians

Radiologists and radiation oncologists are trained in separate residency programs that focus on anatomy, including cross sectional anatomy and on closed-source modalities. Although their residency training differs from that of nuclear medicine (NM) physicians (also traditionally considered imaging professionals) all three specialties are required to have some training in clinical medicine as part of their graduate medical education.

NM physicians are trained in residency programs that focus on human physiology and function. NM physicians are specialists in the use of radiotracers and their metabolism in the human body. Although nuclear medicine physicians are not considered radiologists both radiologists and nuclear medicine physicians are considered imaging professionals.

Technology and its impact on imaging professionals

The differences in the technology used by imaging professionals have defined the training and certification of the imaging workforce. The location of the radioactive substances used in imaging has historically represented the demarcation between imaging professionals.

Radiologists typically use machines that are "closed source" technology meaning that the radioactive material is sealed within the machine. Both X-ray and CT are examples of this kind of technology. MRI, although not radioactive, also uses magnets sealed within the machine (i.e. closed source) to image patients. These machines typically provide anatomical images.

Nuclear medicine physicians use "open-source" imaging modalities specific to nuclear medicine (e.g., gamma cameras, SPECT, and PET technology) to obtain functional images. Gamma cameras measure levels of radioactivity but do not themselves contain radioactive materials. The patient is actually the source of the radiation being measured. Typically, the patient consumes a radioactive tracer that is metabolized by the body. The camera detects the location of that tracer in the body and measures the rate of its absorption in the patient.

Current technological innovation has blurred some of these traditional differences. Radiologists and other medical specialists are using open source applications as the technology has become increasingly capable. And with the introduction of fusion hardware technology (PET/CT) nuclear medicine physicians are now providing closed source CT scans. This has caused some professional uncertainty in terms of education, clinical training, and assessment of competence for all physician specialties using imaging modalities in their practice of medicine.

The impact of technological innovation on education and certification is various.

- Practicing professionals must be trained to use the new technology and to competently interpret the outputs.
- Educational programs training new professionals must revise curriculum and clinical practicum to teach the new modality.
- Professional certification boards and licensing agencies must develop updated standards for currency and competency for both new and practicing professionals using the new technology.
- Other professional groups become interested in applications of the new technology to particular areas of medicine. When regulation and licensure permit, these professional groups may use the technology in their practices eroding the referral base of traditional imaging specialties and blurring the boundaries that benchmark competency.

Certification

Physicians working in imaging are certified by the following organizations:

- **American Board of Radiology**. The American Board of Radiology (ABR) is a Board of the American Board of Medical Specialties. ABR offers certification in diagnostic radiology, nuclear radiology, and radiation oncology as well as subspecialty certificate in pediatric radiology, vascular radiology, and neuro-radiology [Stanley, 2004]. Residencies of varying lengths are required depending on the discipline. The board has discontinued several certifications although physicians practicing in these specialties still carry valid certificates. The discontinued certificates include diagnostic radiology with special competence in nuclear radiology, diagnostic and medical nuclear physics, diagnostic roentgenology, nuclear medicine, radiological physics, radiology, radium therapy, roentgenology, roentgen ray and gamma ray physics, therapeutic and diagnostic radiological physics, therapeutic and medical nuclear physics, therapeutic roentgenology, X-ray, and radium physics.

Current certifications include:

- Certification in diagnostic radiology requires five years of approved training with one year in a clinical specialty such as internal medicine, pediatrics, surgery, obstetrics and gynecology, neurology, family practice, emergency medicine or a surgical specialty followed by four years of residency in diagnostic radiology with rotations in nuclear medicine and mammography [ABR, 2005].
- Certification in radiation oncology requires five years of residency including a postgraduate year in a medical or surgical specialty and four years of a clinical radiation oncology residency [ASTRO, 2003].
- Subspecialty certification in neuro-radiology requires a residency in diagnostic radiology followed by a one year fellowship in neuro-radiology program [ABR, 2005].
- Subspecialty certification in nuclear radiology requires completion of a diagnostic radiology residency followed by a one year fellowship in a nuclear medicine program [ABR, 2005].
- Subspecialty certification in pediatric radiology requires a residency in diagnostic radiology followed by a one year fellowship in a pediatric radiology program [ABR, 2005].
- Subspecialty certification in vascular and interventional radiology requires completion of a diagnostic radiology fellowship and a one year fellowship in a vascular and interventional radiology program [ABR, 2005].

- **American Board of Nuclear Medicine.** The American Board of Nuclear Medicine (ABNM) is a board of the American Board of Medical Specialties. ABNM provides certification for physicians in clinical nuclear medicine. The examination requires knowledge of medical uses of radioactive materials and knowledge in various areas of a number of physical sciences.

  - Certification in nuclear medicine requires a one-year residency in a clinical care specialty like internal medicine, pediatrics, or surgery followed by a two-year residency in a nuclear medicine training program [ABNM, 2005].
  - Dual certification in nuclear medicine and diagnostic/nuclear radiology is available through a joint program of the ABR and ABNM. Six years of accredited training in board approved programs is required including a preparatory clinical year, four years in a residency in diagnostic radiology including a six month rotation in nuclear medicine followed by one year of residency in a combined nuclear medicine and nuclear radiology program. Certifying examinations from both boards are required [ABNM, 2005].
  - Dual certification is nuclear medicine and internal medicine is available through a cooperative program of ABNM and the American Board of Internal Medicine. The program includes four years of combined training in both medical disciplines. A candidate for dual certification must pass both certifying examinations [ABNM, 2005].
  - Dual certification in nuclear medicine and neurology is available through a program of the American Board of Psychiatry and Neurology and ABNM. Candidates must complete five y ears of combined accredited training in nuclear medicine and neurology. Passage of both certifying examinations is required [ABNM, 2005].
  - Certification in nuclear medicine and cardiology is available to candidates who have completed a residency in internal medicine that included rotations in internal medicine subspecialties, a three month rotation in invasive cardiology, and six month rotation in noninvasive cardiology with an emphasis on nuclear cardiology as well as one year of training in nuclear medicine [ABNM, 2005].
- **Certification Board of Nuclear Cardiology.** Although not a board of the American Board of Medical Specialties, the Certification Board of Nuclear Cardiology [CBNC] is having an impact on imaging practice. There are about 4,000 physicians certified by the board for practice in nuclear cardiology [CNBC, 2005]. The board was founded in 1996 to award certificates to physicians who successfully pass a certifying examination.

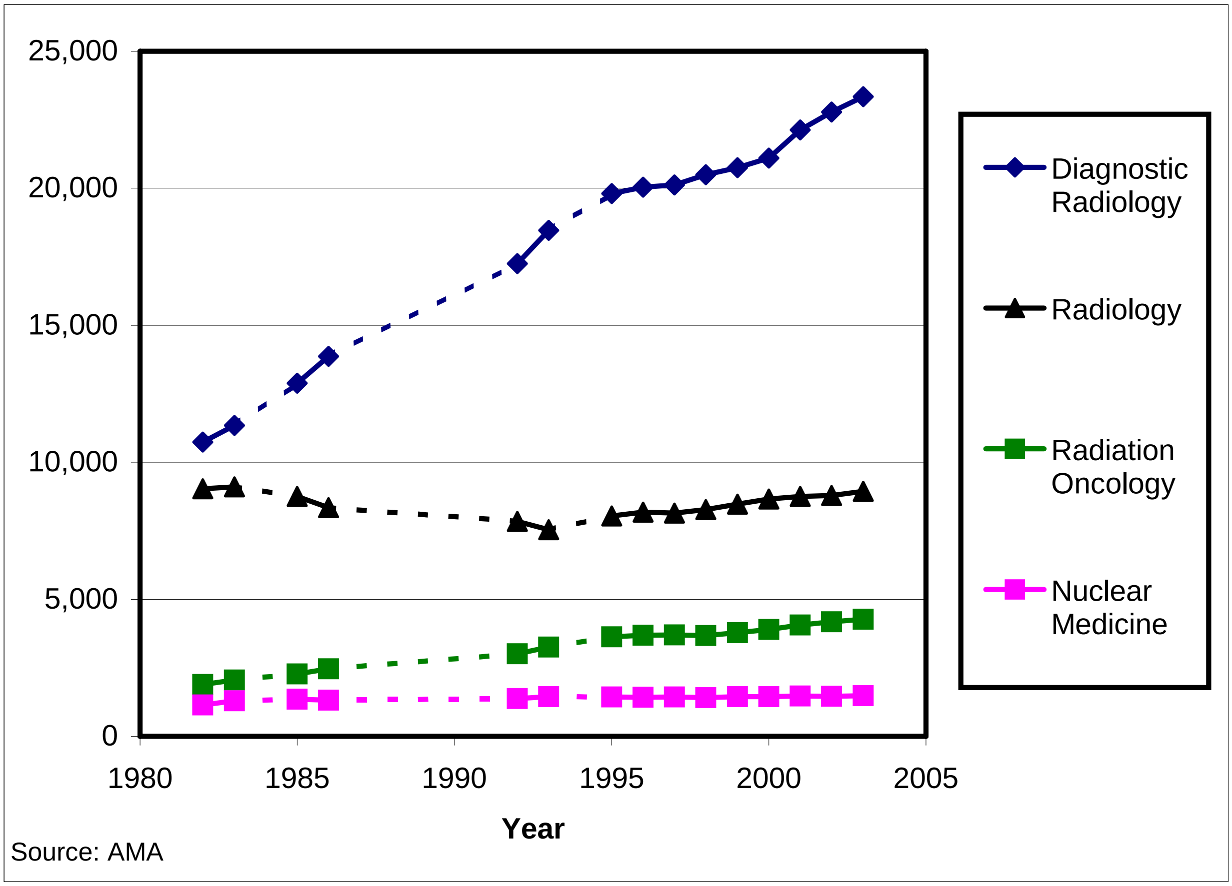
This is a subspecialty certification developed by the American Society of Nuclear Cardiology (ASNC) to certify competence to practice nuclear cardiology. Candidates must be board certified or board eligible in nuclear cardiology, nuclear medicine or radiology and must have training and/or education equivalent to level 2 training in nuclear cardiology as defined by ASNC or have provided at least 300 nuclear cardiology studies, 30 of which have angiographic correlation [Wacker, 1997].

4. Future Supply

The number of new entrants to the field, the number of practicing professionals, and the number of departures from the field determines the supply of any profession in any given period [Bhargavan (a), 2002]. To change supply, the radiology profession must increase production of new radiologists as well as the productivity of practicing radiologists [Bhargavan (a), 2002]. It is difficult to have a significant impact on supply given the structure of graduate medical education, which is governed by public funding. The number of residency slots for training radiologists is not elastic with few options to voluntarily increase production in GME residency and fellowship programs. Expansion of supply may require involvement of other medical specialties in imaging and encouragement of more sub-specialization in particular areas of imaging among radiology residents.

Analysis of the growth in the number of imaging specialists shows that the supply of diagnostic radiologists (the radiology specialty is now called diagnostic radiology) has increased substantially since 1980 while the supply of nuclear medicine physicians and radiation oncologists has remained relatively consistent, suggesting stable demand for these two imaging specialties (Figure 11). However, demand for nuclear medicine physicians and radiation oncologists is likely to increase in the near future with the development of new molecular imaging applications in both oncology and nuclear medicine that advance diagnostic capabilities, monitor the efficacy of treatment protocols, and permit therapeutic intervention at the molecular level.

Figure 11. Numbers of Physicians in Selected Radiologic Specialties in the U.S. 1982 to 2003



Recently, concern has been expressed about a developing shortage of radiologists that has increased dramatically since 1998. This shortage is suggested by decreasing levels of unemployment and increasing numbers of vacancies in positions for radiologists [Saketkhoo, 2003]. In addition, salaries for diagnostic radiologists have increased and graduates from education programs have indicated an increase in the number of job offers [Saketkhoo, 2003].

Observers suggest that the current shortage is likely to become severe. However, although there is substantial anecdotal information to suggest that there is currently a shortage of imaging professionals that is likely to continue, making such a statement in absolute terms is difficult. This is true for several reasons:

It has been difficult in the past to project the level of demand for physicians in most specialties. A review of historical projections suggests that employment projections for physicians have not been particularly accurate. Health workforce in general has experienced cyclical problems of over- and under-supply that are difficult to resolve given the very changeable environment in which health care is provided in the U.S.

The current and future supply of imaging professionals is of concern to a number of stakeholders including the American College of Radiology who recently convened a task force to study and ultimately to address the issue [Sunshine, 2004]. There are several factors suggested by their research that could affect the supply of imaging professionals in the future.

- Faculty shortages are a concern for the profession. The supply of radiologists practicing in academic settings is a critical indicator of ability to produce new physicians [Sunshine, 2004]. Academic positions typically pay less than private practice employment creating a disincentive to a career in academic medicine. In a study examining help wanted advertisements as an indicator of shortage, researchers found that in 2002, 42.7% of all advertisements for radiologists were for academic positions despite the fact that only 20% of positions in radiology are academic [Saketkhoo, 2003]. Some institutions are increasing the funds available to academic practices in order to encourage physicians with an interest in teaching. Faculty in educational programs is essential to ensure continuing production of qualified radiologists.
- The lack of supply of academic radiologists is also a concern since academic research is important to the advancement of any profession. Most clinical radiologists are not trained as scientific investigators so academic research professionals are critical to knowledge in the field [Dunnick, 2003].
- The number of radiology residents doing fellowships appears to be decreasing putting students into the workforce one year earlier [Sunshine, 2004]. This may increase the expected supply of new professionals in a given year but it also suggests an eventual decrease in supply of sub specialists in fields requiring fellowships such as neuroradiology and nuclear medicine.
- In the 1990s some radiologists retired early because of the excellent performance in the equities market. The present downturn in the economy may delay retirement for

radiologists and may promote the return of others to practice [Sunshine, 2004]. This would have a relatively short-term effect on the supply of radiologists.

- Although experiencing greater productivity due to technological innovation, radiologists are also working more hours and taking fewer vacations [Sunshine, 2004] suggesting that demand is high and supply is short. This may also be a function of decreased payment for units of service by MCOs driving the need to increase productivity to maintain a desired level of income [Sunshine, 2004].
- The development of technology called CAD (computer aided detection) is an innovation that may augment interpretation and might, over time, substitute for second readings by radiologists. The sensitivity and specificity of this relatively new technology must be improved for any substantive effect on the supply of radiologists. However, with improvements it could prove valuable in the struggle to maintain sufficient resources for interpreting diagnostic studies. Whether this technology will substitute or just augment the work of radiologists remains to be seen.

5. Expected Demand

As with physicians in general, prediction of demand for imaging professionals is a difficult exercise. Observers comment that a series of shortages for imaging professionals have alternated with soft demand for the professions [Sunshine, 2004]. Predicting absolute demand for professionals in any area of medicine is especially difficult because a number of external environmental factors affect the numbers of physicians and allied health workers needed.

Effective demand for imaging professionals is determined by a number of important factors that vary on an ongoing basis.

- Demand is presently driven by the capability of imaging technology. As capability increases and applications to a number of body systems are perfected, demand is expected to increase. Examples of new applications driving demand are imaging applications in neurology in Alzheimer’s disease and attention deficit disorder [PACS Market, 2004].
- Both the growth rate of the population and the aging of the population affect demand for services [Bhargavan (a), 2002]. Over the last decade, there has been a 4.5% annual

increase in the number of procedures performed by radiologists with a concomitant annual increase in complexity of 1.75% [Saketkhoo, 2003]. This growth has generated a 6% increase in imaging relative value units billed annually. However, there has only been a 1.5% annual growth in the number of radiologists over the same period [Saketkhoo, 2003].

- These figures, reflecting increased utilization, have led to projection of a deficit of 10,000 to 15,000 radiologists by the year 2015. This would be a significant shortage considering that this deficit is about half the number of currently practicing radiologists [Saketkhoo, citing Bhargavan, 2003]. In an analysis of supply and demand for radiologists over the first thirty years of the century, in all cases the growth rate of demand outstripped the anticipated supply of radiologists [Bhargavan (a), 2002].
- The non-invasive nature of imaging studies and developments in therapeutic applications in imaging will likely encourage demand. Research in radio-immunotherapy suggests future applications in treatment protocols that will drive increasing demand for non-invasive imaging therapies. Progress in molecular and cellular imaging research suggests that imaging will play an increasingly important role in health care.
- The rate of demand per person affects demand as well as the number of procedures per radiologist [Bhargavan (a), 2002]. Increased efficiency of radiologists generated by more efficient technology has affected the production levels of radiologists. Demand from the population for a number of different kinds of imaging studies has also affected resources.
- Even though radiologists have more average throughput, more studies are being done on a per patient basis. Evaluation of the effect of increased efficiency of radiologists is difficult especially because it is diluted by demand for more services from the population.
- In addition, teleradiology permits some physicians to work at a distance from the site of acquisition and also allows radiologists to work for several employers. This technology also enables outsourcing to other countries, like India, where time differences permit twenty-four hour coverage for radiology departments in the U.S. These “nighthawk” service providers reduce demand for on call work by radiologists. Many of the doctors

providing these services in foreign countries are U.S. trained physicians [Sunshine, 2004].

- Projection of demand is especially difficult since technology in development and not yet in use will also affect and likely increase the number of applications available, also encouraging demand. Health care analysts and economists indicate that the two factors that most significantly confound accurate demand estimates are age adjusted demand and technological change. [Bhargavan (a), 2002].
- Fusion technology now permits a study that previously required two separate visits (one for a PET study, the other for a CT study), to be performed in a single encounter. This is a factor that increases efficiency and also moderates demand.
- A worldwide shortage of imaging professionals is expected to hinder progression in the market for imaging services [Medical Technology Watch Canada]. Without competent professionals to provide and interpret imaging studies, the use of technology will be limited.
- The capability of picture archiving and communication systems (PACS) and radiology information systems (RIS) has enhanced the productivity of radiologists [Sunshine, 2004]. This is a factor that could moderate demand. As future improvements in technology ease the work of obtaining and interpreting images, demand for more imaging professionals might be eased.
- Any changes in managed care policy or Medicare payment policy could also reduce demand [Sunshine, 2004]. Some imaging studies such as MRI are expensive. Some MCOs have required preauthorization for these studies, a factor that could potentially contain demand.

6. Federal Regulation

One factor that deserves special attention is Federal regulation regarding importation of nuclear materials and restraints on production of radionuclides. This is a factor that contains demand for both diagnostic and therapeutic applications in nuclear medicine. Although not an issue of immediate relevance to this report on imaging workforce, some comment is essential regarding the public’s aversion to radioactivity as an important deterrent to proliferation of technology using radioactivity. This is particularly germane to our discussion since the production and supply of radiopharmaceuticals used in nuclear medicine ultimately affects the supply of imaging services. Unlike closed-source applications (X-ray and CT) that use stable contained sources of radioactivity that do not require continual renewal, nuclear medicine studies, including PET and SPECT, require ongoing renewable supplies of consumable radioactive tracers with short half-lives. A steady, safe, and reliable source for a number of radiopharmaceuticals is critical to the ability to provide these kinds of imaging services. This is also an important concern since much of the innovation in imaging is occurring in open-source applications.

Public distaste for nuclear material is evidenced in the lack of interest in nuclear power and the subsequent reduction in infrastructure and resources of the U.S. Department of Energy. Many nuclear power plants whose byproducts are essential materials for the production of radiopharmaceuticals for nuclear medicine studies have closed or have limited their annual production to a few isotopes for medical applications. As a result, much of the raw material for production of radiopharmaceuticals is imported from international sources under strict government guidelines. This situation impacts not only FDA approved radioisotopes and radiopharmaceuticals but also radiopharmaceuticals in development. Subsequent impact on research exploring new imaging applications is obvious.

Radiopharmaceuticals are used in over 100 nuclear medicine procedures with capability to image every major organ system [About the USA, 2004]. There are 17 elemental groupings of radiopharmaceuticals now in use in 51 compounds with different biological affinities (meaning that they are organ or site specific). One hundred and seventeen (117) radiopharmaceuticals derived from these compounds are in use. Fifty-three (53) of these radiopharmaceuticals are from the base compound technetium [Nuclear Medicine Research Council]. Sixty-five percent of all nuclear medicine studies performed in the U.S. use technetium [Nuclear Medicine Research Council]. Technetium is a “daughter” isotope of molybdenum, which is produced entirely outside the U.S.

This reliance on foreign sources for production of radioactive material is concerning especially in light of new applications in PET and SPECT that will drive rising demand. The cost of building nuclear reactors is prohibitive to most private industry so reliance on government involvement is unlikely to change. A few corporate enterprises and academic centers have cyclotrons capable of producing some radioisotopes but this production is neither sufficient in quantity nor sufficient in capability to meet supply demands from the market [Expert Panel, 1999]

7. Impact of New Imaging Technologies

As imaging technology becomes more capable, specialists other than traditional imaging physicians are using imaging in their medical practices. The proliferation of imaging technologies in outpatient settings like physician offices and clinics and the use of imaging technology by other specialties such as cardiologists and oncologists could potentially suppress demand for traditional imaging professionals, particularly if economic incentives remain high.

This diversion of imaging studies to non-imaging professionals is documented. Recent studies indicate that although there was a 2% increase in myocardial perfusion imaging studies provided by radiologists between 1997 and 2002, during the same time period there was a 78% increase in the number of myocardial perfusion imaging studies provided by cardiologists [Mitka, 2005].

Anecdotes suggest that the use of imaging technology by other than traditional imaging professionals is having a significant effect on demand for imaging professionals. Whether this trend is beneficial to the patient is debatable given that the training of radiologists permits a more holistic interpretation of imaging studies than the training provided to a specialist physician with a particular body focus. Whereas a cardiologist may be interested in heart-specific information related to a patient complaint, a radiologist would have a more comprehensive, inclusive interest. One example would be a patient complaining of shortness of breath who might be imaged by a cardiologist to diagnose any cardiac condition but whose background lung lesion might be overlooked [Mitka, 2005]. A radiologist would be trained to examine all aspects of the image and to find that lesion. Different specialties must work together to determine appropriate use of technology with the goal of achieving appropriate and accurate patient diagnosis from imaging studies [Mitka, 2005].

B. Imaging Technologists

The number of radiologic procedures provided to patients is large and growing. Over 300 million imaging procedures are provided annually to seven out of ten Americans [ASRT, 2005(a)]. The technologists who operate the various imaging equipment are an important part of the workforce providing imaging services. Radiologic technologists working in any or all of the multiple radiology modalities are among the largest group of allied health professions in the U.S. numbering a quarter of a million professionals. Radiologic technologists are trained and certified in three primary modalities:

- radiology;
- radiation therapy;
- nuclear medicine; and
- beginning in January of 2006, sonography [ARRT, 2005].

Technologists may also be certified as specialists in a number of different imaging modalities including:

- mammography;
- CT;
- MRI;
- sonography;
- vascular sonography;
- breast sonography;
- cardiovascular radiology;
- cardiac interventional radiology; and
- vascular interventional radiology [ARRT, 2005].

Nuclear medicine technologists may also become certified in the sub specialties of cardiology or PET [NMTCB, 2005].

1. Current Practice

The Bureau of Labor Statistics indicates that there are approximately 250,000 jobs for imaging technologists in the U.S. (Table 2). The average mean annual salary varies by specialty. Technologists work in general and medical surgical hospitals, other hospitals, offices of physicians, outpatient care centers, and medical and diagnostic laboratories as well as a variety of other health settings [BLS, (a) 2004].

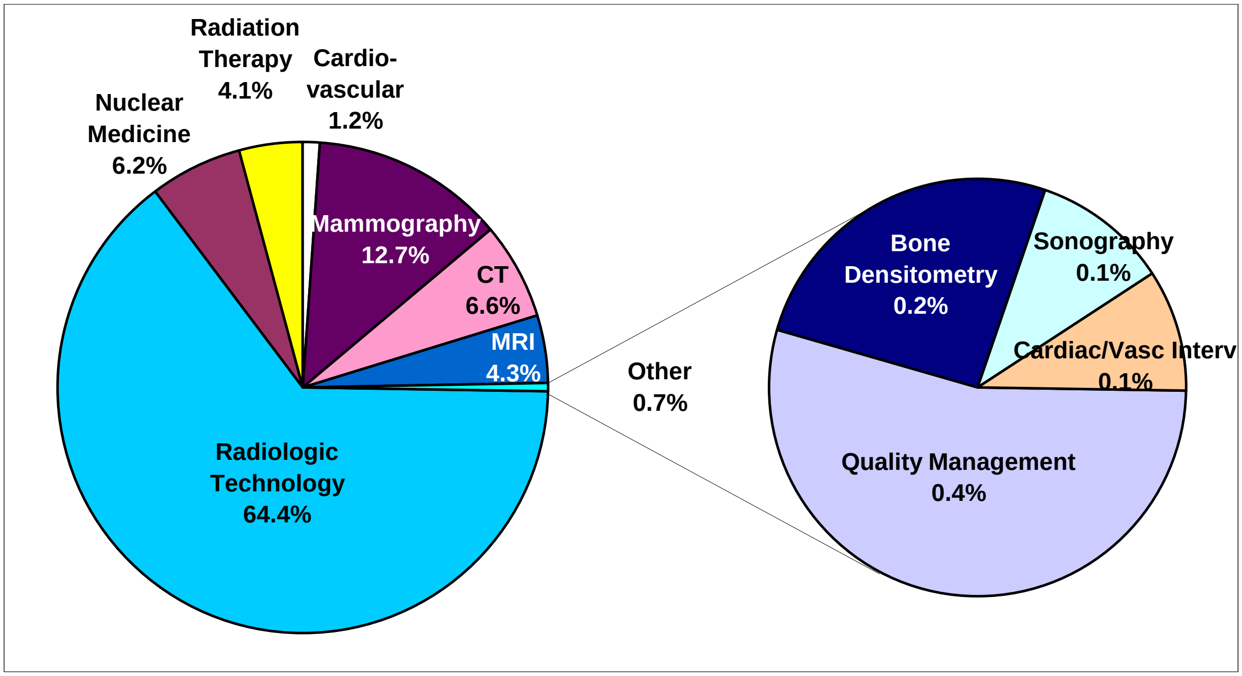
Table 2. Occupational Employment and Mean Annual Wages of Imaging Technologists, U.S., 2004

Occupation	Number	Mean Annual Salary
Radiation Therapists	14,470	$60,420
Nuclear Medicine Technologists	17,520	$61,210
Diagnostic Medical Sonographers	41,280	$53,620
Radiologic Technologists and Technicians	177,200	$44,530
Total	250,470	N/A

Source: BLS, (a) 2004

Technologists may have multiple certifications. In 2005, there were approximately 258,000 certified imaging technologists in the U.S. holding over 350,000 certifications in a range of specialty areas [ARRT (a), 2005, NMTCB, 2005]. Figure 12 shows the number of certified radiologic and nuclear medicine technologists certified in selected imaging specialty areas as of 2005.

Figure 12. Number of Certified Technologist By Specialty Area, U.S., 2005



Source: ARRT, (a) 2005, NMTCB, 2005)

2. Education and Certification

Education programs for technologists vary in content and in length. Technologists are trained in one-year certificate programs, two-year certificate and associate degree programs, and four-year bachelor's programs. These programs are offered in vocational and community colleges, in hospital based training programs, and in four-year university settings [ASRT, 2005]. Generally, radiologic technologist education programs are at the two year certificate/ associate's degree level while radiation therapy and nuclear medicine education is generally at the bachelor's degree level.

In September of 2005, the American Registry of Radiologic Technologists listed 897 accredited education programs in radiography, radiation therapy and nuclear medicine in schools across the U.S.. These programs are accredited by the Joint Review Committee on Education in Radiologic Technology (JRCERT), by the Joint Review Committee on Educational Programs in Nuclear Medicine Technology (JRCNMT) or by the Regional Institutional Accrediting Agencies. Table 3 shows technology education programs by state and by discipline.

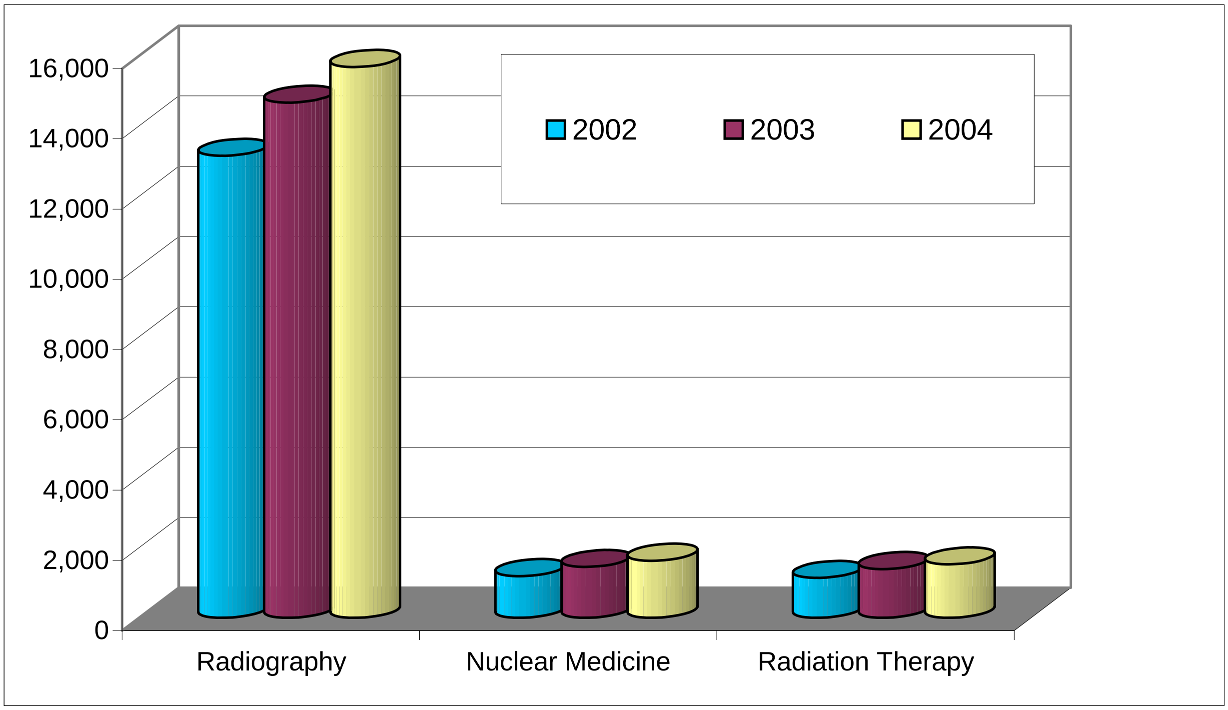
Table 3. Educational Programs for Radiologic Technologists, Radiation Therapy Technologists, and Nuclear Medicine Technologists, By State, U.S., 2005

State	Radiology	Radiation Therapy	Nuclear Medicine	Total Number
Alaska	1	0	0	**1**
Alabama	11	1	1	**13**
Arizona	5	0	1	**6**
Arkansas	11	2	2	**15**
California	32	5	7	**44**
Colorado	9	1	1	**11**
Connecticut	11	2	1	**14**
Delaware	2	0	1	**3**
District of Columbia	2	1	0	**3**
Florida	42	6	8	**56**
Georgia	28	3	3	**34**
Hawaii	1	0	0	**1**
Idaho	4	0	0	**4**
Illinois	31	4	4	**39**
Indiana	20	3	2	**25**
Iowa	14	1	2	**17**
Kansas	5	1	1	**7**
Kentucky	17	2	2	**21**
Louisiana	14	1	1	**16**
Massachusetts	10	4	5	**19**
Maryland	13	1	2	**16**
Maine	4	1	4	**9**
Michigan	23	6	2	**31**
Minnesota	14	3	2	**19**
Mississippi	10	0	1	**11**
Missouri	19	2	3	**24**
Montana	5	0	0	**5**
Nebraska	7	1	1	**9**
Nevada	2	1	1	**4**
New Hampshire	2	1	0	**3**
New Jersey	17	3	3	**23**
New Mexico	6	0	1	**7**
New York	33	7	8	**48**
North Carolina	26	5	5	**36**
North Dakota	5	0	0	**5**
Ohio	27	4	8	**39**
Oklahoma	13	1	1	**15**
Oregon	3	1	1	**5**
Pennsylvania	45	3	7	**55**
Rhode Island	2	0	1	**3**
South Carolina	12	1	2	**15**
South Dakota	6	0	1	**7**
Tennessee	14	3	5	**22**
Texas	43	5	5	**53**
Utah	2	1	2	**5**
Virginia	16	4	3	**23**
Vermont	3	1	1	**5**
Washington	8	1	1	**10**
West Virginia	9	1	3	**13**
Wisconsin	19	2	5	**26**
Wyoming	2	0	0	**2**
Totals	680	96	121	897

Source: ARRT,(b) 2005; NMTCB, 2005

Educators reported increasing enrollments in imaging technology education programs from 2000 to 2004 (Figure 13). The percentage of education program directors reporting full enrollments in radiologic technology education programs was 77.5% in 2004, 75% in 2003, 66% in 2002, and 50% in 2001 [ASRT, 2004].

Figure 13. Enrollment Trends in Technology Education Programs in Radiography, Nuclear Medicine, and Radiation Therapy, U.S. 2002 to 2004



Source: ASRT,(b), 2004

The majority of states require licensure for radiologic technologists, but there is wide variation in who is required to be licensed. In some states all technologists must be licensed, in some radiologic technologists must be licensed, but not nuclear medicine technologists, and in some others only technologists using specific modalities like mammography must be licensed. New York was the first state to require licensure of radiologic technologists in 1965 [ASRT (c), 2005]. A Federal bill has been proposed which is expected to redress this variation. Called the Consumer Assurance of Radiologic Excellence (the CARE bill), the bill was introduced to Congress to ensure that patients are receiving quality services when having radiologic procedures [ASRT (a), 2005]. One aspect of this proposed law is that it would require licensure of all imaging technologists in all states. Table 4 provides information about state licensure for technologists as of 2004.

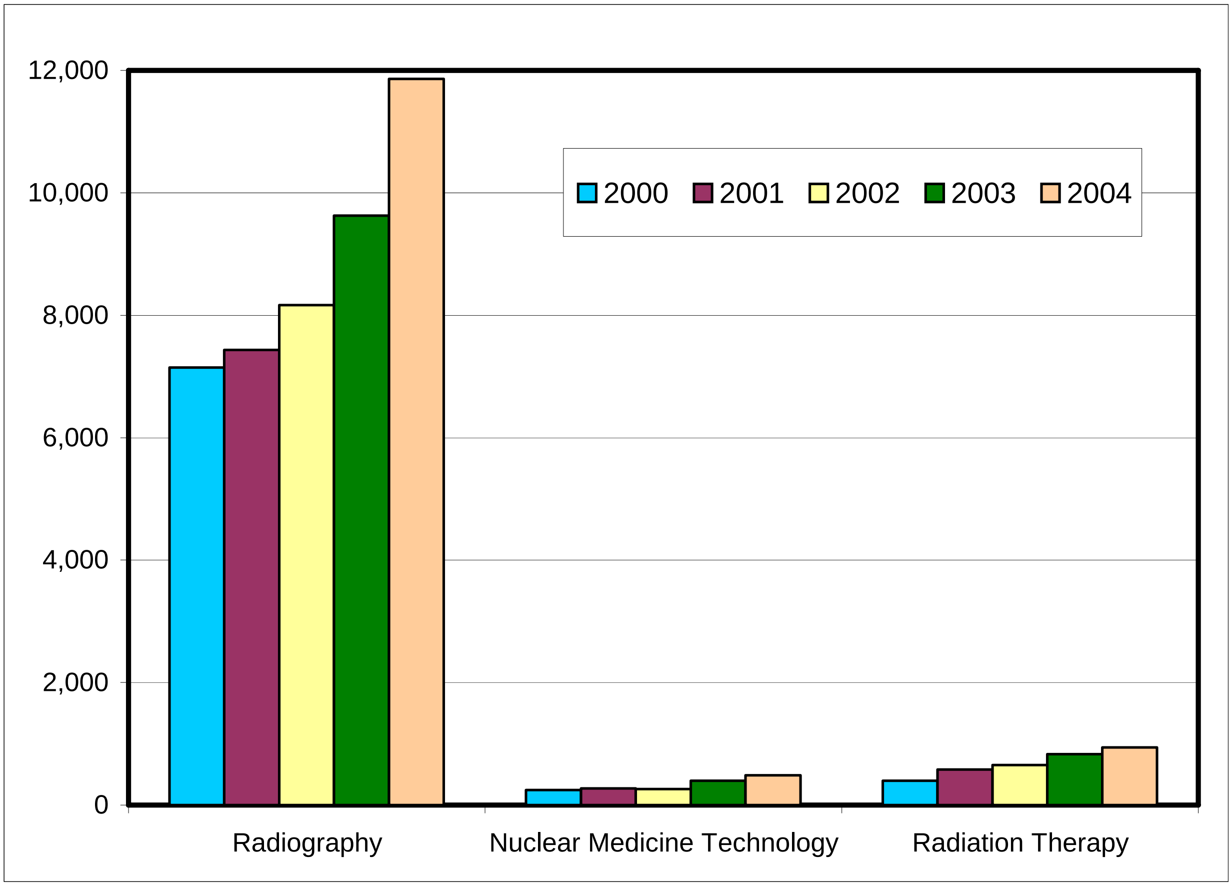
Table 4. State Regulation of Radiologic Technologists and Nuclear Medicine Technologists, as of 2004

Alabama	None
Alaska	None
Arizona	Licensure 2004 (NM) 1997 (RT)
Arkansas	Licensure 1999 (NM)(RT)
California	Licensure 1969 (NM)(RT)
Colorado	Licensure (RT) Limited Scope Mammography and Non-ARRT Registered
Connecticut	Licensure 1993 (RT)
Delaware	Licensure (NM)(RT)
District of Columbia	None
Florida	Licensure 1979 (NM)(RT)
Georgia	None
Hawaii	Licensure 1974 (NM)(RT)
Idaho	None
Illinois	Licensure 1990 (NM)(RT)
Indiana	Licensure 1982 (RT)
Iowa	Licensure 1987 (RT)
Kansas	Licensure 2004 (RT)
Kentucky	Licensure 1978 (RT) Limited Scope, Certification
Louisiana	Licensure 1984 (NM)(RT)
Maine	Licensure 1984 (NM)(RT)
Maryland	Licensure 1992 (NM)(RT)
Massachusetts	Licensure 1987 (NM)(RT)
Michigan	Licensure Limited Scope Mammography
Minnesota	Licensure (NM)(RT) Must be ARRT registered, pass exam or be licensed in other state
Mississippi	Licensure 1996 (NM)(RT)
Missouri	None
Montana	Licensure 1977 (RT)
Nebraska	Licensure 1987 (NM)(RT)
Nevada	Licensure Limited Scope Mammography
New Hampshire	None
New Jersey	Licensure 1968 (NM)(RT)
New Mexico	Licensure 1983 (NM)(RT)
New York	Licensure 1965 (NM)(RT) Limited Scope
North Carolina	None
North Dakota	Licensure 2003, Advanced Practice Fluoroscopy
Ohio	Licensure 1995 (NM)(RT)
Oklahoma	None
Oregon	Licensure 1979 (RT)
Pennsylvania	Licensure (RT)(NM) Limited Scope (must pass ARRT or state exam)
Rhode Island	Licensure 1994 (RT)(NM)
South Carolina	Licensure 1999, Certification
South Dakota	None
Tennessee	Licensure (RT) (Must pass ARRT exam or state exam)
Texas	Licensure 1987 (RT)(NM)
Utah	Licensure 1989 (RT)(NM)
Vermont	Licensure 1984 (RT)(NM)
Virginia	Licensure 1997 (RT) Limited Scope
Washington	Licensure 1991 (RT)(NM)
West Virginia	Licensure 1997(RT)
Wisconsin	All CT technologists and radiation therapists must be ARRT certified
Wyoming	Licensure 1985 (RT)(NM)

Source: ASRT,(c) 2004; SNM, 2004

Imaging technologists are certified by either the American Registry of Radiologic Technologists (ARRT) or by the Nuclear Medicine Technology Certification Board (NMTCB). ARRT sponsors certification in all imaging technology specialties including nuclear medicine. However, the majority of nuclear medicine technologists certify with the Nuclear Medicine Technology Certification Board. About one-third of all nuclear medicine technologists are certified by both the ARRT and the NMTCB [CHWS, 2005]. Figure 14 shows the increase in the number of imaging technologists sitting for the first time for certification exams offered by the ARRT in three specialty areas. In all specialties, there has been an increase in first time examinees between 2000 and 2004 [ARRT, 2005].

Figure 14. Number of Technologists Writing Certification Examinations for the First Time by Specialty Area, U.S., 2004



Advanced Practice for Technologists

The Radiology Assistant (RA) or the Radiology Practitioner Assistant (RPA) is an emerging advanced practice role for technologists. As in other areas of medicine, the role of these professionals is as a “physician extender” to provide basic services to patients and to increase access to care in areas where radiologists are not available. Advanced practice roles may also contribute to greater efficiencies in practice for the physicians with whom they work.

The role of an RA or RPA has been endorsed by the American College of Radiology and the American Registry of Radiologic Technologists is developing the certification examination. As with other medical professions, the specific scope of practice is determined by state legislation. Generally, however, an RA or an RPA would be permitted to more actively participate in advanced diagnostic procedures including such tasks as injection of contrast media and radioactive isotopes and aspiration of fluids. Although prohibited from making definitive diagnosis, an RA would also be permitted to make initial observations about an image prior to a complete interpretation by a radiologist. A radiology assistant would also be permitted to obtain patient consents and perform pre and post procedure evaluations (Washington State Department of Health, 2005).

Technologists studying for an RA or an RPA are required to complete academic coursework in anatomy, physiology, patho-physiology, radiologic procedures, radiation safety, radiation biology, fluoroscopic procedures, medical-legal, professional and governmental standards, drugs and contrast media, and patient communication, assessment and management [ARRT, 2005]. A radiology assistant will also be required to complete a clinical preceptorship working under a mentoring radiologist and to pass a certification examination. Once certified, the radiology assistant will work under the auspices of a radiologist mostly under general supervision. However, a few procedures will require personal supervision of the radiologist [ARRT Annual Report, 2005].

3. Future Supply

The Bureau of Labor Statistics anticipates employment growth for all imaging technologists. Demand for imaging technologists is expected to increase faster than average through the year 2012 [BLS , O*Net, 2005]. This increased demand is driven by several factors:

- the aging of the population;
- increased demand for diagnostic imaging and therapeutic applications of imaging technology;
- the need to replace departing and retiring workers in the field; and
- technological innovation that will increase demand [BLS, O*Net, 2005].

The Bureau of Labor Statistics also suggests several factors that might moderate demand including the costs associated with imaging studies and the reimbursement policies of insurers [BLS, O*Net, 2005]. Technological innovations may be too expensive for widespread use and insurance companies may mandate limits on their use which ultimately affects demand for professionals.

The Bureau of Labor Statistics also indicates that the number of imaging modalities now in use will alter the professional requirements for technologists. Radiologic technologists who have skills in using the different kinds of imaging technology as well as familiarity with the more complex imaging modalities will be highly employable as providers seek multi-skilled professionals to increase efficiency and control costs [BLS, O*Net, 2005].

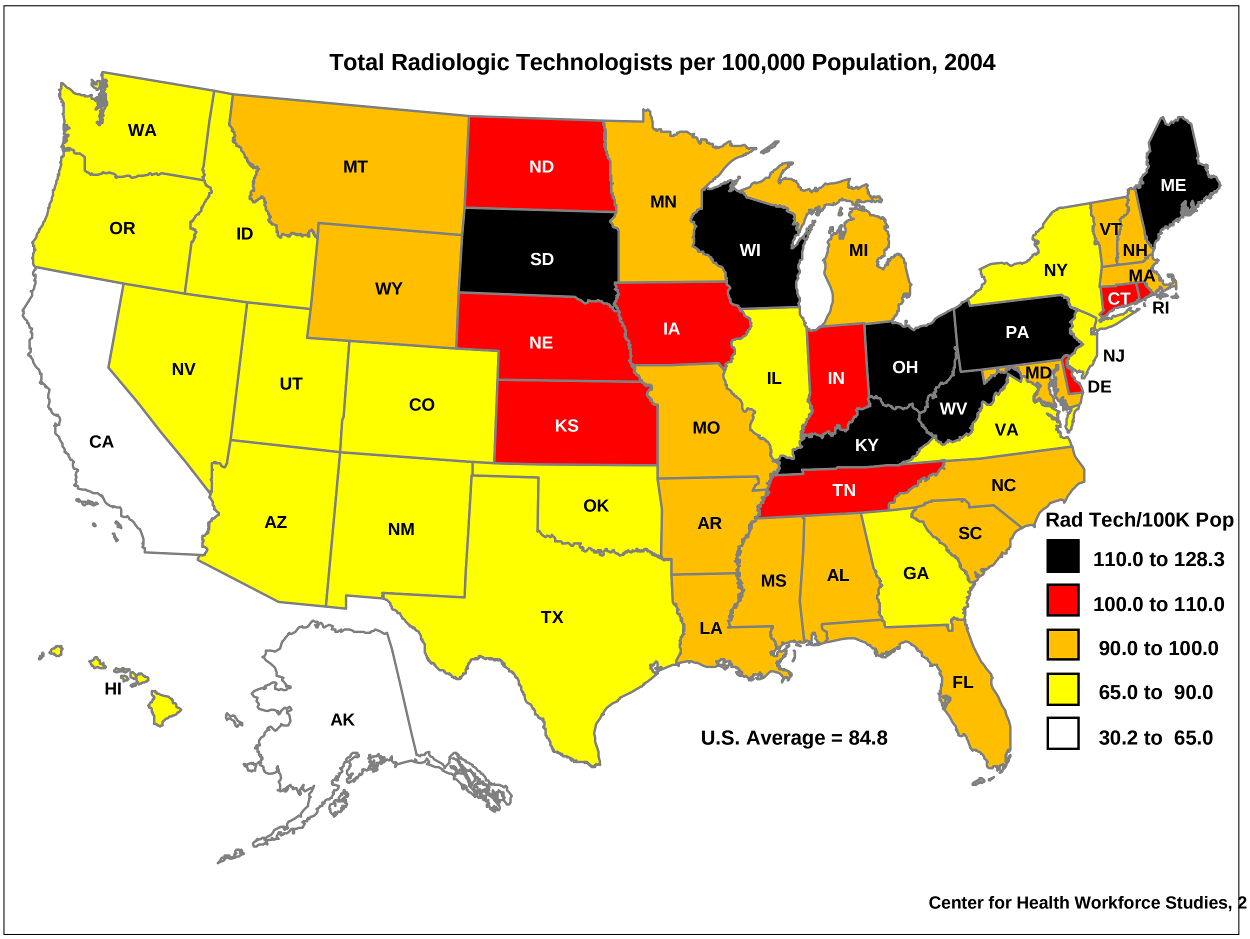
4. Expected Demand

Although there are some states in which the location of technologists mirrors that of radiologists, generally there is no observable correlation (Figure 15). The location of radiologic technologists is generally more directly linked to the location of the technology that they operate rather than to the physicians who read the images. In fact, it has become common practice for health care providers to contract with radiologic group practices not directly employed by the provider to interpret studies. As a result, a single radiologic physician group might conceivably read and interpret studies for a number of health care institutions. This practice is supported by computer systems that permit interpretation of images at a distance from the site of acquisition.

Technologists, however, must be on-site with the machines to provide services directly to patients.

The result of all this is that the future demand for technologists is likely to be more closely related to the location of the patients they serve (and the cameras they operate) than the physicians with whom they work. These patterns may evolve as the organization of imaging practices evolves in the future.

Figure 15. Radiologic Technologists per 100,000 Population in the Fifty States, 2004



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Appendix A. Imaging Residency Programs in the U.S., 2006

The table in this appendix lists the available imaging residency programs by state and by specialty with the number of available slots and the number of filled positions until June 2006 according to the Accreditation Council for Graduate Medical Education.

Table A-1. Numbers of Imaging Residency Programs in the U.S. in the 50 States, 2005

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
Alabama			
Nuclear Medicine	1	0	4
Radiation Oncology	1	8	7
Diagnostic Radiology	3	65	60
Neuroradiology	1	4	4
Pediatric Radiology	1	1	0
Vascular and Interventional Radiology	1	4	1
Total Alabama	**8**	**82**	**76**
Alaska			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Alaska	**0**	**0**	**0**
Arizona			
Nuclear Medicine	0	0	0
Radiation Oncology	1	5	5
Diagnostic Radiology	2	36	38
Neuroradiology	2	7	5
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	0
Total Arizona	**6**	**49**	**48**
Arkansas			
Nuclear Medicine	1	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	28	24
Neuroradiology	1	1	1
Pediatric Radiology	1	1	1
Vascular and Interventional Radiology	1	2	2
Total Arkansas	**5**	**32**	**28**
California			
Nuclear Medicine	8	0	17
Radiation Oncology	8	58	55
Diagnostic Radiology	16	401	369
Neuroradiology	9	25	19
Nuclear Radiology	1	2	1
Pediatric Radiology	5	8	3
Vascular and Interventional Radiology	9	23	22
Total California	**56**	**517**	**486**
Colorado			
Nuclear Medicine	8	0	17
Radiation Oncology	1	6	0
Diagnostic Radiology	1	32	30
Neuroradiology	1	2	0
Pediatric Radiology	1	2	0
Vascular and Interventional Radiology	1	3	3
Total Colorado	**13**	**45**	**50**
Connecticut			
Nuclear Medicine	1	0	1
Radiation Oncology	1	8	7
Diagnostic Radiology	7	100	102
Neuroradiology	1	4	5
Nuclear Radiology	1	3	2
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	2	5	3
Total Connecticut	**13**	**120**	**120**

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
Delaware			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	24	16
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	0
Total Delaware	**2**	**25**	**16**
District of Columbia			
Nuclear Medicine	2	0	3
Radiation Oncology	2	8	8
Diagnostic Radiology	3	48	43
Neuroradiology	2	5	2
Pediatric Radiology	1	4	2
Vascular and Interventional Radiology	3	6	0
Total District of Columbia	**13**	**71**	**58**
Florida			
Nuclear Medicine	1	0	4
Radiation Oncology	2	15	13
Diagnostic Radiology	6	154	146
Neuroradiology	2	7	7
Pediatric Radiology	2	2	1
Vascular and Interventional Radiology	5	19	10
Total Florida	**18**	**197**	**181**
Georgia			
Nuclear Medicine	1	0	6
Radiation Oncology	1	10	11
Diagnostic Radiology	3	84	75
Abdominal Radiology	1	5	4
Neuroradiology	2	8	5
Pediatric Radiology	1	2	0
Vascular and Interventional Radiology	1	5	2
Total Georgia	**10**	**114**	**103**
Hawaii			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	21	19
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Hawaii	**1**	**21**	**19**
Idaho			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Idaho	**0**	**0**	**0**
Illinois			
Nuclear Medicine	3	0	9
Radiation Oncology	4	31	31
Diagnostic Radiology	11	213	182
Abdominal Radiology	1	2	1
Neuroradiology	4	11	0
Nuclear Radiology	1	3	0
Pediatric Radiology	1	3	0
Vascular and Interventional Radiology	5	17	12
Total Illinois	**30**	**280**	**235**

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
Indiana			
Nuclear Medicine	1	0	0
Radiation Oncology	1	7	7
Diagnostic Radiology	1	68	67
Neuroradiology	1	4	2
Pediatric Radiology	1	2	2
Vascular and Interventional Radiology	2	6	3
Total Indiana	**7**	**87**	**81**
Iowa			
Nuclear Medicine	1	0	3
Radiation Oncology	1	7	5
Diagnostic Radiology	1	33	29
Neuroradiology	1	3	2
Pediatric Radiology	1	1	1
Vascular and Interventional Radiology	1	2	0
Total Iowa	**6**	**46**	**40**
Kansas			
Nuclear Medicine	0	0	0
Radiation Oncology	1	4	5
Diagnostic Radiology	2	32	30
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	1
Total Kansas	**4**	**37**	**36**
Kentucky			
Nuclear Medicine	0	0	0
Radiation Oncology	2	10	10
Diagnostic Radiology	2	40	36
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Kentucky	**4**	**50**	**46**
Louisiana			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	4	80	75
Neuroradiology	1	2	1
Pediatric Radiology	1	1	0
Vascular and Interventional Radiology	1	3	1
Total Louisiana	**7**	**86**	**77**
Maine			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	12	14
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Maine	**1**	**12**	**14**
Maryland			
Nuclear Medicine	2	4	6
Radiation Oncology	3	21	22
Diagnostic Radiology	3	96	89
Endovascular Surgical Neuroradiology	1	2	0
Neuroradiology	2	9	8
Pediatric Radiology	1	1	1
Vascular and Interventional Radiology	2	10	6
Total Maryland	**14**	**143**	**132**

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
Missouri			
Nuclear Medicine	3	0	8
Radiation Oncology	1	14	11
Diagnostic Radiology	4	128	133
Endovascular Surgical Neuroradiology	1	2	2
Neuroradiology	2	8	7
Nuclear Radiology	1	5	0
Pediatric Radiology	1	2	0
Vascular and Interventional Radiology	2	7	6
Total Missouri	**15**	**166**	**167**
Montana			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Montana	**0**	**0**	**0**
Nebraska			
Nuclear Medicine	1	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	2	32	30
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	1
Total Nebraska	**4**	**33**	**31**
Nevada			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Nevada	**0**	**0**	**0**
New Hampshire			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	16	16
Neuroradiology	1	1	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	3	3
Total New Hampshire	**3**	**20**	**19**
New Jersey			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	8	105	89
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	0
Total New Jersey	**9**	**106**	**89**
New Mexico			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	21	23
Neuroradiology	1	2	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	0
Total New Mexico	**3**	**24**	**23**

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
New York			
Nuclear Medicine	12	0	33
Radiation Oncology	12	74	75
Diagnostic Radiology	28	577	531
Abdominal Radiology	2	3	2
Musculoskeletal Radiology	3	5	4
Neuroradiology	13	29	21
Pediatric Radiology	5	5	0
Vascular and Interventional Radiology	13	27	13
Total New York	**88**	**720**	**679**
North Carolina			
Nuclear Medicine	0	0	0
Radiation Oncology	3	20	17
Diagnostic Radiology	3	112	107
Abdominal Radiology	1	4	2
Musculoskeletal Radiology	1	4	3
Neuroradiology	3	14	13
Nuclear Radiology	2	4	3
Pediatric Radiology	1	2	0
Vascular and Interventional Radiology	3	9	2
Total North Carolina	**17**	**169**	**147**
North Dakota			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total North Dakota	**0**	**0**	**0**
Ohio			
Nuclear Medicine	1	0	0
Radiation Oncology	4	22	21
Diagnostic Radiology	7	160	152
Endovascular Surgical Neuroradiology	1	1	1
Musculoskeletal Radiology	1	1	1
Neuroradiology	4	9	6
Nuclear Radiology	2	3	0
Pediatric Radiology	4	10	9
Vascular and Interventional Radiology	4	7	4
Total Ohio	**28**	**213**	**194**
Oklahoma			
Nuclear Medicine	1	0	2
Radiation Oncology	0	0	0
Diagnostic Radiology	2	41	41
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	2	0
Total Oklahoma	**4**	**43**	**43**
Oregon			
Nuclear Medicine	1	0	0
Radiation Oncology	1	4	4
Diagnostic Radiology	1	20	21
Neuroradiology	1	2	2
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	3	3
Total Oregon	**5**	**29**	**30**

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
Pennsylvania			
Nuclear Medicine	3	0	9
Radiation Oncology	6	42	44
Diagnostic Radiology	14	316	305
Abdominal Radiology	1	8	6
Cardiothoracic Radiology	1	2	1
Musculoskeletal Radiology	1	1	0
Neuroradiology	7	19	11
Nuclear Radiology	1	5	0
Pediatric Radiology	3	10	3
Vascular and Interventional Radiology	6	23	11
Total Pennsylvania	**43**	**426**	**390**
Rhode Island			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	24	21
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	3	3
Total Rhode Island	**2**	**27**	**24**
South Carolina			
Nuclear Medicine	1	0	1
Radiation Oncology	1	4	4
Diagnostic Radiology	1	28	27
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	3	2
Total South Carolina	**4**	**32**	**34**
South Dakota			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total South Dakota	**0**	**0**	**0**
Tennessee			
Nuclear Medicine	2	0	6
Radiation Oncology	1	4	4
Diagnostic Radiology	5	133	100
Neuroradiology	1	2	1
Pediatric Radiology	1	1	1
Vascular and Interventional Radiology	3	7	2
Total Tennessee	**13**	**147**	**114**
Texas			
Nuclear Medicine	3	0	5
Radiation Oncology	4	36	33
Diagnostic Radiology	8	278	261
Neuroradiology	5	15	9
Nuclear Radiology	1	1	0
Pediatric Radiology	3	7	5
Vascular and Interventional Radiology	7	16	8
Total Texas	**31**	**353**	**321**

State	Number of Programs	Number of Approved Positions	Number of Positions Filled
Utah			
Nuclear Medicine	0	0	0
Radiation Oncology	1	5	5
Diagnostic Radiology	1	20	18
Neuroradiology	1	4	4
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	2	0
Total Utah	**4**	**31**	**27**
Vermont			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	12	14
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	1	1	1
Total Vermont	**2**	**13**	**15**
Virginia			
Nuclear Medicine	1	0	1
Radiation Oncology	3	19	17
Diagnostic Radiology	4	107	85
Neuroradiology	2	7	4
Nuclear Radiology	1	1	1
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	3	8	4
Total Virginia	**14**	**134**	**112**
Washington			
Nuclear Medicine	1	0	3
Radiation Oncology	1	8	2
Diagnostic Radiology	4	84	79
Neuroradiology	1	6	5
Pediatric Radiology	1	3	2
Vascular and Interventional Radiology	1	3	2
Total Washington	**9**	**104**	**93**
West Virginia			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	1	14	13
Neuroradiology	1	1	1
Nuclear Radiology	1	1	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total West Virginia	**3**	**16**	**14**
Wisconsin			
Nuclear Medicine	2	0	4
Radiation Oncology	2	14	16
Diagnostic Radiology	4	80	74
Musculoskeletal Radiology	1	2	0
Neuroradiology	2	6	6
Pediatric Radiology	1	2	0
Vascular and Interventional Radiology	2	5	0
Total Wisconsin	**14**	**109**	**100**
Wyoming			
Nuclear Medicine	0	0	0
Radiation Oncology	0	0	0
Diagnostic Radiology	0	0	0
Neuroradiology	0	0	0
Pediatric Radiology	0	0	0
Vascular and Interventional Radiology	0	0	0
Total Wyoming	**0**	**0**	**0**

Appendix B. Glossary of Terminology

This appendix contains a glossary of terminology related to imaging. It is provided to introduce the reader to a number of commonly used terms in imaging. This glossary is by no means exhaustive. It is intended only as an introduction to imaging science and technology and as clarification of some of the terminology used in this report.

Attenuation Correction is a statistical procedure that assumes the imperfect measurements of variables and determines their true correlation [Wikipedia, 2005]. Attenuation correction in imaging addresses the measurement error from an imaging procedure. Attenuation in PET refers to a loss of gamma ray signal energy due to absorption, divergence, or scatter as the ray moves through the body [MI-central.com, 2005]. During in vivo imaging, tissue density and organ activity can affect image quality with higher degrees of attenuation in bone imaging than in tissue imaging. Attenuation correction improves quantification of images and improves the specificity of the imaging technique. Fused hardware technologies like SPECT/CT provide improved attenuation correction of the images that are obtained [Bucsko, 2004].

Closed-Source Radiation is a sealed source of radiation. In imaging, certain modalities contain closed sources of radiation including X-Ray machines, CT machines, and fluoroscopes.

Computer Aided Detection and Diagnosis (CAD) is computerized technology with the capability to recognize and analyze an image. CAD systems can read digital images or can digitize film media. . This technology is designed to help radiologists detect anomalies in tissue. CAD is being used in mammography to improve detection of breast cancers [VIDAR, 2005].

Computed Axial Tomography (CAT) (CT) uses X-ray to visualize density in tissues [BMC, 2005]. This technology produces a series of detailed two-dimensional X-ray images of a small area of the body along a single axis of the bodily structure. These slices are then integrated through a mathematical process known as tomographic reconstruction to create three dimensional cross sectional images. In CT, the camera rotates around the body while multiple scans are acquired in progression. Scans typically take only a few seconds [Answers.com, 2005]. CT is used extensively in diagnostic studies of tumors and aneurysms, to evaluate changes in lung parenchyma, to image coronary arteries, in diagnosis of a wide range of abdominal diseases, and to image complex bone fractures [Answers.com, 2005]. CT technology produces 8 slice, 16 slice, 32 slice or 64 slice images.

Cross sectional imaging provides a different orientation to body tissue and organs than traditional X-ray. One author described it as viewing a horizontal patient from the perspective of his/her feet [Strickland, 2005]. CT, MRI, and some ultrasound technology produce cross sectional images. Typically, the patient remains completely still as the table moves through a camera with an opening (the gantry) or as the camera rotates around the patient capturing a rapid succession of images.

Fluoroscopy is an imaging technique using a radiologic device called a fluoroscope to examine the function of an organ or a body system. Fluoroscopy differs from X-ray in that a continuous X-ray beam is used to assess an organ in real time. The overall dosage of radiation is generally lower than that required for an X-ray that produces a still film or digital image [Answers.com, 2005]. The technique uses an X-ray tube and a fluorescent screen with the body structure of interest placed between. Fluoroscopy provides live X-rays on a screen permitting a radiologist to view function in real time. It is generally used during the performance of a procedure like cardiac angiography, basketing a kidney stone, or monitoring the esophagus during swallowing [My.webmd.com, 2005]. This instrument can also be coupled with an image intensifier to perform thin needle biopsies of tumors [Abbott Diagnostics, 2005]

Functional Imaging is imaging that evaluates how an organ or body system reacts to a recently administered treatment or tracer. Functional imaging permits the viewer to monitor cellular change and metabolic process in real time. The diagnostic and therapeutic applications of functional imaging continue to grow especially since imaging is less invasive than other diagnostic tools. Glucose utilization in tumor cells is an example of a functional imaging application that is widely used to understand the proliferation of cancer cells and also to evaluate the efficacy of treatment interventions [Bioon.com, 2005].

Gamma Camera is a device used in nuclear medicine studies to detect gamma rays emitted from a patient. The gamma camera consists of several parts including a collimator, scintillation detector, photo multiplier tubes, position logistic circuitry, and a data analysis computer. Gamma cameras are used in nuclear medicine studies, in SPECT, in PET, and in PET/CT studies [Vancouver, 2005]. Gamma cameras are capable of detecting several hundred thousand emissions per second and of locating the XY coordinate of each emission. Gamma cameras then build a spatial image that provides functional information about the human body [Answers.com, 2005].

Gated Imaging is an acquisition protocol that permits imaging of an organ at various stages of functioning. A beating heart can be imaged at a number of points in its contraction by dividing the views into smaller views. In cardiac imaging, for instance, gated studies are accomplished through SPECT studies done in conjunction with an ECG machine that monitors heartbeats [Vancouver, 2005].

Imaging contrast agents are enhancement agents that permit imaging of body structures for different purposes. Three of the most common reasons for using contract agents are 1) to detect location in body organs (anatomic localization), 2) to understand how agents attach to molecules in the human body (receptor localization), or 3) to understand how these agents are activated by specific biochemical or physical conditions and specific enzymes (activatable agents) [Bioon.com, 2005]. Contrast agents may be radioactive or not. Barium is an example of a widely used contrast agent.

In vivo imaging is a study performed in a living organism. In nuclear medicine, in vivo imaging measures the absorption and metabolism of a radiotracer.

In vitro imaging - (literally “in or within glass”) refers to studies done in test tubes, or culture dishes outside a living organism [Wikipedia, 2005]. . Testing is done outside of the human body to examine tissue and cells to understand reaction to an intervention or to diagnose a condition. In vitro imaging is commonly used in pharmaceutical research and in pathology labs.

Magnetic Resonance Imaging (MRI) uses the absorption properties of hydrogen nuclei in conjunction with radio waves, magnetic fields, and computer technology to image body tissues. This machine produces cross sectional two and three-dimensional images that are sometimes enhanced through use of a non-radioactive contrast agent [ASRT, 2005]. MRI is often used in brain imaging because of its high degree of detail. The magnetic properties of blood permit physicians to image blood flow with the MRI [NIDA, 2005].

Mammography is an imaging study using especially designed film and digital X-ray machines to image breast tissue.

Molecular Imaging is high resolution imaging that images specific molecular pathways at the cellular or molecular level. Molecular imaging is used to image molecular and cellular events in living organisms, to study biological process, and to diagnose and manage disease. Newer technologies like PET, SPECT, and optical imaging are technological innovations that permit non-invasive molecular imaging [MI-central.org, 2005].

Nuclear medicine is a medical specialty that uses unsealed radioactive substances for both diagnosis and treatment of patients. These medical specialists use gamma cameras that detect, map, and measure the location of radioactive substances in the human body and produce either two or three-dimensional images for evaluation of patient conditions and efficacy of treatment protocols [Answers.com, 2005].

Open-Source Radiation is an unsealed source of radiation. Radiotracers (radioactive substances with unstable nuclei that decay over a short time period) are an example of an open source application in imaging. Radiotracers are administered to or consumed by a patient and provide information about anatomical function in the body in real time.

Optical imaging uses photons in ultraviolet light that are near the infrared range to create images. The wavelengths that are produced are visible to humans [MI-central.com, 2005]. Much of the research investigating diagnostic applications of optical imaging is in vivo animal studies.

Picture Archiving and Communication Systems (PACS) is a computerized storage and retrieval system that has capabilities for viewing images, reporting findings, and providing remote access to pictures stored on magnetic or optical media. PACS permits storage at the local level but also provides interface to wider information network systems for access by a number of users [VIDAR, 2005]. Some PACS systems are also equipped with voice recognition technology.

Planar Imaging is an acquisition protocol in imaging in which the detector camera or device remains stable during the imaging process producing two-dimensional images at a single angle. Traditional X-ray and most bone scans are planar imaging studies [Vancouver, 2005].

Positron Emission Tomography (PET) measures emissions from radioactively labeled drugs or analogues of natural compounds like glucose that have been injected in, inhaled by, or ingested by a patient. PET technology employs gamma cameras sensitive to gamma ray emissions. PET studies are generally more versatile than SPECT studies requiring less time and lower doses of radiotracers to image blood flow, oxygen and glucose metabolism and drug concentration in tissues. The radiotracers used in PET have short half-lives necessitating a cyclotron in close proximity to the equipment. SPECT studies may be the preferred application for some imaging studies since they are less costly and more widely available. SPECT tracers are also longer lasting and do not require a cyclotron in close proximity for production [NIDA, 2005]. PET and SPECT both produce images of functional processes in the human body [Wikipedia, 2005].

Radiation Therapy uses ionizing radiation to treat both malignant and benign medical conditions. Therapy may occur as a course of treatment on a daily, weekly, or monthly basis [ASRT, 2005].

Radiographs or X-Rays are the most well known of imaging modalities. The X-ray modality uses equipment with radioactive source material. X-rays are performed to examine skeletal and bone injury and used, with certain dyes, to examine diseased tissue such as in the intestine or lungs [Answers.com, 2005].

Radioisotope is a naturally occurring or artificially created isotope of an element with an unstable nucleus that decays until stability is achieved. During decay, alpha, beta or gamma rays are emitted. After decay is complete, the end product is a stable non-radioactive isotope of another element. Many materials contain traces of radioactive isotopes [Answers.com].

Radiology Assistant/ Radiology Practitioner Assistant is an advanced practice radiologic technologist who has completed the requisite didactic and clinical training for certification. The radiology assistant typically works under the general supervision of a radiologist except when performing certain specialized procedures that require the personal supervision of the radiologist [ARRT (a), 2005].

Radiology Information System (RIS) is a computerized information system designed for use in a radiology department. The system may include film/chart tracking, management reports, and a scheduler among other applications [VIDAR, 2005].

Radionuclides are atoms with unstable nuclei. Radionuclides of a variety of compounds with various half-lives are also called radioactive isotopes. Radionuclides are often chemically bound to a complex, like glucose, that acts within the human body and has affinity for preferential uptake in certain areas of the body. For instance, some compounds seek bone while others travel to the heart. Each radionuclide has a unique gamma-ray emission energy spectrum and gamma cameras can limit the emissions that are measured during an imaging study to a particular part of that spectrum. Radionuclides are consumed by a patient and have no effect on the patient dissipating within a relatively short time period. Radionuclides permit the imaging of body functions using gamma cameras that detect and measure the emissions from the patient. Depending on the half-life of the compound selected, a cyclotron located relatively near the imaging center may be needed to produce the radionuclide [Answers.com, 2005].

Radiopharmaceuticals are pharmaceuticals labeled with a radioisotope used to treat diseases such as thyroid disease [Answers.com, 2005].

Radiotracers are identifiable substances with radioactive properties that are used to follow the course of a physical, chemical or biological process [Answers.com, 2005].

Single Photon Emission Computed Tomography (SPECT) like PET measures gamma ray emissions from a patient who has consumed a radiotracer for purposes of imaging. SPECT, however, measures single photon gamma ray emissions through a camera while PET measures double gamma ray emissions. This technology employs a rotating camera to produce three-dimensional merged images or gated studies that capture information about anatomical function in a particular body or organ system [Vancouver, 2005]

Sonography (also known as ultrasonography) is the use of non-ionizing high frequency sound waves to image internal structures for diagnosis of disease or injury [BLS (b), 2005; ASRT (b), 2005]

Teleradiology involves the electronic transmission of images from a diagnostic or therapeutic radiology study to a user at another location for purposes of interpretation or consultation. These images may be transmitted over a distance by satellite or through local area networks [VIDAR, 2005].