2.2: Non-Invasive Techniques: Structural Imaging

Learning Objectives

1. Explain how X-rays, CT scans, and MRI scans differ.
2. Describe the pros and cons of the three main structural imaging techniques.

Overview

Structural imaging techniques typically come in three different options: X-rays, computed tomography (CT) or computed axial tomography (CAT) scans, and magnetic resonance imaging (MRI) scans. Each uses different types of technology to provide a representation of a structure without having to remove the skin or bone that protects that structure. Each of these non-invasive techniques has advantages and disadvantages.

X-Rays

German physicist Wilhelm Röntgen (1845–1923) was experimenting with electrical current when he discovered that a mysterious and invisible “ray” would pass through his flesh but leave an outline of his bones on a screen coated with a metal compound. In 1895, Röntgen made the first durable record of the internal parts of a living human: an “X-ray” image (as it came to be called) of his wife’s hand. Scientists around the world quickly began their own experiments with X-rays, and by 1900, X-rays were widely used to detect a variety of injuries and diseases. In 1901, Röntgen was awarded the first Nobel Prize for physics for his work in this field.

The X-ray is a form of high energy electromagnetic radiation with a short wavelength capable of penetrating solids and...
ionizing gases. As they are used in medicine, X-rays are emitted from an X-ray machine and directed toward a specially treated metallic plate placed behind the patient’s body. The beam of radiation results in darkening of the X-ray plate. X-rays are slightly impeded by soft tissues, which show up as gray on the X-ray plate, whereas hard tissues, such as bone, largely block the rays, producing a light-toned “shadow.” Thus, X-rays are best used to visualize hard body structures such as teeth and bones. Figure \(\PageIndex{1}\) depicts an X-ray of a knee. Like many forms of high energy radiation, however, X-rays are capable of damaging cells and initiating changes that can lead to cancer. This danger of excessive exposure to X-rays was not fully appreciated for many years after their widespread use.

Figure \(\PageIndex{1}\): X-Ray of a Knee: High energy electromagnetic radiation allows the internal structures of the body, such as bones, to be seen in X-rays like these.

Due to the development of other techniques that are considerably better at looking at soft tissue, X-rays are largely not used for studying the brain anymore.

**Modern Medical Imaging**

X-rays can depict a two-dimensional image of a body region, and only from a single angle. In contrast, more modern medical imaging technologies produce data that are integrated and analyzed by computers to produce three-dimensional (3D) images or images that reveal aspects of the body functioning.

**Computed Tomography**

Tomography refers to imaging by sections. **Computed (or computerized) tomography (CT)** is a noninvasive imaging technique that uses computers to analyze several cross-sectional X-rays in order to reveal small details about structures in the body. The technique was invented in the 1970s and is based on the principle that, as X-rays pass through the body, they are absorbed or reflected at different levels. In the technique, a patient lies on a motorized platform while a
computerized axial tomography (CAT) scanner rotates 360 degrees around the patient, taking X-ray images. Figure \(\PageIndex{2}\) shows a CT scanner with a platform for the subject to lie on. A computer combines these images into a two-dimensional view of the scanned area, or “slice.” Figure \(\PageIndex{3}\) shows a series of slices of the brain for one subject.

![Figure \(\PageIndex{2}\): A CT scanner at the University of Pittsburg Medical Center East.](image)

![Figure \(\PageIndex{3}\): A series of axial CT scans of the brain of one subject. Each image is a slice of the brain starting with a bottom slice and incrementally moving to higher and higher slices.](image)

Since 1970, the development of more powerful computers and more sophisticated software has made CT scanning routine for many types of diagnostic evaluations. It is especially useful for soft tissue scanning, such as of the brain and the thoracic and abdominal viscera. Its level of detail is so precise that it can allow physicians to measure the size of a mass down to a millimeter. The main disadvantage of CT scanning is that it exposes patients to a dose of radiation many times higher than that of X-rays. Whether this is particularly dangerous is still being debated (McCollough et al., 2015).

### Magnetic Resonance Imaging

**Magnetic resonance imaging (MRI)** is a noninvasive medical imaging technique based on a phenomenon of nuclear physics discovered in the 1930s, in which matter exposed to magnetic fields and radio waves was found to emit radio
signals. In 1970, a physician and researcher named Raymond Damadian noticed that malignant (cancerous) tissue gave off different signals than normal body tissue. He applied for a patent for the first MRI scanning device, which was in use clinically by the early 1980s. The early MRI scanners were crude, but advances in digital computing and electronics led to their advancement over any other technique for precise imaging, especially to discover tumors. MRI also has the major advantage of not exposing patients to radiation.

Drawbacks of MRI scans include their much higher cost, and patient discomfort with the procedure. The MRI scanner subjects the patient to such powerful electromagnets that the scan room must be shielded. The patient must be enclosed in a metal tube-like device for the duration of the scan, sometimes as long as thirty minutes, which can be uncomfortable and impractical for ill patients. The device is also so noisy that, even with earplugs, patients can become anxious or even fearful. These problems have been overcome somewhat with the development of “open” MRI scanning, which does not require the patient to be entirely enclosed in the metal tube. Figure 4 shows an MRI machine with a platform for the patient to lie on. Patients with iron-containing metallic implants (internal sutures, some prosthetic devices, and so on) cannot undergo MRI scanning because it can dislodge these implants.

Figure 4: An MRI machine.

Using Structural Imaging Techniques to Study a Disorder: Autism Spectrum Disorder

One example that we will use throughout this chapter is that of how we use these research techniques to study Autism Spectrum Disorder (ASD). ASD is a developmental disorder frequently characterized by issues including various combinations of interaction issues, communication difficulties, and even repetitive behaviors. Throughout each section, we will discuss some of the ways the main tools of brain research have been used to examine this disorder.

Structural imaging techniques with ASD have focused on which brain structures have physical differences. MRIs have found a thicker frontal cortex (Carper & Courchesne, 2005) and a thinner temporal cortex (Hardan et al., 2006) in patients with ASD. These areas are notable because the frontal cortex is linked to communication and language abilities and the temporal cortex is linked to auditory processing (ie. language input), both of which are issues that many with ASD struggle with.

Summary

Structural imaging techniques, including X-rays, CT scans, and MRIs, allow researchers to get a look at what the brain
looks like without having to do anything invasive to the patient, like surgery. These techniques, particularly CT scans and MRIs are extremely useful in constructing an image of what the brain looks like and allow doctors to detect any structural abnormalities in their patients. They also allow researchers to learn about the sizes of different structures in the brain and possibly correlate those differences to various functions.

References


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