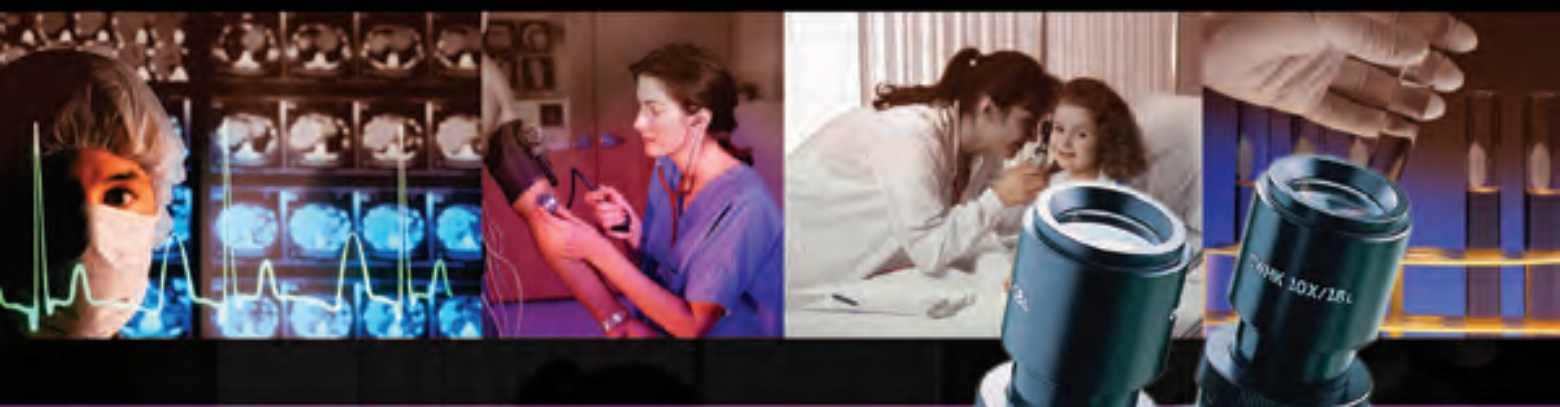
Laboratory Tests & Diagnostic Procedures in Medicine

John H. Dirckx, M.D.



Health Professions Institute

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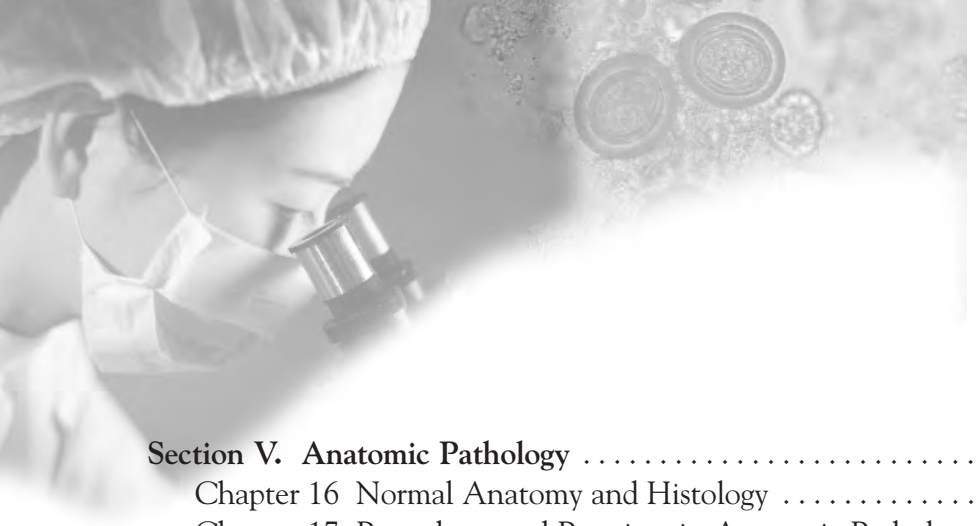
For my daughter Janet,

with love

Contents



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Preface

The purpose of this book is to bring together, in a single reference work, useful information on the broad range of special diagnostic examinations and laboratory tests that form an integral part of modern medicine. The book is designed for the use of medical transcriptionists and other professional handlers of health-care records and data, including legal and insurance personnel, technical writers and editors, and journalists.

Material is included here on six principal types of diagnostic procedure: physical measurements, electrodiagnostics, endoscopy, medical imaging, anatomic pathology, and clinical pathology. For each test or procedure, sufficient information is provided about methodology, indications or purposes, and range of results to enable the reader to recognize pertinent terminology and to grasp the general sense of a report. Because the book is intended for persons who are charged neither with performing diagnostic procedures nor with interpreting their results, details and technicalities that are irrelevant for that audience have been rigorously excluded. Normal ranges and other interpretive data are given solely for purposes of orientation or clarification and should not be applied to actual test results.

The style of presentation presupposes some basic knowledge of medicine, including particularly human anatomy, physiology, and pathology, as well as some familiarity with the terminology of those fields. Procedures have been grouped or classified principally by method or technical basis, and only secondarily by body system or type of disease.

The organization of material follows a logical developmental sequence so as to render the work suitable for use as a textbook. The workbook format is intended to augment and enhance the student's learning experience, whether the book is used for independent study or as an adjunct in a formal academic course. Because each division (sections, chapters, and discussions of individual tests) is more or less self-contained, the book can also be used strictly as a reference work. Cross-references between chapters have been kept to a minimum. The resulting occasional repetition of material already presented in a previous section provides an automatic review and reinforcement of learning when the book is read as a text.

It is a pleasure to acknowledge Sally Pitman's encouragement and technical support at every stage of the preparation of this book and to thank Ellen Drake for making valuable suggestions and for preparing the exercises and answer keys. Special thanks to Linda Campbell for compiling the table of normal lab values and helping the artist select appropriate medical images for graphic design.

Art Acknowledgments

Illustrations of anatomy of the heart, conducting system of the heart, sample electrocardiogram with intervals, respiratory system, fiberoptic bronchoscopy, digestive system, gastroscope, cystoscope, cerebral circulation, coronary circulation, and karyotype are reprinted with permission from ***Melloni's Illustrated Medical Dictionary***, 4th ed. (London: The Parthenon Publishing Group, 2002).

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Brian Mullan, M.D., Univ. of Iowa's *Currents Magazine*, and Virtual Hospital, **http://www.vh.org**

Greggory R. DeVore, M.D, **http://www.fetalecho.com**

J. Hornak, **http://www.cis.rit.edu**

Imaginis Corporation: **http://imaginis.com/cancer/cancer_medicalimaging.asp**

P. Gregory, Biology Laboratory Specialist at Tyler Junior College, **http://science.tjc.edu/images/histology/epithelium.htm**; tubular glands from Betsy Ott, Tyler Junior College, Tyler, TX, at the same site.

Clinical Chemistry and Hematology Laboratory, Wadsworth Center, NY State Dept. of Health; **http://www.wadsworth.org/chemheme**

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Finally, the cover and artistic graphic designs throughout the book were provided by Parks Printing, Modesto, CA.

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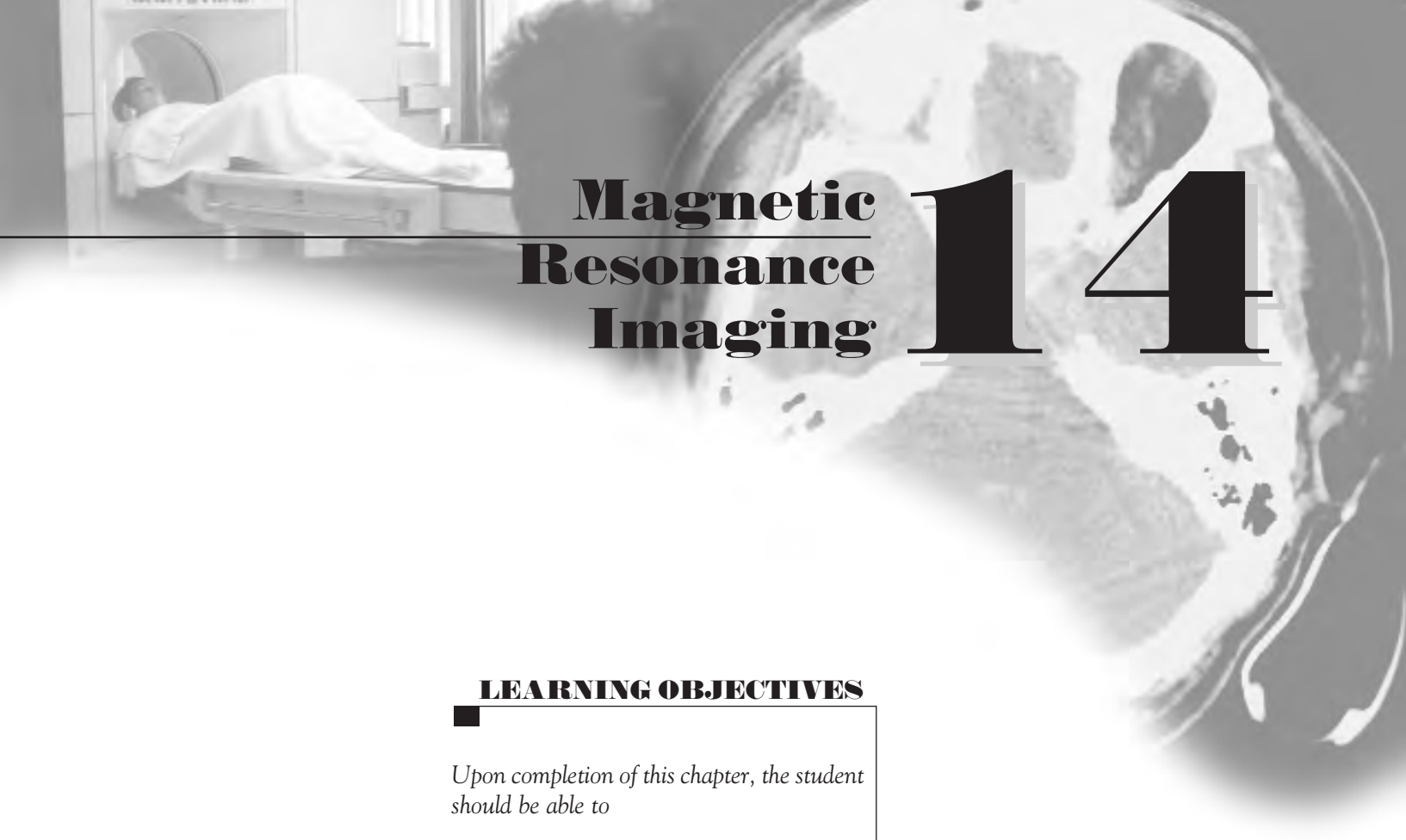


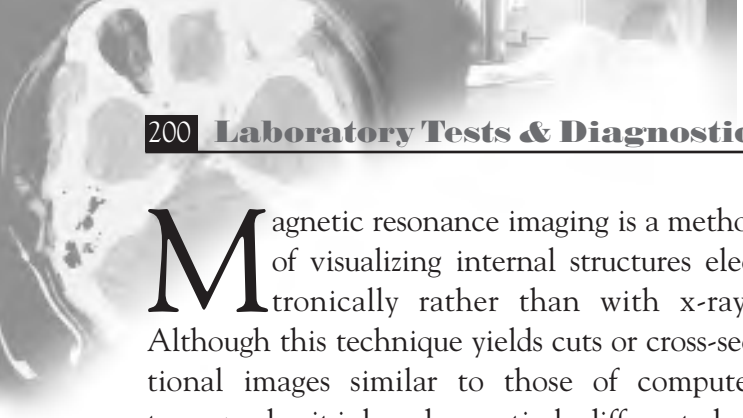
Magnetic Resonance Imaging 14

LEARNING OBJECTIVES

Upon completion of this chapter, the student should be able to

- Give a general explanation of how magnetic resonance imaging works;
- State some of the advantages and limitations of this diagnostic method;
- Mention some special MRI examinations.

Chapter Outline



Magnetic resonance imaging is a method of visualizing internal structures electronically rather than with x-rays. Although this technique yields cuts or cross-sectional images similar to those of computed tomography, it is based on entirely different physical principles.

As with x-ray and ultrasound, MRI detects and records differences in the physical properties of contiguous or adjacent tissues—for example, bone as contrasted with muscle, or normal liver as contrasted with a cyst. But whereas an x-ray examination detects varying resistance of tissues to penetration by x-rays, and ultrasonography detects varying resistance to penetration by sound waves, MRI detects varying concentrations or densities of hydrogen atoms (protons) in tissues.

A magnet attracts not only iron atoms but also any other atoms that, like iron, have an unequal number of protons and neutrons in their nuclei. The degree to which such an atom responds to magnetic attraction depends on its nuclear structure and is expressed as a physical constant called **spin**.

The simplest of all atoms is that of hydrogen, which, with but a single proton in its nucleus, possesses spin and responds to magnetic attraction. If the human body is placed in a static magnetic field of sufficient strength, then a significant number of its hydrogen atoms align themselves with the field like trillions of infinitesimal compass needles.

In an MRI examination, the patient is placed inside a static magnetic field generated by a large, powerful magnet. A pulse of radio waves (excitation pulse) is then used to create, for a brief period, a second magnetic field at a right angle to the static field. While this second field is acting on the body, the hydrogen ions (protons) change their orientation, and when the second field is turned off, they go back to their previous orientation to the static magnetic field.

As the protons return to their previous orientation, they give off a stream of radiofrequency energy or "signal," which can be detected by a suitably placed receiving coil. The intensity of the signal given off by any tissue is proportional to the hydrogen ion concentration (or proton density) of that tissue. Muscle emits a very high signal, bone a very low one, air or gas almost none.

The time it takes for the protons to return to their former orientation after an excitation pulse is called the spin-lattice relaxation time, abbreviated as T1 (the Greek letter *tau*). This time interval, a fraction of a second, is directly proportional to the hydrogen ion density or proton density (PD) of the sample. The greater the proton density of the tissue examined, the greater the delay in returning to the previous orientation, and the longer the T1.

When the excitation pulse is applied, the protons in the sample respond together, or in phase, as they take up their new orientation. After the excitation pulse ceases, but before all the protons have come back to their former orientation to the static magnetic field, they tend to get out of phase with each other, as adjacent molecules collide. Once the protons go out of phase, a signal can no longer be detected by the receiving coil. The time it takes for the protons to go out of phase is called the spin-spin relaxation time, or T2. Obviously T2 is always shorter than T1.

Because both T1 and T2 vary in proportion to the proton density of the sample, they can be used by a computer to generate an image of the sample. However, direct measurement of T1 is not possible, since the signal is lost as soon as the protons go out of phase. There are also technical obstacles to the precise measurement of T2. Some of these obstacles are eliminated by the **spin echo technique**, in which the excitation pulse is followed, after a brief interval, by a second and stronger pulse. This results in the generation

of an echo signal, from which T2 can be determined. The time that elapses between the first pulse and the appearance of the echo is called the **echo time** (TE).

In order to obtain cross-sectional images, it is necessary to modify the magnetic resonance system by adding yet a third magnetic field. This **gradient magnetic field**, created by a separate coil, introduces a positional element into the signals detected by the receiver. A computer decodes and analyzes the signals, generating two-dimensional cross-sectional images of the subject in much the same way that CT images are produced *(see Fig. 14.1)*. The series of images or slices generated are displayed on a screen and recorded on film. As with CT, images are oriented as if the subject were supine and the observer were at the subject's feet.

The intensity of the signal emitted by various tissues, and the contrast between various tissues, can be adjusted by manipulating the strength, direction, and duration of pulses. In practice, a number of different pulses and time intervals are used in predetermined series called pulse sequences, and the resulting spin echo signals are averaged. Repetition time (TR) is the interval between one pulse sequence and the next.

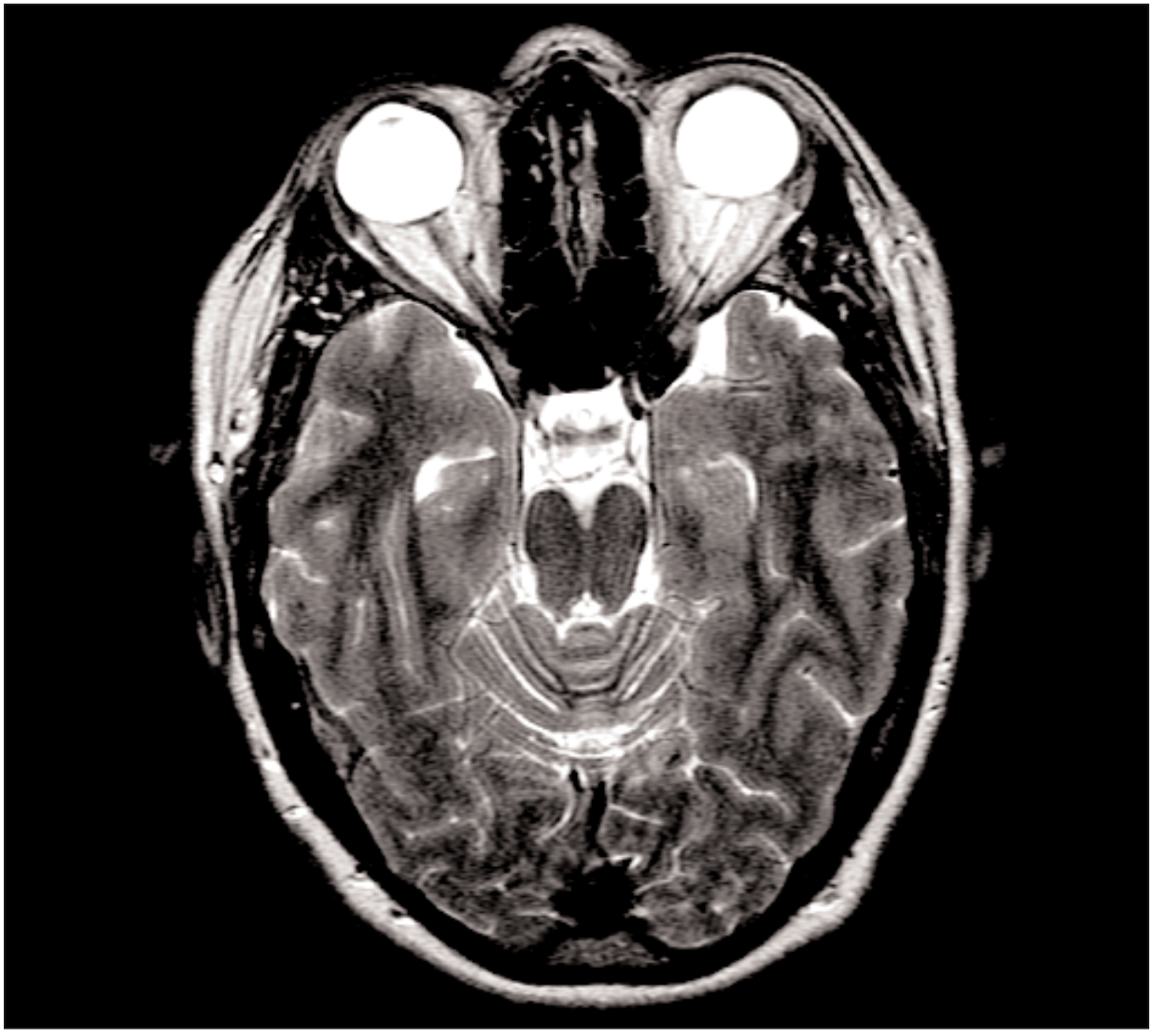


Fig. 14.1. MRI of head. Reference: J. Hornak, http://www.cis.rit.edu

An image generated with a pulse sequence using a relatively short TR (0.6 seconds or less) is called a T1 weighted image, because it reflects the T1 of the specimen to a greater extent than the T2. An image generated with a longer TR (2.0 seconds or more) is called a T2 weighted image. Differential weighting of MRI images is carried out because T1 and T2, although they are both related to proton density, reflect somewhat different properties of tissues.

In a T1 weighted image, water and watery fluids (urine, cerebrospinal fluid) appear dark because their intensity with this technique is low; they are therefore said to be hypointense. Fat, fresh hemorrhage, slowly moving blood, and fluids with high protein content such as mucus appear bright (are hyperintense) with T1 weighting. In contrast, water is hyperintense in a T2 weighted image and soft tissues including muscle and fat yield a low signal. Regardless of weighting, bone, calcifications, and air or gas are always hypointense, appearing dark in an MR image.

With an inversion recovery pulse sequence, the first excitation pulse is aimed directly opposite to the field (that is, at an angle of 180° to it) and the second pulse is delivered at a 90° angle to it. A STIR (short T1 inversion recovery) sequence is particularly useful in suppressing the signal emitted by fat (which has a shorter T1) while retaining the signals characteristic of soft tissue (intermediate T1) and water (long T1) proton densities. A FLAIR (fluid-attenuated inversion-recovery) sequence generates T2-weighted images with no appreciable signal from fluid, making it valuable in detecting lesions in the subarachnoid space and ventricular system of the brain.

MRI has largely replaced conventional radiography for applications in which it provides superior discrimination among tissue densities. In the examination of the central nervous system, MRI shows the plaques of demyelination characteristic of multiple sclerosis. Although CT is preferred for distinguishing between ischemic and hemorrhagic strokes and in identifying subarachnoid hemorrhage, MRI is a more sensitive indicator of early ischemia and infarction, and of lesions in the posterior cranial fossa (brain stem and cerebellum).

MRI is also valuable in determining the location, size, and shape of tumors, particularly in the brain and liver, and in the diagnosis of bone and joint disorders (internal derangements, ligamentous tears, spinal cord compression due to disk herniation or spinal stenosis). MRI may detect tumors at an earlier stage than mammography, and has been recommended by some authorities for annual surveillance of women at high risk.

Because the apparatus generates a strong magnetic field, jewelry, watches, and other metal objects must be removed before the examination. MRI is contraindicated for patients with ferrous metal prostheses or implanted cardiac pacemakers. For the duration of the examination, which may take more than an hour, the patient lies motionless on a narrow table within the cylindrical magnet. Some patients become claustrophobic in these circumstances or may find it difficult to remain still. MRI examination is often not feasible in the critically ill or injured patient, who may require supportive care and frequent assessment.

Magnetic resonance imaging does not expose the patient to ionizing radiation. Although no adverse effects on the fetus have been documented, the American College of Obstetricians and Gynecologists and the National Radiological Protection Board have advised against the use of MRI during the first trimester of pregnancy.

Contrast agents, such as barium and iodides, that are used in radiology are not effective in improving the clarity of MRI images. However, the metallic element gadolinium possesses physical properties that render it particularly suitable as a contrast agent in MRI examinations. Although biologically inert, it enhances the MRI signal of any tissue or area in which it accumulates by shortening the T1 of adjacent protons.

Intravenously administered gadolinium is quickly distributed throughout the circulation, showing blood vessels, highly vascular tissues, and zones of hemorrhage with great clarity. MRI angiography with intravenous gadolinium is useful in rapid diagnosis of aortic aneurysm and renal artery stenosis. This contrast medium can also be used in procedures such as arthrography. Injected gadolinium is cleared from the body in 3-6 hours. Unlike iodide contrast media, it is not toxic to the kidneys, and allergic and other side-effects are rare.

Exercises

Fill in the Blanks

1. Magnetic resonance imaging is similar to computed tomography in that it _____.

2. An MRI magnet attracts not only iron atoms but also any other atoms that, like iron, have _____ and neutrons in their nuclei.

3. _____ is a physical constant which is an expression of the degree to which such an atom, depending on its nuclear structure, responds to magnetic attraction.

4. T2 is always _____ than T1.

5. Cross-sectional images are obtained in an MRI scan by adding a third magnetic field called the _____.

6. In practice, a number of different pulses and time intervals are used in predetermined series called _____.

7. Images that appear bright on an MRI are said to appear _____.

8. Images that appear dark on an MRI are said to appear _____.

9. A _____ is particularly useful in suppressing the signal emitted by fat (which has a shorter T1) while retaining the signals characteristic of soft tissue (intermediate T1) and water (long T1) proton densities.

10. A _____ generates T2-weighted images with no appreciable signal from fluid, making it valuable in detecting lesions in the subarachnoid space and ventricular system of the brain.

11. _____ enhances the MRI signal of any tissue or area in which it accumulates by shortening the T1 of adjacent protons.

Multiple Choice: Circle the letter of the best answer from the choices given.

1. The degree to which such an atom responds to magnetic attraction depends on its nuclear structure and is expressed as a physical constant called
   A. Excitation pulse.
   B. Spin.
   C. Echo time (TE).
   D. Spin-lattice relaxation time (T1).
   E. Spin echo technique.

Exercises

2. The time it takes for the protons to return to their former orientation after an excitation pulse is called the
   A. Spin-lattice relaxation time (T1).
   B. Echo time (TE).
   C. Spin-spin relaxation time (T2).
   D. Spin.
   E. Repetition time (TR).

3. The time it takes for the protons to go out of phase is called the
   A. Spin-lattice relaxation time (T1).
   B. Repetition time (TR).
   C. Spin-spin relaxation time (T2).
   D. Spin.
   E. Echo time (TE).

4. Following the excitation pulse, after a brief interval, by a second and stronger pulse is called the
   A. Pulse sequence.
   B. Excitation pulse.
   D. Spin.
   E. Spin echo technique.

5. The time that elapses between the first pulse and the appearance of the echo is called the
   A. Repetition time (TR).
   B. Spin.
   C. Echo time (TE).
   D. Spin-lattice relaxation time (T1).
   E. Spin echo technique.

6. The interval between one pulse sequence and the next is known as the
   A. Repetition time (TR).
   B. Spin.
   C. Echo time (TE).
   D. Spin-lattice relaxation time (T1).
   E. Spin echo technique.

7. An image generated with a pulse sequence using a relatively short TR (0.6 seconds or less) is called
   A. Spin image.
   B. A T2 weighted image.
   C. Gradient image.
   D. A T1 weighted image.
   E. Spin echo image.

Exercises

8. An image generated with a longer TR (2.0 seconds or more) is called
   A. Spin image.
   B. A T2 weighted image.
   C. Gradient image.
   D. A T1 weighted image.
   E. Spin echo image.

9. An intravenously administered imaging agent that is quickly distributed throughout the circulation, showing blood vessels, highly vascular tissues, and zones of hemorrhage with great clarity, and thus useful in MRI angiography in rapid diagnosis of aortic aneurysm and renal artery stenosis, is known as
   A. Barium.
   B. Ultravist.
   C. Visipaque.
   D. Gadolinium.
   E. Angiografin.

Short Answers

1. Define or explain:
   a. gadolinium _____
   _____
   b. pulse sequence _____
   _____

2. List some types of examination for which MRI is preferred to conventional radiography.
   _____
   _____
   _____
   _____

3. In what circumstances might MRI examination not be feasible?
   _____
   _____
   _____
   _____

Exercises

4. What types of examination mentioned in this chapter might be performed in an emergency situation?

_____

_____

_____

_____

5. List some differences between a T1 weighted image and a T2 weighted image.

_____

_____

_____

_____

6. How does MRI differ from standard x-rays and ultrasonography?

_____

_____

_____

_____

7. Summarize how MRI images are made.

_____

_____

_____

_____

Activities for Application and Further Study

1. Find on the Internet photos of both traditional and open MRI machines. Survey your classmates, friends, and family members to find out how many, if any, would have problems being placed in a traditional MRI. Is there a difference in cost between closed and open MRI? If so, would that make a difference to those you survey?

2. Find on the Internet examples of normal and abnormal brain MRI images. Can you see the abnormalities? Can you label the lobes of the brain and other structures based on the MRI images?