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Neuroradiology

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Assessment:

After deciding to shift topics to neuroradiology and beginning to research the field, my interest is continually growing. Neuroradiology focuses on the imaging of the central nervous system, spine, head, and neck. Although neuroradiologists are responsible for interpreting images of and performing procedures on less body parts than body imaging diagnostic radiologists, the few areas of the body that are studied in neuroradiology are more complex and can have more issues than the rest of the body. Studying and interpreting the brain and other parts of the nervous system sounds more interesting to me than looking at images of other body parts. Also, I was not comfortable with the idea of performing some of the interventional procedures that diagnostic radiologists complete, but the procedures that are performed by neuroradiologists and specifically neurointerventional surgeons sound like something that I could handle doing.

The most useful techniques in neuroradiology are magnetic resonance imaging (MRI) and computed tomography (CT). This is due to the fact that images from MRI scans show the brain much more clearly than other types of imaging since MRI focuses on tissues and the brain is not covered by brightly colored bones. Using MRI in neuroradiology is a good idea because MRI does not use radiation, so patients are safer in an MRI machine than in other imaging machines. A specific form of MRI that is used in neuroradiology is functional MRI or fMRI. fMRI allows neuroradiologists to focus in on a specific portion of the brain and observe the occurrence of metabolic processes. This is different from normal MRI, which is used to image anatomical parts of the body rather than the physiological side. fMRI seems like it plays a large part in diagnosis by neuroradiologists because it uses contrast material to observe where basic processes of the brain and other parts of the body are going wrong. Once a radiologist can tell where the issue is coming from, it becomes easier to diagnose and possibly fix. PET scans are also used to observe metabolic processes, but must be used alongside CT or MRI scans. This brings to mind the question of why PET scans are used instead of fMRI in certain scenarios. The requirement of two methods of scanning to reach a diagnosis compared to one seems unnecessary.

A major benefit of neuroradiology compared to regular diagnostic radiology is the low amount of radiation that patients are exposed to. Since x-rays are almost never used in neuroradiology, there is not much risk of radiation exposure from them. MRI and fMRI are the most used techniques, and they do not include any radiology. Whereas CT in body imaging typically exposes a patient to a high amount of radiology that can lead to the development of cancer, the risk of carcinogenic effects in neuroradiology is very low. Interventional procedures allow slightly more exposure, but can end up being lifesaving, and the small risk is typically worth it in the end. Overall, neuroradiology seems much safer radiation-wise than diagnostic radiology and it is a better choice of topic for me.

Neuroradiology

Definition

Neuroradiology is a subspecialty of diagnostic radiology that makes use of various diagnostic and interventional techniques to evaluate and treat conditions of the central nervous system (brain and spinal cord), spine, head, and neck.

Description

Historical background

Radiology as a medical specialty began with the discovery of x-rays in 1895 by Wilhelm Roentgen (1845–1923), a German physicist who was awarded the first Nobel Prize in Physics for this discovery in 1901. The earliest radiological studies of the central nervous system were radiographs of the skull that were performed to evaluate brain tumors. Ventriculography, a technique for improving radiographic visualization of structures inside the brain by injecting air into the ventricles of the brain through holes drilled in the skull, was developed in 1918 by Walter Dandy (1886–1946). Ventriculography was followed in 1927 by arteriography, which was a technique for studying the arteries of the brain by injecting a contrast material through a catheter inserted into the femoral artery in the thigh and threading upward until it reached the carotid artery. A series of radiographs were taken as the contrast material spread through the arteries of the brain. Arteriography was developed by Egas Moniz (1874–1955), a Portuguese neurologist. The first doctor hired as a full-time neuroradiologist was Cornelius Dyke (1900–1943), who took the specialized position at the Neurological Institute in New York City in 1930.

It was not until the 1960s that neuroradiology became a distinctive subspecialty within diagnostic radiology. Juan Taveras (1919–2002), a radiologist from the Dominican Republic who had joined the Neurological Institute, developed the first neuroradiology fellowship program sponsored by the National Institutes of Health (NIH) in 1960. A second fellowship program quickly followed at the Albert Einstein College of Medicine in

the Bronx. In 1962, Taveras gathered a group of 14 neuroradiologists from Canada and the United States at a dinner meeting to form what is now the American Society of Neuroradiology (ASNR).

Taveras was also instrumental in recognizing the importance of the new imaging technologies that emerged in the 1970s, particularly computed tomography (CT) scanning, which was developed at the Maida Vale Hospital in London in 1971 and brought to the United States in 1973, and magnetic resonance imaging (MRI), which came along in the late 1970s and early 1980s. These technologies not only allowed neuroradiologists to diagnose and treat disorders of the brain that could not be detected by the older techniques of radiography (such as multiple sclerosis and other disorders of the white matter of the brain), but they were also much less invasive and could be repeated as often as needed to monitor injuries to brain tissue caused by trauma, infection, or metabolic disorders. CT and MRI also allowed neuroradiologists to start treatment much more rapidly, with improved outcomes for the patients. Further refinements of these technologies have allowed for such advances as direct imaging of the blood flow in the arteries of the brain without the need to inject contrast materials.

Current subspecialties

As of 2017, neuroradiology has developed some subspecialties of its own:

- **Interventional neuroradiology. Interventional radiologists treat as well as diagnose various disorders of the central nervous system using minimally invasive techniques. This subspecialty is also known as neurointerventional surgery. Radiologists in this subspecialty frequently treat disorders of the blood vessels in the brain and take tissue biopsies.**
- **Pediatric neuroradiology. Pediatric neuroradiology is the subspecialty that diagnoses and treats disorders of the central nervous system in children.**

Imaging modalities

Neuroradiologists have a range of imaging modalities available for use as of 2011:

- **Conventional radiography.**
- **CT scans. Also known as computed axial tomography, CT is an imaging technique in which a computer synthesizes data from a large series of two-dimensional x-ray**

images taken around a single axis of rotation to generate a three-dimensional image of internal organs.

- **MRI. MRI is an imaging technique, first used on humans in 1977, that aligns the magnetic nuclei (especially protons) of the patient in a strong uniform magnetic field. The nuclei absorb energy from tuned radio frequency pulses and emit radio frequency signals as their excitation decays. The signals are converted into a series of tomographic images; these images can be constructed because the protons in different tissues return to their equilibrium state at different rates. MRI is particularly useful for imaging tissues like those in the brain, which have little density contrast. Unlike CT scanning, MRI does not involve the use of radiation.**
- **Functional MRI (fMRI). Functional magnetic resonance imaging is a refinement of MRI that allows radiologists to detect and measure metabolic changes taking place in a specific area of the brain. These changes are reflected in increased blood flow to active areas of the brain. The differences in the rate of blood flow can be measured by evaluating the relative levels of oxygenated and deoxygenated hemoglobin in the blood flowing through the vessels. The magnetic resonance signal of blood differs according to the level of oxygenation.**
- **Ultrasound. Ultrasound is a diagnostic method that uses high-frequency sound waves to create images of the body's internal structures. The echoes of the sound waves are displayed in real time on a computer screen. Also known as sonography, ultrasound does not involve the use of radiation.**
- **Discography. Discography is a technique for investigating whether a disk in the spinal column is the source of the patient's back or neck pain by injecting a contrast material directly into the disk. It is usually followed by a CT scan.**
- **Positron emission tomography (PET). A PET scan is an imaging technique in which a radioactive tracer that emits subatomic particles called positrons is given to the patient. The concentrations of the tracer within body tissues are combined by computer analysis to form three-dimensional images. PET scans are typically used to evaluate the body's metabolic processes (the biochemical functioning of the organ or tissue). They are often done alongside CT or MRI scans, which yield information about the anatomy of the structures. To obtain this information about structure and function at the same time, most PET scans as of 2017 are performed with combined PET/CT machines.**

- **Single-photon emission computed tomography (SPECT). SPECT is an imaging technique similar to CT scanning that uses gamma rays instead of x rays to create the image. A radioisotope that emits gamma rays is injected into the patient's bloodstream. It is selectively absorbed by the organ or structure to be imaged. A gamma camera is then rotated around the patient to capture the images. As of 2017 some manufacturers are making combined SPECT/CT units that can perform both types of scan at the same time.**

Conditions diagnosed or treated

Neuroradiologists detect and treat disorders of the brain, head, neck, and spine. The imaging techniques used most often are CT and MRI imaging, with less frequent use of ultrasound and plain radiography. The conditions investigated and treated by neuroradiologists, and the procedures they employ, include the following:

- **Abnormalities and disorders of the spine. These can be detected by myelography followed by a CT scan. Myelography is a technique in which a contrast material is injected into the cerebrospinal fluid within the spinal cord and subjected to x-rays. The technique can be used to detect herniated spinal disks, tumors of the spine, or narrowing of the spinal column.**
- **Biopsies of the skull, scalp, bone, or spine. Neuroradiologists use CT scanning and a fluoroscope to guide them while removing samples of tissue after administering a local anesthetic.**
- **Disorders of the arteries in the brain. Neuroradiologists use cerebral angiography to diagnose aneurysms (bulges or weakened areas in the arterial wall that may rupture); arteriovenous malformations; narrowing of the arteries in the brain caused by atherosclerosis; and identifying cerebral arteries that are feeding a brain tumor. Cerebral angiography can also be used to monitor the effectiveness of stent placement and other treatments.**
- **Disorders of the central nervous system. Neuroradiologists diagnose various central nervous system disorders by administering spinal taps, which involve injecting medications or contrast materials directly into the spinal cord.**

Interventional neuroradiologists frequently treat disorders of the blood vessels in the head and neck. They are trained to perform the following procedures:

- **Aneurysm coil embolization. Aneurysms are bulges or weak spots in a cerebral artery that can rupture and cause severe headache or even death. An interventional neuroradiologist can embolize (block off) an aneurysm by threading a catheter into the artery and inserting one or more platinum coils. The artery forms a blood clot (embolus) around the coils, sealing off the aneurysm and greatly reducing the risk of rupture. Embolization can also be used to treat congenital arteriovenous malformations (AVMs) and severe nosebleeds that do not respond to other therapies. In the case of nosebleeds, small particles of gelfoam may be used as well as platinum coils.**
- **Stroke therapy. After using a CT scan or CT angiography, an interventional radiologist can insert a catheter into the blocked cerebral blood vessel to deliver a clot-busting drug in patients who have reached the hospital within six hours after the stroke. They can also use various devices (e.g., Merci or Penumbra) to retrieve the clot from inside the vessel.**
- **Angioplasty and stent placement. Angioplasty is a procedure in which a blood vessel is reopened or restructured. An interventional neuroradiologist can perform an angioplasty by using an imaging technique to guide a balloon-tipped catheter into a blocked artery or vein to the point of blockage. The balloon is then inflated to reopen the vein, after which it is deflated and the catheter removed. To ensure that the blood vessel remains open, the neuroradiologist may place a stent, which is a wire tube or other tube-like device inserted to keep the blood vessel open permanently.**
- **Treatment of head and neck tumors.**
- **Treatment of vasospasm. Vasospasm is a condition in which a blood vessel suddenly constricts, shutting off blood flow to a body part or organ. It can lead to stroke if it occurs in one of the arteries of the brain. An interventional neuroradiologist can confirm a diagnosis of vasospasm with an angiogram and then treat it by either balloon angioplasty or a dose of intra-arterial verapamil (Isoptin) or nimodipine (Nimotop).**

Pediatric neuroradiologists diagnose and treat the following central nervous system disorders in fetuses, newborn infants, and young children:

- **Aneurysms and arteriovenous malformations in the brain**
- **Disorders that affect the development of the brain in children**
- **Responses of brain tumors to chemotherapy and radiation therapy**

- **Epileptic seizures**

KEY TERMS

Benign—

In medicine, a condition that is not harmful.

Central nervous system—

The part of the nervous system that includes the brain and spinal cord.

Computed tomography—

A type of x-ray in which a three-dimensional picture of the head is created by scans done at many different angles. The data are combined to produce a detailed, cross-sectional image.

Magnetic resonance imaging—

Imaging that uses magnetic fields and radio waves instead of x-rays. The imaging data is processed by computer software to provide detailed images.

Neurologist—

A physician specialized in treatment of diseases and disorders affecting the brain and spinal cord.

Paralysis—

Loss of muscle function.

Like adult interventional neuroradiologists, pediatric neuroradiologists can perform angioplasty, embolization, and other endovascular procedures that eliminate the need for invasive surgery.

Educational requirements and certification

To practice neuroradiology, a person must hold an MD or DO (doctor of osteopathy) degree from an accredited medical school and complete a year of internship, followed by four years of residency in radiology. At this point most candidates will take the board

examination of either the American Board of Radiology (ACR) to earn an MD, or the American Osteopathic Board of Radiology to earn a DO.

Following board certification, the radiologist will enter a fellowship program approved by the Accreditation Council for Graduate Medical Education (ACGME) in order to specialize in neuroradiology. According to the ACGME, there are 85 accredited fellowship programs in neuroradiology for the academic year 2011–12, with 252 on-duty residents enrolled. Most fellowship programs are one year in length, although interventional neuroradiologists may take an additional year of training. After completing the fellowship and an additional year in practice, the neuroradiologist is eligible to take an examination for the Certificate of Added Qualification (CAQ) from the American Board of Radiology.

QUESTIONS TO ASK YOUR DOCTOR

- **Why do I need neuroradiology?**
- **Can you explain how the treatment will be done?**
- **Are there risks to the treatment?**
- **Will there be a recovery period following the neuroradiology?**
- **What is my prognosis?**
- **What are the benefits and hazards of the surgery?**
- **How many of these surgeries have you done?**
- **How many of the surgeries have had complications?**
- **How long will I be hospitalized after the surgery?**
- **What will my recovery be like?**
- **Is my condition life threatening?**

Safety concerns

The growing use of imaging techniques that use radiation (radiography, CT scans, PET, and SPECT) has led to concern about the possible long-term effects (particularly the increased risk of cancer) of exposure to radiation. This concern is particularly acute in patients whose conditions may require repeated x-rays or CT imaging to monitor the effectiveness of therapy. It is important to keep in mind that people are exposed to background radiation from cosmic rays and radioactive materials in the earth in their

everyday lives. The amount of background radiation varies somewhat with geographic location; people living on the high plateaus of the Four Corners region of the Southwest receive more radiation than those living in other parts of North America at sea level. In addition, frequent fliers receive additional small doses of cosmic rays during each airplane trip; however, on the whole, the dose of radiation from one chest x-ray is about the same as that received from background radiation in ten days.

The long-term risks of developing cancer from CT scans of the central nervous system are considered low for one CT scan of the spine and very low for one CT scan of the head. Interventional neuroradiology, by contrast, makes much more extensive use of radiation than diagnostic neuroradiology, particularly for such complex procedures as balloon angioplasty and stent placement, or embolization of AVMs. These procedures are often lifesaving, and the long-term risks of cancer from exposure to radiation are secondary. Patients should discuss with their doctors the risks and benefits of diagnostic imaging and treatments that require exposure to radiation. Ultrasound and MRI can be used for some interventional procedures, and these approaches do not involve radiation.