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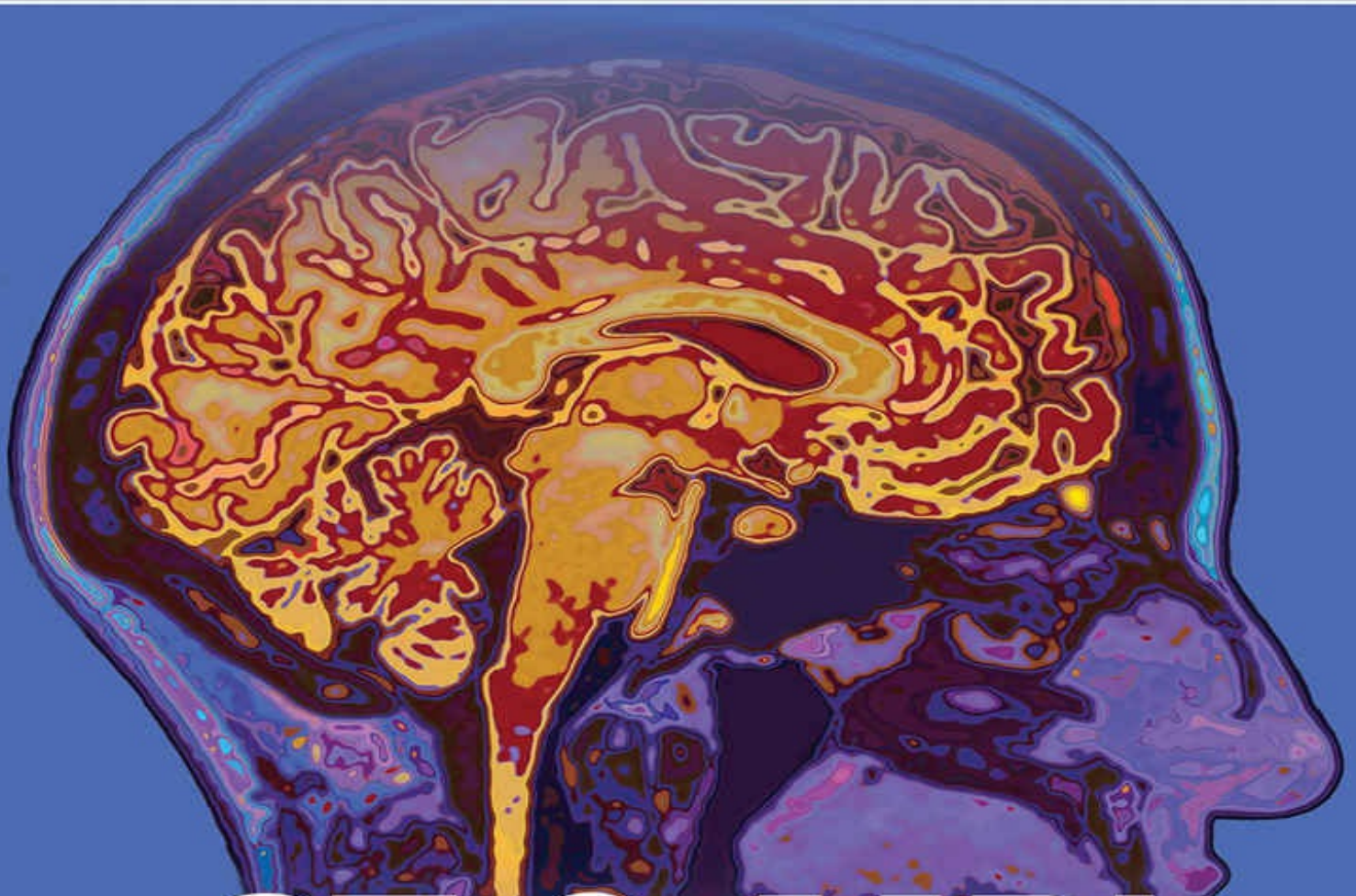
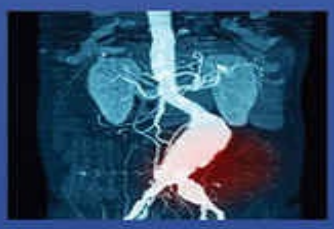


CT & MRI PATHOLOGY

A POCKET ATLAS





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Mc Graw Hill Education

CT & MRI PATHOLOGY

A Pocket Atlas

Third Edition

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CONTENTS

Contributing Authors
Preface
Acknowledgments
Special Acknowledgments
Nuclear Magnetic Resonance Imaging (NMRI)

PART I
PRINCIPLES OF IMAGING IN COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMAGING

PART II
CONTRAST MEDIA

CT and MRI Contrast Agents

CT Contrast Agents

Contrast-Induced Nephropathy
Metformin (Glucophage)

MR Contrast Agents

Nephrogenic Systemic Fibrosis
Intravenous (IV) Contrast and the Pregnant Patient

PART III
CENTRAL NERVOUS SYSTEM

Brain

Neoplasm

Acoustic Neuroma

Astrocytoma

- Brain Metastasis
- Craniopharyngioma
- Ependymoma
- Glioblastoma Multiforme
- Lipoma
- Medulloblastoma
- Meningioma
- Oligodendroglioma
- Pituitary Adenoma

Brain

Congenital

- Agenesis of the Corpus Callosum
- Arachnoid Cyst
- Crainosynostosis
- Dandy-Walker Syndrome
- Encephalocele
- Hydrocephalus
- Neurofibromatosis (NF1)
- Tuberous Sclerosis

Brain

Phakomatosis

- Sturge-Weber Syndrome
- Von Hippel-Lindau Disease

Brain

Vascular Disease

- Arteriovenous Malformation
- Intracranial Aneurysm
- Intracerebral Hemorrhage (Hemorrhagic Stroke)
- Ischemic Stroke (Cerebrovascular Accident)
- Neurovascular Compression Syndrome (NVCS)
- Superior Sagittal Sinus Thrombosis

Brain

Degenerative Disease

- Alzheimer's Disease
- Multi-Infarct Dementia
- Normal-Pressure Hydrocephalus
- Parkinson's Disease

Brain

Demyelinating

- Multiple Sclerosis

Brain

Infection

- Brain Abscess
- Cysticercosis

Brain

Trauma

- Brain Herniation
- Diffuse Axonal Injury
- Epidural Hematoma
- Subarachnoid Hemorrhage
- Subdural Hematoma

Spine

Congenital

- Arnold-Chiari Malformation
- Syringomyelia/Hydromyelia
- Tethered Cord

Spine

Degenerative

- Herniated Disk
- Spinal Stenosis
- Spondylolisthesis

Spine

Demyelinating

Multiple Sclerosis (Spinal Cord)

Spine

Infection

Vertebral Osteomyelitis

Spine

Tumor

Metastatic Disease to the Spine

Spinal Ependymoma

Spinal Hemangioma

Spinal Meningioma

Spine

Trauma

Burst Fracture

C1 Fracture

Cervical Facet Lock

Vertebral Compression Fracture

Spinal Cord Hematoma

Fracture/Dislocation (C6-C7)

Odontoid Fracture

Spine

Vascular Disease

Spinal Cord Ischemia/Infarction

PART IV

HEAD AND NECK

Congenital

Brachial Cleft Cyst

Tumor

Cavernous Hemangioma (Orbital)
Cholesteatoma (Acquired)
Glomus Tumor (Paraganglioma)
Parotid Gland Tumor (Benign Adenoma)
Thyroid Goiter

Infection

Peritonsillar Abscess
Submandibular Salivary Gland Abscess

Sinus

Mucocele
Sinusitis

Trauma

Intraocular Foreign Body
Tripod Fracture

PART V
CHEST AND MEDIASTINUM

Cardiac

Aberrant Right Subclavian Artery
Aortic Regurgitation
Atrial Myxoma
Coronary Artery Disease
Pericardial Effusion
Situs Inversus
Superior Vena Cava Syndrome

Infection

Histoplasmosis

Lungs

Adult Respiratory Distress Syndrome
Asbestosis
Bronchogenic Carcinoma

Bullous Emphysema
Mesothelioma
Pleural Effusion
Pulmonary Emboli
Pulmonary Fibrosis
Pulmonary Metastatic Disease
Sarcoidosis

Mediastinum

Hodgkin Disease
Thymoma

Aorta

Aortic Coarctation
Aortic Dissection

Breast

Breast Cancer
Breast Implant Leakage

Trauma

Aortic Tear
Diaphragmatic Hernia
Lung Contusion
Pneumothorax

PART VI
ABDOMEN

Gastrointestinal

Carcinoid
Colorectal Cancer
Crohn’s Disease
Free Intraperitoneal Air
Gastric Carcinoma
Intussusception

- Ischemic Bowel
- Large Bowel Obstruction
- Mesenteric Adenitis
- Mesenteric Ischemia
- Small Bowel Obstruction
- Volvulus

Hepatobiliary

- Cavernous Hemangioma
- Choledochal Cysts
- Choledocholithiasis
- Fatty Infiltration of the Liver
- Focal Nodular Hyperplasia
- Hemochromatosis
- Hepatic Adenoma
- Hepatic Cysts
- Hepatic Metastases
- Hepatoma

Pancreas

- Pancreatic Adenocarcinoma
- Pancreatic Pseudocyst
- Pancreatitis

Genitourinary

- Agenesis of the Kidney
- Angiomyolipoma
- Horseshoe Kidney
- Perinephric Hematoma
- Polycystic Kidney Disease
- Pyelonephritis
- Renal Artery Stenosis
- Renal Calculus
- Renal Cell Carcinoma

Renal Infarct
Wilms' Tumor

Infection

Appendicitis
Diverticulitis
Perinephric Abscess
Renal Abscess

Trauma

Liver Laceration
Renal Laceration
Splenic Laceration

Miscellaneous

Adrenal Adenoma
Adrenal Metastases
Aortic Aneurysm (Stent-Graft)
Hernia: Hiatal Hernia
Hernia: Inguinal Hernia
Hernia: Spigelian Hernia
Hernia: Ventral Hernia
Lymphoma
Soft-Tissue Sarcoma
Splenomegaly

PART VII
PELVIS

Adenomyosis
Benign Prostatic Hyperplasia
Bladder Cancer
Cervical Cancer
Ovarian Carcinoma
Ovarian Cyst

Prostate Carcinoma
Rectal Cancer
Uterine Leiomyoma (Fibroid Uterus)

PART VIII
MUSCULOSKELETAL

Shoulder

Hill-Sachs Fracture (Defect)
Labral Tear
Pectoralis Major Tendon Tear
Rotator Cuff Tear

Elbow

Biceps Brachii Tendon Tear
Triceps Tendon Tear

Hand and Wrist

Carpal Tunnel Syndrome
Gamekeeper Thumb
Ganglion Cyst
Kienbock Disease
Triangular Fibrocartilage Tear

Hip

Avascular Necrosis (Osteonecrosis)
Femoral Neck Fracture
Hip Dislocation

Knee

Anterior Cruciate Ligament Tear
Baker Cyst
Bone Contusion (Bruise)
Lateral Collateral Ligament Tear
Meniscal Tear
Osteoarthritis

Osteosarcoma
Patellar Fracture
Posterior Cruciate Ligament Tear
Quadriceps Tear
Radiographic Occult Fracture
Tibial Plateau Fracture
Unicameral (Simple) Bone Cyst

Ankle and Feet

Achilles Tendon Tear
Brodie Abscess
Diabetic Foot
Peroneal Tendon Tear
Sinus Tarsi Syndrome

Vascular

Peripheral Arterial Disease

Miscellaneous

Ewing Sarcoma

Index

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PREFACE

In this third edition of the *CT and MRI Pathology: A Pocket* Atlas, several new additions have been included. Probably the first noticeable new addition is the section titled *CT and MRI Contrast Agents*. This section contains an overview of the pertinent issues concerning contrast agents used in CT and MRI. New cases in cardiac, spine, a series of hernia cases, and additional musculoskeletal cases have been added throughout the book to increase the breadth of this new edition.

ACKNOWLEDGMENTS

I would like to express my gratitude to my wife Rebecca and my children Kayla, Emily, and Megan for allowing me time away from home to complete this new edition. Many thanks to all the wonderful people around the United States and throughout the world who have benefited from this book and their kind compliments.

It has been 30 years since my initial diagnosis of cancer. I would like to thank my Lord and Savior Jesus Christ for His loving grace and mercy, and the many miracles I have seen and experienced along life's journey.

Thank you,
Michael

First, I am grateful to all of you who made the first edition of the CT & *MRI Pathology: A Pocket Atlas* so popular in 2003 that it led to the second edition in 2012 and now to the third edition. I would like to thank Michael Grey for all his support and help. Finally, I would like to thank my wonderful wife Uma for always being there for me.

Thank you,
Jagan

SPECIAL ACKNOWLEDGMENTS

From the initial publication of the first edition of *CT & MRI Pathology: A Pocket Atlas* textbook in 2003 to this current third edition many individuals have given me invaluable support and encouragement and helped to see this book through. To them I have thanked and given credit in previous editions.

Along life's journey, others have come and influenced my life in special ways, and I would like to take this opportunity to express my deep appreciation to them. Without these people, I know that I would not be where I am today.

Charles Coffey II
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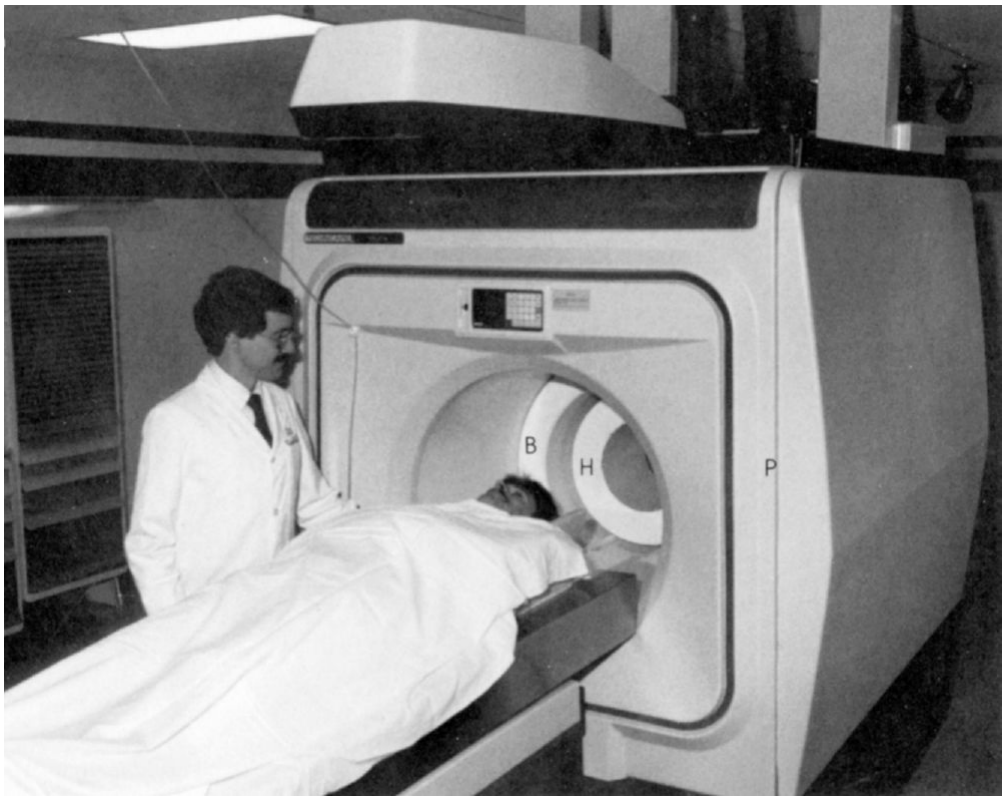
Marilyn Paulk
Paul Sarvela

I am forever grateful to God for these friends and how they have touched my life.

Thank you all!
Michael L. Grey

NUCLEAR MAGNETIC RESONANCE IMAGING (NMRI)



This is a photo of the first commercially made Nuclear Magnetic Resonance (NMR) Imaging unit in the world. NMR Imaging is commonly referred to today as Magnetic Resonance Imaging (MRI).

This photo shows the Head coil (H), the Body coil (B) in the center of the bore, and the plastic housing (P). This NMR unit was a Technicare 0.15T Resistive system. As a show site to the world, visitors were frequent, and many tours were given to introduce this new technology to the world.

This photo was taken in the mid-1980s. By that time, several companies had also begun producing their own NMR units. The gentlemen posing for this photo are Michael Grey (standing) and the service engineer (positioned on the patient couch).

PART I

Principles of Imaging in Computed Tomography and Magnetic Resonance Imaging

PRINCIPLES OF IMAGING IN COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMAGING

Since the initial discovery of x-ray by Wilhelm Conrad Roentgen on November 8, 1895, the field of radiology has experienced two major breakthroughs that have revolutionized how we look into the patient's body. The first, computed tomography (CT) came in the early 1970s. The second, magnetic resonance imaging (MRI) was initially introduced in the early 1980s.

In CT, a finely collimated x-ray beam is directed upon the patient. As the x-ray tube travels around the patient, x-rays are emitted toward the patient. As these x-rays interact with the various tissues in the patient's body, some of the x-rays are attenuated by the tissues while others are transmitted through the tissues and interact with a very sensitive electronic detector. The purpose of these detectors is to measure the amount of radiation that has been transmitted through the patient. After the amount of radiation has been measured, the detector converts the amount of radiation received into an electronic signal that is sent to a computer. The computer then performs mathematical calculations on the information received and reconstructs the desired image. This information is assigned a numerical value that represents the average density of the tissue in that respective pixel/voxel of tissue. These numerical values reflect the patient's tissue attenuation characteristics and may be referred to as Hounsfield numbers, Hounsfield units (HU), or CT numbers that range from approximately −1000 (air) to +3000 (dense bone or tooth enamel). CT uses water as its standard value and it is assigned a Hounsfield number of 0.

To diagnose a disease process, the radiologist looks for changes in the normal density (HU) of an organ, an abnormal mass, or an altered or loss of normal anatomy. The advantages of CT include its ability to image patients that (1) have experienced trauma, (2) are suspect to have had a stroke, (3) are acutely ill, (4) have a contraindication to MRI, or (5) require

better bone detail that can be scanned in CT in a quick and efficient manner. In addition, since the development of helical (spiral) CT in the early 1990s with single-slice technology and further technological advances in the mid-1990s to multi-slice imaging, CT is able to perform volumetric imaging quickly and generate reformatted anatomic images in any plane (e.g., sagittal or coronal). The disadvantages of CT include (1) exposure to the radiation dosage, (2) possible reaction to the iodinated contrast agent, (3) lack of direct multiplanar imaging, and (4) loss of soft-tissue contrast when compared to MRI.

MRI incorporates the use of a strong magnetic field and smaller gradient magnetic fields in conjunction with a radiofrequency (RF) signal and RF coils specifically tuned to the Larmor frequency of the proton being imaged. An image is acquired in MRI by placing the patient into a strong magnetic field and applying an RF signal at the Larmor frequency of the hydrogen proton (42.58 MHz/T). Gradient magnetic fields are used to assist with spatial localization of the RF signal. The gradients are assigned to the tasks of slice selection, phase encoding, and frequency encoding or readout gradient. In the magnet, the patient's hydrogen protons align either parallel (with) or antiparallel (against) the magnetic field. The RF signal is rapidly turned on and off. When the RF signal is turned on, the protons are flipped away from the parallel axis of the magnetic field. Once the RF is turned off, the protons begin to relax back into the parallel orientation of the magnetic field. During the relaxation time, a signal from the patient is being received by the coils and sent to the computer for image reconstruction. This process is repeated several times until the image is acquired.

There are several different types of pulse sequences used in MRI to acquire patient information. These can be grouped into proton (spin) density, and T1-weighted and T2-weighted pulse sequences. These pulse sequences demonstrate the anatomy differently and help differentiate between normal and abnormal structures. A combination of these pulse sequences may be used to assist with the diagnosis.

A T1-weighted pulse sequence uses a short TR (repetition time) and short TE (echo time) values to produce a high or bright signal in substances such as fat, acute hemorrhage, and slow-flowing blood. Structures such as cerebrospinal fluid and simple cysts may appear with a low or dark signal. In many cases, the pathologic process will appear with low signal in T1-weighted images.

A proton-density-weighted image uses long TR and short TE values to produce images based on the concentration of hydrogen protons in the

tissue. The brighter the area, the greater the concentration of hydrogen protons. The darker the area, the fewer the number of hydrogen protons.

A T2-weighted pulse sequence uses long TR and long TE values to obtain a high signal in substances such as cerebrospinal fluid, simple cysts, edema, and tumors. Structures such as fat and muscle will appear with low signal. Many pathologic conditions present with high signal on T2-weighted pulse sequences.

MRI has several advantages such as (1) it acquires patient information without the use of ionizing radiation; (2) it produces excellent soft tissue contrast; (3) it can acquire images in the transverse (axial), sagittal, coronal, or oblique (orthogonal) planes; and (4) image quality is not affected by bone. The disadvantages primarily associated with MRI would include: (1) any contraindication that would present a detrimental effect to the patient or health care personnel; (2) long scan time when compared to CT; and (3) cost. The effects of the magnetic field, varying gradient magnetic fields, or the RF energy used pose the greatest harmful effects to biomedical implants that may be in the patient's body. Before entrance into the strong magnetic field can be obtained, everyone including patients, family members, health care professionals, and maintenance workers must be screened for any contraindications that may result in injury to themselves or others. These may include any biomedical implant or device that is electrically, magnetically, or mechanically activated such as pacemakers, cochlear implants, and certain types of intracranial aneurysm clips and orbital metallic foreign bodies. The contraindications focus on devices that may move or undergo a torque-effect in the magnetic field, overheat, produce an artifact on the image, or become damaged or functionally altered. Most magnets used in MRI are superconductive and the magnetic field is always on. Any ferromagnetic material (e.g., O^2 tank, wheelchairs, stretchers, scissors) may become a projectile and potentially cause an injury or death when brought into the magnetic environment.

PART II

Contrast Media

CT AND MRI CONTRAST AGENTS

Technologists working in computed tomography (CT) or magnetic resonance imaging (MRI) are responsible for performing a wide variety of examinations on a diverse population of patients. Many of these examinations require the use of a contrast agent. It is very important, therefore, that the technologist has a working knowledge of how to perform venipuncture and how to safely administer the specific contrast agent required. To safely administer a contrast agent, the technologist must be able to determine five things:

- The specific contrast agent to be used;
- The correct amount to be used;
- The appropriate injection site;
- The correct injection rate; and
- The appropriate gauge of the IV needle to be used.

Upon the completion of the examination, all pertinent details of the venipuncture and administration of the contrast agent should be documented in the patient chart by the technologist, along with the overall patient outcome. To ensure the safety of the patient, it would be beneficial for the technologist to have an overview of the main points to consider prior to using either a CT or an MRI contrast agent.

CT Contrast Agents

Water-soluble contrast agents, which consist of molecules containing atoms of iodine, are used extensively in CT. Although risk of adverse reaction is low, there is a real risk inherent in their use which can run from mild to life threatening. Due to these safety risks, newer but more expensive, low-osmolar contrast agents have replaced the older, cheaper high-osmolar ionic contrast agents. Adverse side effects are uncommon for these agents ranging from 5% to 12% with ionic to 1% to 3% with nonionic, low-osmolality intravascular contrast agents.

Mild reactions are the most common type of reaction and usually do not

require treatment. Patients experiencing any of the typical reactions should be observed for 30 minutes following the onset to ensure that the reaction does not become more severe. Common signs and symptoms include:

- Nausea/vomiting.
- Urticaria/pruritis.
- Sneezing.
- Itchy/scratchy throat.
- Feeling warm/chills.
- Headache/dizziness/anxiety/altered taste.

Moderate reactions are not life threatening but commonly require treatment for symptoms. Some of these reactions may become severe if not treated. Common signs and symptoms include:

- Diffuse urticaria/pruritis.
- Diffuse erythema, stable vital signs.
- Facial edema without dyspnea.
- Throat tightness or hoarseness without dyspnea.
- Wheezing/bronchospasm, mild or no hypoxia.
- Protracted nausea/vomiting.
- Isolated chest pain.
- Vasovagal reaction that requires and is responsive to treatment.

Patients should be monitored until symptoms resolve. Benadryl is effective for relief of symptomatic hives. Beta agonist inhalers help with bronchospasm (wheezing) and epinephrine is indicated for laryngeal spasm. Leg elevation (Trendelenburg position) is indicated for vasovagal reaction and hypotension.

Severe reactions, which are potentially life-threating reactions, usually occur within the first 20 minutes following the intravascular injection of contrast. Severe reactions are rare but should be recognized and treated immediately. Common signs and symptoms include:

- Diffuse edema, or facial edema with dyspnea.
- Diffuse erythema with hypotension.
- Laryngeal edema with stridor and/or hypoxia.
- Anaphylactic shock (hypotension with tachycardia).
- Vasovagal reaction resistant to treatment.

- Arrhythmia.
- Convulsions, seizures.
- Hypertensive emergency.

Severe bronchospasm or severe laryngeal edema may progress to unconsciousness, seizures, hypotension, dysrhythmias, cardiac arrest, and needs immediate cardiopulmonary resuscitation.

Local side effects, such as extravasation of the contrast agent at the injection site, may cause pain, swelling, skin slough, and deeper tissue necrosis. The affected limb should be elevated. Warm compress may help with absorption of the contrast agent while a cold compress is more effective in reducing pain at the injection site. With the current use of power injectors, extra care should be taken in observing the injection site during the administration phase of the contrast agent.

While the terms extravasation and infiltration have been used interchangeably, a difference should be noted. An infiltration is the inadvertent administration of a non-vesicant fluid (i.e., normal saline) into the surrounding tissues. An extravasation is the inadvertent administration of a vesicant fluid (i.e., contrast agent, chemotherapy) into the surrounding tissue. A vesicant fluid can cause necrosis or tissue damage when it escapes from the vein.

Contrast-Induced Nephropathy

Contrast-induced nephropathy (CIN) is defined as acute renal failure (sudden deterioration in renal function) occurring within 48 hours of contrast injection and is a significant source of morbidity. CIN is a subgroup of post-contrast acute kidney injury (AKI). Most prominent risk factors are diabetes and chronic renal insufficiency. Adequate hydration is essential in the prevention of CIN. Patients should be encouraged to drink several liters of water/fluid 12 to 24 hours before and after intravascular administration of contrast. As a prophylactic treatment, an intravenous bolus of N-acetylcysteine (Mucovit) may also be recommended at a dose given orally (600 mg twice daily) on the day before, and on the day of contrast administration. Another option is that 500 ml of normal saline is given over 30 minutes prior to the exam and 500 ml of normal saline over 4 hours after the examination.

Metformin (Glucophage)

Metformin (Glucophage) is an oral antihyperglycemic agent used to treat

type 2 diabetes mellitus. It may potentially cause fatal lactic acidosis. Metformin should be discontinued for 48 hours following an iodinated contrast administration and reinstated only after renal function is reevaluated and found to be normal.

High-risk patients for adverse contrast reactions should be identified and consideration given as to whether a contrast agent should be given. In cases where administrating a contrast agent may not be in the best interest of the patient, alternative imaging such as ultrasound may be helpful. Further, it may be possible for the radiologist to monitor the non-contrast CT exam to assess the images as they are acquired. If contrast is needed, the patient should be adequately hydrated. Premedication should be considered.

Risk factors include the following:

1. Previous history of adverse reaction tointravenous contrast.
2. Clear history of asthma or allergies. A history of an allergy to shellfish or iodine is not a reliable indicator of a possible contrast reaction.
3. Known cardiac dysfunction including severe congestive heart failure, severe arrhythmias, unstable angina, recent myocardial infarction or pulmonary hypertension.
4. Renal insufficiency, especially in patients with diabetes mellitus.
5. Sickle cell disease.
6. Multiple myeloma.
7. Age over 65.

All the patients having CT contrast should be screened appropriately. For patients at risk for reduced renal function, serum creatinine/eGFR (glomerular filtration rate) is to be obtained. Technologists need the patient’s age, gender, weight, and serum creatinine to use the GFR calculator (found online). Patients who have a GFR of less than 30 ml/min, should not be given contrast.

Premedication has been proven to decrease but not eliminate the frequency of contrast reactions. Two regimens listed by American College of Radiology (ACR) include either:

1. Prednisone 50 mg taken orally at 13 hours, 7 hours, and 1 hour before contrast administration.
2. Methylprednisolone 32 mg taken orally at 12 hours and 2 hours prior to contrast administration.

Benadryl 50 mg orally, IM, or IV should be taken or given 1 hour prior to contrast for either of regimen (above).

Nonionic low-osmolality contrast should be used with either regimen (above).

MR Contrast Agents

Gadolinium chelates are the most commonly used MR contrast agents. These agents differ according to being either ionic or nonionic, and according to their osmolality and viscosity. Their distribution and elimination is very similar to water-soluble iodine-based contrast agents used in CT. Injected intravenously gadolinium chelates diffuse rapidly into extracellular fluid and blood pool spaces and are excreted by glomerular filtration. About 80% of an injected dose is excreted within 3 hours. MR imaging is usually done immediately after injection.

Adverse reactions to gadolinium contrast agents are quite uncommon. Common signs and symptoms for mild reactions include:

- Nausea/vomiting.
- Headache.
- Warmth or coldness at the injection site.
- Paresthesia.
- Dizziness.
- Itching.

Life-threatening reactions are rare. Gadolinium has no nephron toxicity at doses used for MR. Since gadolinium agents are radiopaque, they have been used in conventional angiography in patients with renal impairment or severe reaction to iodinated contrast.

Nephrogenic Systemic Fibrosis

Nephrogenic systemic fibrosis (NSF), originally described in 2000, is a systemic disorder characterized by widespread tissue fibrosis following the administration of a gadolinium-based contrast agent in individuals with noticeable advanced renal failure. This disease causes fibrosis of the skin and connective tissues throughout the body. Patients affected develop skin thickening that may prevent bending and extending of joints, resulting in their decreased mobility. Affected patients experience fibrosis that has

spread to other parts of the body such as the diaphragm, muscles of the thigh and lower abdomen, and interior areas of the lung vessels. The clinical course is progressive and fatal.

High-risk patients for reduced renal function include:

- Age 65 or over.
- Diabetes mellitus.
- History of renal disease or renal transplants.
- History of liver transplantation, hepatorenal syndrome.

As a safety precaution, serum creatinine (eGFR) should be obtained in all patients with reduced renal function. Patients, who have a GFR of less than 30 ml/min, should not be given contrast.

Intravenous (IV) Contrast and the Pregnant Patient

The safety of fetal exposure to CT and MR contrast agents are not well described in the literature. The current recommendation is to avoid routine administration of contrast agents in pregnant patients unless the information is critical to the management of the patient (risk versus benefit). Alternate imaging studies like ultrasound also must be considered.

PART III

Central Nervous System

BRAIN

NEOPLASM

Acoustic Neuroma

Description: An acoustic neuroma, also known as a vestibular schwannoma, is a benign fibrous tumor that arises from the Schwann cells covering the vestibule portion of the eighth cranial nerve. These tumors are well encapsulated, compress but do not invade the nerve. Acoustic neuromas account for approximately 80% to 85% of all cerebellopontine angle (CPA) tumors and make up 10% of all intracranial tumors.

Etiology: There is no known cause for this tumor. Bilateral eighth cranial nerve schwannomas are pathognomonic for neurofibromatosis type II.

Epidemiology: Acoustic neuromas account for approximately 5% to 10% of all intracranial tumors. They are the most common tumors affecting the cerebellopontine angle. Males and females are affected equally. The average age of onset is between 40 and 60 years.

Signs and Symptoms: Sensorineural hearing loss, tinnitus, and vertigo are common in patients.

Imaging Characteristics: Note: MRI is the imaging modality of choice.

CT

- Well-rounded hypodense to isodense mass on noncontrast study.
- Hyperdense with contrast enhancement.

MRI

- T1-weighted (T1W) imaging without contrast is usually isointense to slightly hypointense.
- T1-weighted pulse sequence with contrast enhancement demonstrates

the tumor with a marked enhancement.

- T2-weighted images may demonstrate an increase (hyperintense) in signal.
- Baseline imaging following surgery should include a precontrast T1-weighted and fat-suppression postcontrast pulse sequences.

Differential Diagnosis: Include mainly meningioma, metastasis, and paraganglioma.

Treatment: Surgery intervention is required.

Prognosis: Depending on the size of the acoustic neuroma, the prognosis is encouraging and usually is curative.

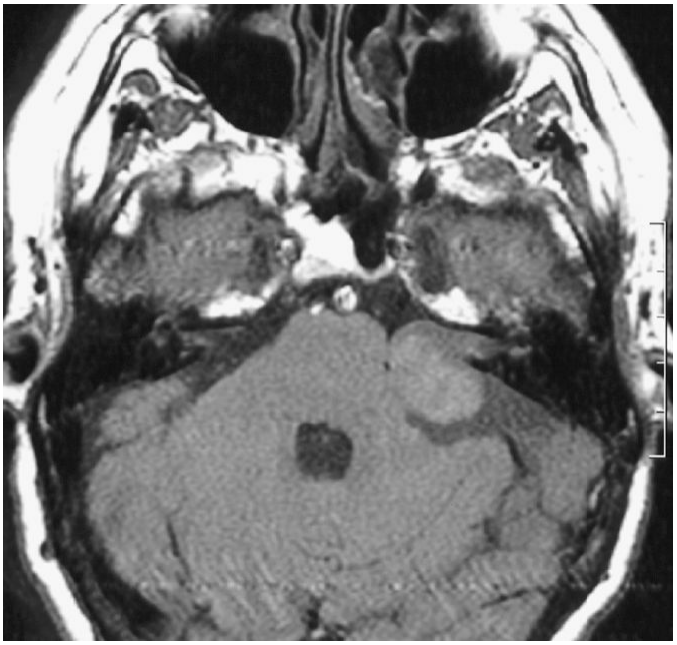


FIGURE 1. Acoustic Neuroma. Noncontrast T1-weighted axial image demonstrating round isointense mass at the left cerebellopontine (CP) angle.

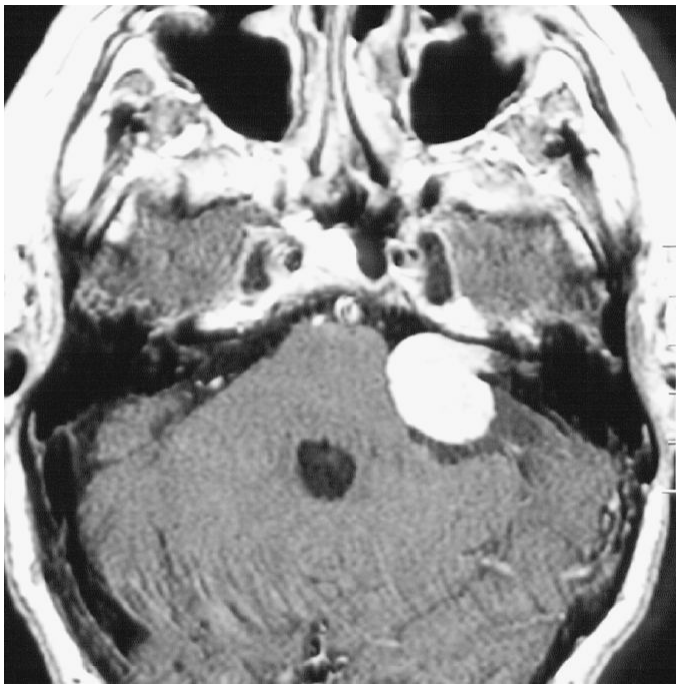


FIGURE 2. Acoustic Neuroma. Postcontrast T1-weighted axial image demonstrating an intense contrast enhancing extraaxial mass at the left cerebellopontine angle close to the left internal auditory canal (IAC) consistent with an acoustic neuroma.

Astrocytoma

Description: Astrocytomas are the most common primary intracranial neoplasm. They originate from the astrocysts of the brain. The World Health Organization (WHO) subdivided astrocytomas into four histologic grades: Grade I (circumscribed astrocytoma); Grade II (diffuse astrocytoma); Grade III (anaplastic astrocytoma); and Grade IV - (glioblastoma multiforme).

Etiology: Unknown.

Epidemiology: Account for approximately 10% to 30% of cerebral gliomas in adults.

Signs and Symptoms: Typically are associated with an increase in pressure within the skull. May include headaches, visual problems, change in mental status, seizures, and vomiting.

Imaging Characteristics: Approximately two-thirds of all low-grade