ACVR | Diagnostic Imaging

ACVR | Equine Diagnostic Imaging

# GENERAL PRELIMINARY EXAM STUDY GUIDE

## INTRODUCTION

This study guide is intended to support candidates in their preparation for the ACVR Diagnostic Imaging Preliminary Examination by providing a structured framework of key topics, concepts, and representative examples of the knowledge expected of entry-level veterinary radiologists. It is designed to serve as a companion resource to assist with focused study and self-assessment.

However, this guide is **not an exhaustive source** of all material that may be assessed on the examination. Candidates are expected to demonstrate a working understanding of the **current imaging literature**, including foundational texts and peer-reviewed articles relevant to each topic. Independent review of the broader scientific and clinical body of knowledge remains an essential component of preparation—not only for examination success but also for professional competence in clinical practice.

The **references provided** throughout this guide are **examples** of core and supplemental sources that support understanding of the material. They are included to help direct further reading but do **not represent a complete list** of the literature that candidates should be familiar with.

Acknowledgements

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# KEY CONCEPTS

## A: IMAGING MODALITIES (42%)

Knowledge of the following imaging modalities, specifically the criteria used to select between available techniques and equipment based on clinical presentation, patient history, and imaging goals for the purposes of capturing images and reducing the influence of artifacts.

### CONTRAST MEDIA

- The mechanisms of action for radiographic/CT contrast, ultrasound contrast, MRI contrast
    - Agent properties and selection
    - Agents used for each modality
    - The chemical structure and composition of iodinated contrast medium (e.g. osmolality, viscosity, etc.)
    - The physical and chemical properties of barium sulfate solutions
    - Gadolinium-based contrast agents
- The indications for contrast studies
    - Formulation (e.g. liquid, paste, microbubbles, etc.)
    - Routes of administration (e.g. oral, rectal, intravenous, intra-arterial, intrathecal, intravesical, etc.)
    - Study optimization (e.g. positioning, dose, timing, radiographic technique, etc.)
    - Positive contrast, negative contrast and double contrast studies
- The mechanism of excretion of contrast agents
- Interpretation pitfalls (e.g. pseudolesions, artifacts, etc.)
- Safety and Contraindications
    - The risk of contrast agents including contraindications and managing contrast reactions
    - Management of adverse effects (e.g. risk of hypersensitivity, nephrotoxicity, extravasation injury etc.)
- Species-specific considerations (e.g. cats, exotic species)

### RADIOGRAPHY

- Choose appropriate detector systems (CR, DR, film-screen) based on image quality, workflow, and cost.
- Match generator type (single-phase, high-frequency, constant potential) and focal spot size to imaging need.
- Characteristics of controllable x-ray tube factors contribution to image quality and exposure.

    - Image optimization
    - Balance mA, kVp, exposure time, and distance to achieve diagnostic quality and dose optimization.
    - Proper collimation, filtration, and patient positioning
- Scatter and beam shaping
    - Apply beam-restricting devices (cones, collimators) and filtration to reduce scatter and patient dose.
    - Select grid ratio, frequency, and focal distance appropriately for patient size and examination type.
    - Air-gap technique as an alternative to grids
- Identify key artifacts, cause, and how to fix artifacts
- Image geometry
    - Recognize the relationship between source-image distance (SID), object-image distance (OID), and geometric distortion.
    - Magnification radiography and its implications for resolution and distortion.
    - Foreshortening
- Clinical applications
    - Stress view radiographs
    - Positional radiographs

## ULTRASONOGRAPHY

- Ultrasound Physics, Equipment and Image Formation
    - Physical characteristics of the ultrasound beam formation and their relationship (e.g. parts of ultrasound probe, frequency, velocity, etc.)
    - Basic interactions of ultrasound with matter (e.g. reflection, scatter, etc.)
    - Characteristics of various transducer types (e.g. linear, curved, electronic, mechanical, piezoelectric properties)
    - Definition of and factors affecting axial and lateral resolution
    - Contrast media used in ultrasound including types of agents and clinical use
    - Factors that influence image resolution
    - Physical factors influencing the propagation of ultrasound in tissues and the factors that influence acoustic impedance.
    - Methods of image formation and display
    - Relationship between wavelength, frequency, impedance and the velocity of sound in tissues
    - Propagation of the ultrasound beam through tissues
    - Basics in calculation of reflected interfaces within tissue and the pulse echo operation (e.g. pulse repetition frequency, pulse duration, duty factor, etc.)
    - Knobology – the use and controls on an ultrasound machine, their use and what they do (e.g. gain, Time Gain Compensation (TGC), Focus).
    - The Bernoulli equation and its use

- The indications, contraindications, and modes of actions of harmonic imaging
- Ultrasound artifacts, their cause and how they could help or hinder the exam (e.g. Improper scanning technique, reverberation, acoustic enhancement, etc.)

- Doppler Principles
  - The Doppler principle and be able to calculate the velocity of blood flow given various parameters related to the Doppler frequency shift
  - Difference between continuous wave, pulsed wave and color flow Doppler techniques
  - Clinical application of Doppler and basic interpretation principles
  - Analysis of arterial wave forms using pulsatility index, resistive index and A/B ratios
  - Color flow imaging techniques and their use. (e.g. color Doppler, power Doppler)
- Echocardiography
  - M-mode, 2-D and Doppler examination with recognition of normal and abnormal Doppler tracings of cardiac valves
  - Basic cardiac anatomy from right and left parasternal window
  - Basic cardiac direct and indirect measurements used in echo
  - Calculate the pressure gradients using a modified Bernoulli equation
  - Common acquired and congenital disease findings
- Identify key artifacts, cause, and how to fix artifacts
- Indications, proper selection of equipment, scanning protocol, normal anatomy, principles of interpretation, and appearance of normal anatomy and disease in the following:
  - Abdominal
  - Thorax
  - Neck
  - Musculoskeletal
  - Ocular
  - Non cardiac Doppler ultrasonography

## COMPUTED TOMOGRAPHY

- CT scanners
  - Basic components of a CT scanner
  - Physics, advantages and disadvantages of various types and generations of CT scanners (e.g. single slice, multislice, flat panel)
  - Components and detector types
  - Advantages and disadvantages of CT scanners
- Image Settings (e.g. window level & width, kVp, mAs, pitch, slice thickness, reconstruction algorithm, etc.)
  - How window level and window width influence the capturing of CT images
- Knowledge of when to use and how to interpret Hounsfield Units
- Identify key artifacts, cause, and how to fix artifacts for each modality (e.g. beam hardening, motion, ring, partial volume, metal streaks, etc.)
- Clinical considerations

    - Know the indications, scanning protocol (imaging planes, desirable slice thickness, and use of contrast media), normal anatomy, common artifacts, principles of interpretation and appearance of disease
    - Patient positioning
- Principles of safety in CT
    - Metrics include Multiple Scan Average Dose (MSAD), Computed Tomography Dose Index (CTDI), Dose Length Product (DLP)
    - Method of dose calculation and reduction and how this influences other image parameters

### MAGNETIC RESONANCE IMAGING

- Advantages of different type of MRI magnets and magnet designs
- Basic function of components of MRI machine
- Know the basic differences between commonly used receiver coil types (surface, quadrature, array) and their use
- Principles and parameters associated with MRI (e.g. Larmor frequency, Repetition Time (TR), Echo Time (TE), free induction decay, etc.)
- Method for acquiring the following pulse sequences and their common clinical uses
    - Example – T1-weighted, T2-weighted, proton density (PD), spin echo, fat suppression techniques, diffusion-weighted imaging
    - Inversion recovery sequences (FLAIR, STIR)
    - Gradient echo
    - Angiography/time of flight
    - How to discern between sequences based on the image (e.g. T1 vs T2-weighted image)
    - Physics of how images are obtained and the resultant image depending on sequence type
- Imaging parameters (e.g. field of view, timing, slice thickness, Nex) and how they affect image quality
    - Signal to noise ratio and contrast to noise ratio
    - Spatial resolution
    - Artifacts and mitigation
    - How slice and timing parameters impact the quality of MRI images
- When to choose MRI over other imaging modalities (specific anatomy or disease processes)
- How imaging features of abnormalities may appear on MRI vs other imaging modalities
- Identify key artifacts, cause, and how to fix artifacts (e.g. truncation, magic angle, etc.)

## B: DIGITAL IMAGE MANAGEMENT (7%)

### DIGITAL IMAGE QUALITY

- Image Acquisition Systems
    - Computed Radiography (CR)
    - Digital Radiography (DR): use of direct or indirect conversion detectors

- Factors that affect  image quality and how to correct them
    - Spatial Resolution
    - ACVR Minimum Standard
    - Contrast Resolution
    - Temporal Resolution
    - Noise
    - Dynamic Range
    - Artifacts
- Performance Metrics
    - Signal-to-Noise Ratio (SNR)
    - Detective Quantum Efficiency (DQE)
- Field of View (FOV)
- Image Optimization
    - How to optimize image quality for the individual studies
    - Post-processing and its effect on the image

### IMAGE VIEWING ENVIRONMENT

- Monitor
    - Resolution, luminance, contrast ratio
    - Anti-glare screen
    - Number of monitors (diagnostic + admin)
    - Calibration
- Room lighting
- Workstation ergonomics
- Workflow considerations to avoid visual fatigue and improve diagnostic accuracy

## C: RADIATION AND EQUIPMENT SAFETY (22%)

### PERSONAL PROTECTIVE EQUIPMENT

- Requirement of use of occupational radiation monitoring is required
- Personal protective equipment
    - Lead apparel
    - Use of lead aprons, gloves, thyroid shields, mobile lead barriers, and glasses
    - Materials and thickness
    - Maintenance (cleaning, assessing for damage)
- ALARA Principle
- Inverse square law
- Shielding and barriers

- Occupational dose limits
    - Knowledge of the average background radiation levels and sources
- Dose reduction techniques
- Special risk situation
    - Fluoroscopy
    - Portable and large animal imaging

## SAFETY REGULATIONS FOR RADIATION EXPOSURE

- Radiation dose assessment (e.g. absorbed dose, equivalent dose, effective dose , etc.) and dose optimization
- ALARA principle and its relationship to radiation safety standards
- Dose monitoring and record keeping
- Important calculations
    - Inverse-square law
    - Attenuation
    - Barrier thickness
    - CT dose
- Clinical relevance
    - Patient safety
    - Occupational exposure
- Common situations involving higher exposure and mitigating risks (e.g. fluoroscopy, interventional procedures, portable x-ray in large animal practice, repeated studies, etc.)
- Implications of side effects
    - For animals
    - For veterinary personnel

## SIDE EFFECTS OF RADIATION EXPOSURE

- Differences in apoptotic and mitotic cell death caused by radiation exposure
- Difference between lethal cell damage, sub-lethal cell damage, and potentially lethal cell damage
    - Stochastic effects
    - Dose ranges and associated risks (values primarily from human data but applied in veterinary radiation safety guidelines)
    - Tissue radiosensitivity
- Factors influencing radiation side effects
    - Total dose (larger exposure vs. repeated small exposures)
    - Type of radiation and their effects on tissues (X-rays, gamma, beta, alpha, nuclear)
    - Exposed tissue characteristics (cell cycle stage)
    - Individual species and age
    - Short-term vs. long-term effects
- Effects of radiation on the developing embryo/fetus in utero

- Phases of acute radiation syndrome, including the bone marrow, gastrointestinal and CNS radiation syndromes
- Effects of chronic radiation exposure

## MRI MACHINE SAFETY

- Risks of static magnetic fields (e.g. skin burns, tissue heating, etc.)
    - Effect of field strength
- Risks and effects of radiofrequency exposure
- The specific absorption rate (SAR) with respect to patient safety and MR parameters that increase SAR
- MR personnel safety
    - Noise
    - Metal projectiles being drawn to the magnet
    - Pregnancy related MR safety
    - MR safety zones
- Implanted devices
    - Which implants/materials are considered safe, unsafe, and conditional
- Quench
    - Indications, process and results of magnet quenching
    - Safety considerations of magnet quenching

## RADIOBIOLOGY

- Molecular impact of particle and electromagnetic radiation
- Basic mechanisms of acute and late radiation injury and cell death
    - Differences in radiation response between acute and late responding tissues
    - Effects of radiation on tissues detected by imaging (including but not limited to radiation induced lung and bone changes)
- How radiation affects cells
    - Mechanisms of electromagnetic radiation induced cell death
    - Differences between apoptotic and mitotic cell death related to radiation induced cellular injury
    - Differences between lethal damage, sub-lethal damage and potentially lethal damage
- RBE (relative biological effectiveness) and how RBE may be influenced by other factors
- LET (linear energy transfer) and how LET relates to RBE and the oxygen effect

## MEASUREMENT OF RADIATION EXPOSURE

- Types of Radiation Exposure
    - Occupational
    - Patient
    - Environmental
- Units of Measurement
    - Absorbed dose (Gray, Gy)
    - Equivalent dose (Sievert, Sv)
    - Air kerma (Gy or mGy)
    - Exposure (Coulomb/kg, C/kg)
- Common Dosimeters
    - Thermoluminescent dosimeters (TLDs)
    - Optically stimulated luminescence (OSL) dosimeters
    - Film badges
    - Electronic personal dosimeters
- Radiographic Dose Measurement
    - Dose-area product (DAP, $Gy{\cdot}cm^2$)
    - Computed Tomography Dose Index (CTDI)
    - Dose Length Product (DLP)
- Factors Influencing Dose
    - Technique factors: mAs, kVp, exposure time, collimation, filtration
    - Patient size and thickness
    - Equipment type
    - Shielding
- Safety Standards & Guidelines
    - ALARA principle
    - Occupational limits
    - Pregnant personnel
    - Regulatory bodies
        - International Commission on Radiological Protection (ICRP)
        - National Council on Radiation Protection and Measurements (NCRP)
        - Local veterinary radiology regulations
- Radiation Protection Tools
    - Time
    - Distance
    - Shielding
    - Collimation

## D: PHYSICS AND MATHEMATICS (29%)

## MODALITY APPLIED PHYSICS

- Factors that affect contrast resolution in each modality
    - Intrinsic vs extrinsic
- Factors that affect spatial resolution in each modality
- Radiography and computed tomography
    - X-ray Physics & Generation
        - Types of radiation: characteristic x-rays, Bremsstrahlung
        - Factors affecting X-ray beam quality and intensity
        - X-ray tube and focal spot: size selection, anode type/material, heel effect
        - Tube loading, heat capacity, cooling charts
        - Generator types: alternating current, direct current, high-frequency
        - Energy transfer: transformer, anode, cathode, collimator housing, x-ray tube
        - Rectification processes
        - Heel effect and anode angle impact on radiation delivery
        - Ripple effect and implications for diagnostic imaging
        - Constant vs pulsed radiation delivery: impact on image quality
    - Image Detector Systems
        - Computed radiography (CR) and digital radiography (DR)
        - Detector component differences
        - CT detector arrays: composition and image creation
        - CT image formation and reconstruction
        - Cone beam vs fan beam acquisition: configuration differences and effects on image quality
    - Interaction with Matter
        - Photoelectric effect vs Compton scatter: processes and outcomes at the anatomic level
        - Half value layer
        - Beam hardening
        - Hounsfield units and relationship to linear attenuation coefficients of tissue types
- Computed Tomography (CT)
    - CT detector arrays: composition and image creation
    - CT image formation and reconstruction (e.g. filtered back projection and iterative reconstruction methods, reconstruction algorithms)
    - CT parameters (e.g. matrix size, field of view, slice thickness, pitch, etc.)
    - Determination of CT voxel size, contrast resolution, spatial resolution
    - Cone beam vs fan beam acquisition: configuration differences and effects on image quality
- MRI
    - Precession and precessional frequency
    - Creation of MR signal
        - Flip angle
        - Relaxation, recovery, and decay
        - T1 vs T2 and differences between tissues
        - T2* decay
    - Image weighting
        - T2 vs T1 vs PD

- Image acquisition parameters
    - Time of repetition (TR), Time of echo (TE), Time of Inversion (TI)
- Pulse sequences
    - Spin echo vs gradient echo
    - Mechanism and parameters differences between sequence types
- Image formation
    - Spatial encoding and scan plane
    - Phase and frequency encoding
    - Slice selection and slice thickness

- Ultrasound
  - Relationship between wavelength, frequency, and speed of sound
    - How speed is affected by different media (e.g. air vs bone vs different soft tissues) and frequency changes
  - Interactions of ultrasound with matter
    - Reflection, refraction, scatter, and absorption
    - Acoustic impedance
  - Components of transducers and their function
    - Piezoelectric materials
    - How different composition affects wavelength and frequency
  - Spatial pulse length and relationship with axial resolution, wavelength (λ), and number of cycles in pulse (n)
  - Bernoulli effect
  - Doppler effect and shift
    - How variables will affect the perceived Doppler shift (e.g. reflector speed, angle)

## ELECTROMAGNETIC RADIATION

- Electromagnetic spectrum
  - Relationships between energy, frequency, wavelength, and light speeds
- Electromagnetic radiation as a particle
- Physical characteristics of different types of waves
- Concepts of radiation energy and physical density
- Impact of different types of matter on wave movement
- Interaction of light waves with matter
- Inverse square law and its implications
- Radiation Energy in Radiology
- Beam Quality and Attenuation
  - Intensity
  - Quality
  - Half-Value Layer (HVL)
  - Linear Attenuation Coefficient (μ)
  - Mass Attenuation Coefficient (μ/ρ)

## RESOURCE LIST FOR ACVR PRELIMINARY EXAMINATION

This resource list is a guide to help residents prepare for the Preliminary examination. This list is based on the most referenced sources for the Preliminary examination but is not an exhaustive list. There is no required reading so feel free to use other similar references if you prefer.

- Medical Physics
  - Curry, Thomas S., James E. Dowdey, and Robert C. Murry. *Christensen's physics of diagnostic radiology*. Lippincott Williams & Wilkins, 1990.
  - Bushberg, Jerrold T., and John M. Boone. *The essential physics of medical imaging*. Lippincott Williams & Wilkins, 2011.
  - Held, Kathryn D. "Radiobiology for the radiologist, by Eric J. Hall and Amato J. Giaccia." (2006): 816-817.
  - Kremkau, Frederick W. *Sonography principles and instruments*. Elsevier Health Sciences, 2015.
  - Walter, Huda. "Review of Radiologic Physics." (2010).
  - Bushong, Stewart Carlyle, and Frank Goerner. *Radiologic science for technologists*. Elsevier Health Sciences, 2012.
  - Lionhart, Prometheus. "Radiologic Physics War Machine", 3rd Edition.
  - McRobbie, Donald W., et al. *MRI from Picture to Proton*. Cambridge university press, 2017.
  - Westbrook, Catherine, and John Talbot. *MRI in Practice*. John Wiley & Sons, 2018.

- Anatomy
  - Hermanson, John W., and Alexander De Lahunta. *Miller and Evans' anatomy of the dog-E-book*. Elsevier Health Sciences, 2018.
  - Dyce, Keith M., Wolfgang O. Sack, and Cornelis Johannes Gerardus Wensing. *Textbook of veterinary anatomy-E-Book*. Elsevier Health Sciences, 2009.
  - König, Horst Erich, Hans-Georg Liebich, and K. L. Overall. "Veterinary anatomy of domestic animals." *Text Book and Colour Atlas. 3rd ed. New York, NY. Schattauer* (2014): 303-5.

- Physiology
  - Hall, John E., and Michael E. Hall. *Guyton and Hall Textbook of Medical Physiology E-Book: Guyton and Hall Textbook of Medical Physiology E-Book*. Elsevier Health Sciences, 2020.
  - Klein, T. Bradley G. *Cunningham's Textbook of Veterinary Physiology-E-Book: Cunningham's Textbook of Veterinary Physiology-E-Book*. Elsevier Health Sciences, 2012.

- General clinical references
  - Ettinger, Stephen J., and Edward C. Feldman. *Textbook of Veterinary Internal Medicine-eBook: Textbook of Veterinary Internal Medicine-eBook*. Elsevier health sciences, 2010.
  - Morris, Joanna, and Jane Dobson. *Small animal oncology*. John Wiley & Sons, 2008.
  - Lorenz, Michael D., Joan Coates, and Marc Kent. *Handbook of Veterinary Neurology-E-Book: Handbook of Veterinary Neurology-E-Book*. Elsevier Health Sciences, 2010.

- Fossum TW. Small Animal Surgery. 5th ed. St. Louis, MO: Elsevier; 2020. Selected chapters on orthopedics.

- Imaging references
    - Thrall, Donald E. *Textbook of veterinary diagnostic radiology-E-book*. Elsevier health sciences, 2012.
    - Mattoon, John S., Rance K. Sellon, and Clifford Rudd Berry. *Small animal diagnostic ultrasound E-Book*. Elsevier health sciences, 2020.
    - Penninck, Dominique, and Marc-André d'Anjou, eds. *Atlas of small animal ultrasonography*. John Wiley & Sons, 2015.
    - Douglas, S. W. "Contrast media techniques in radiography." *Journal of Small Animal Practice* 7.12 (1966): 781-790.
    - Murray, Rachel C., ed. *Equine MRI*. John Wiley & Sons, 2010.
    - Schwarz, Tobias, and Jimmy Saunders, eds. *Veterinary computed tomography*. John Wiley & Sons, 2011.
    - Bertolini, Giovanna. "Body MDCT in small animals." *Cham, Switzerland: Springer International Publishing* (2017).
    - Mai, Wilfried, ed. *Diagnostic MRI in dogs and cats*. CRC press, 2018.
    - Boon, June A. *Veterinary echocardiography*. John Wiley & Sons, 2011.
    - Wallack, Seth T. *The handbook of veterinary contrast radiography*. San Diego Veterinary Imaging, 2003.

- Digital imaging and Image viewing environment
    - Thomas, A. M. K. "PACS A Guide to the Digital Revolution. Edited by KJ Dreyer, A Metha and JH Thrall, pp. x+ 435, 2002 (Springer-Verlag, New York NY),£ 76.50 ISBN 0 387 25291 8." (2003): 82-82.
    - Puchalski, Sarah M. "Image display." *Veterinary radiology & ultrasound* 49 (2008): S9-S13.
    - Kagadis, George C., et al. "Medical imaging displays and their use in image interpretation." *Radiographics* 33.1 (2013): 275-290.
    - Larsen EP, Hailu T, Sheldon L, Ginader A, Bodo N, Dewane D, Degnan AJ, Finley J, Sze RW. Optimizing Radiology Reading Room Design: The Eudaimonia Radiology Machine. J Am Coll Radiol. 2021 Jan;18(1 Pt A):108-120. doi: 10.1016/j.jacr.2020.09.041. Epub 2020 Oct 13. PMID: 33065075; PMCID: PMC7553105.

- Radiation and Equipment Safety
    - Bushong, Stewart Carlyle, and Frank Goerner. *Radiologic science for technologists*. Elsevier Health Sciences, 2012.
    - IAEA. *Radiation Protection and Safety in Veterinary Medicine*. International Atomic Energy Agency, 2021.
    - Hall, Eric J., and Amato J. Giaccia. "Radiobiology for the Radiologist." *Int J Radiat Oncol Biol Phys* 66.627 (2006): 10-1016.

Residents are encouraged to review other common veterinary journal for articles related to diagnostic imaging. The majority of the relevant journal articles will be found in the list 10-15 years, however, there may be fundamental concepts in imaging that were published prior to this time frame that are still relevant.

- Veterinary Radiology and Ultrasound

- Radiographics
- American Journal of Veterinary Research

## STUDY GUIDE SAMPLE QUESTIONS

## A: IMAGING MODALITIES

### CONTRAST MEDIA

Ultrasound contrast agents primarily enhance ultrasound images by:

a. increasing tissue density and thus sound wave attenuation.

b. generating microbubble resonance that increases backscatter of ultrasound waves.

c. chemically interacting with tissues to change their acoustic impedance.

d. being absorbed into tissues and creating permanent signal changes.

Key: B

Rationale: Ultrasound contrast agents consist of gas-filled microbubbles that resonate when exposed to the ultrasound waves, producing strong nonlinear backscatter signals that enhance vascular and tissue perfusion imaging. They do not increase tissue density or chemically alter tissue properties. Their effect is transient, as microbubbles are cleared from circulation, so no permanent signal changes occur.

Which contrast agent is primarily excreted via the hepatobiliary system?

a. Iopromide

b. Diatrizoate meglumine

c. Gadoxetate disodium

d. Gadolinium-DTPA

Key: C

Rationale: Gadoxetate disodium is a hepatobiliary-specific MRI contrast agent taken up by hepatocytes and excreted in bile, enabling liver and biliary imaging. Unlike iodinated agents and gadolinium-DTPA, which are mainly renally cleared, gadoxetate has dual renal and hepatobiliary excretion. Barium sulfate is an inert GI contrast agent that is neither absorbed nor hepatically excreted. This dual clearance makes gadoxetate especially useful for veterinary hepatic imaging.

## RADIOGRAPHY

The main purpose for the second set of lead shutters in a variable aperture collimator is to minimize:

a. penumbra.

b. the effect of errors in mirror angle.

c. the number of non-diagnostic energy x-rays.

d. the number of non-diagnostic energy x-rays.

Key: A

Rationale: Because the second set is farther from the focal spot, the edges of its blades project more sharply onto the image field. By narrowing the field at this plane, it reduces the geometric unsharpness (penumbra) caused by beam divergence.

Which type of x-ray generator has the lowest voltage ripple?

a. Single-phase generator

b. 3-phase, 6-pulse generator

c. 3-phase, 12-pulse generator

d. Constant potential generator

Key: D

Rationale: A constant potential generator maintains a steady, nearly ripple-free DC output voltage across the x-ray tube.

## ULTRASONOGRAPHY

What ultrasound artifact would be associated with a cyst?

a. Acoustic enhancement

b. Posterior shadowing

c. Side lobe

d. Mirror image

Key: A

Rationale: Cysts are defined as thin walled, round to oval shape, filled with anechoic fluid and demonstrate posterior acoustic enhancement. Posterior shadowing artifacts are seen with mineralized, metallic or gas structures, not cysts. Side lobe artifact can be seen on the margins of a rounded structure causing faint hypoechoic linear artifacts that extend from the "sides" of the structure. Mirror image artifacts are seen associated with a curved reflective surface (the diaphragm) causing abdominal structures (liver and gallbladder) to appear to be located cranial to the diaphragm.

## COMPUTED TOMOGRAPHY

What CT artifact causes a pattern of radial dark and bright streaks emanating directly from a high frequency object?

a. Aliasing

b. Slice mismatch

c. Truncation

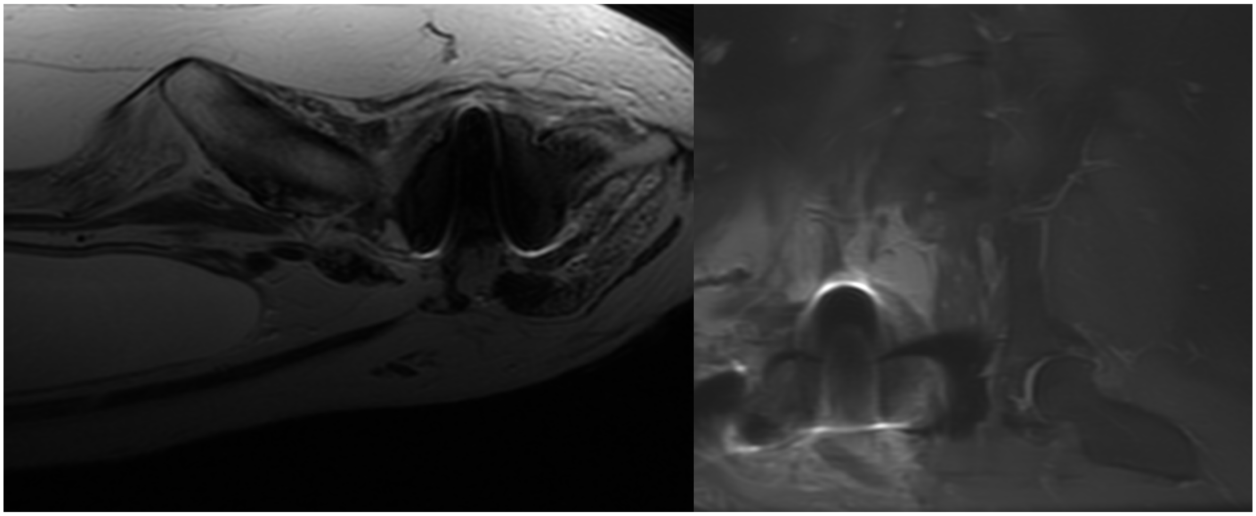
d. High-pitch image distortion

Key: A

Rationale: Aliasing artifact in CT occurs when data sampling is insufficient — that is, the scanner does not collect enough projection samples per rotation to accurately represent rapidly changing attenuation values.

## MAGNETIC RESONANCE IMAGING

Which technical adjustment can reduce the artifact shown in the image?



a. Use gradient echo sequences

b. Use spin echo sequences

c. Flip phase and frequency

d. Increase time to echo

Key: B

Rationale: The artifact is magnetic susceptibility artifact caused by metal (microchip). Using GRE sequences will increase the magnitude of the artifact. The artifact could be reduced by using spin echo sequences or by decreasing time to echo. Phase and frequency would have to effect of the artifact.

# B: DIGITAL IMAGE MANAGEMENT

## DIGITAL IMAGE QUALITY

Which factor most directly determines the spatial resolution in a digital radiography system?

a. Size of the x-ray focal spot

b. Dynamic range of the detector

c. Matrix size and pixel size of the image receptor

d. Window width and level settings used for display

Key: C

Rationale: In digital radiography (DR), the limiting factor for resolution is the detector's sampling frequency, which depends on pixel size and matrix dimensions. Smaller pixels and larger matrices capture finer detail.

In digital radiography, how does a detector with a wide dynamic range improve image quality?

a. Reducing the appearance of saturation artifacts in regions of very high or very low exposure

b. Increasing the inherent spatial resolution of the detector

c. Reducing geometric unsharpness caused by focal spot size

d. Eliminating motion blur from patient movement

Key: A

Rationale: A wide dynamic range enables accurate capture of both dense and lucent areas in one exposure—preventing pixel saturation at the extremes.

## IMAGE VIEWING ENVIRONMENT

What is the recommended ambient lighting condition for diagnostic image interpretation?

a. Bright overhead fluorescent lights

b. Natural daylight from windows

c. Dim, controlled lighting with neutral wall colors

d. Total darkness

Key: C

Rationale: Dim, controlled lighting reduces glare and preserves contrast. Total darkness (D) is also not recommended because the eye needs some adaptation reference.

## C: RADIATION AND EQUIPMENT SAFETY

### PERSONAL PROTECTIVE EQUIPMENT

What is the most important consideration when selecting personal protective equipment (PPE) to reduce radiation exposure in veterinary radiology?

a. Choosing equipment that completely blocks all x-rays
b. Selecting PPE that provides adequate attenuation for the beam energy while allowing comfort and mobility
c. Selecting the lightest available equipment regardless of shielding equivalence
d. Choosing equipment based on appearance or color coding

Key: B

Rationale: The key factor is achieving adequate attenuation appropriate for the x-ray beam energy (typically 60–120 kVp) while ensuring the wearer can move freely and comfortably.

### SAFETY REGULATIONS FOR RADIATION EXPOSURE

Which is a stochastic effect of ionizing radiation?

a. Genetic mutation
b. Cataract formation
c. Skin erythema
d. Hair loss

Key: A

Rationale: Stochastic effects are random, probabilistic outcomes of radiation exposure, where the probability of occurrence increases with dose but severity does not. Examples include cancer induction and heritable genetic mutations. Deterministic (non-stochastic) effects, by contrast, have a threshold and severity increases with dose, such as skin erythema, cataracts, and hair loss.

Reference: Hall EJ, Giaccia AJ. Radiobiology for the Radiologist. 8th ed. Philadelphia, PA: Wolters Kluwer; 2019.

A portable X-ray delivers 0.20 mGy at 2 m. What is the dose at 4 m?

a. 0.05 mGy

b. 0.10 mGy

c. 0.40 mGy

d. 0.80 mGy

Key: A
Rationale: Use the inverse square law for radiation intensity/dose.

Reference (AMA): Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. The Essential Physics of Medical Imaging. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2012: Ch 5.

## MRI MACHINE SAFETY

What type of object is most likely to result in a flying projectile in the MRI room?

a. Titanium total hip replacement stem

b. Mercury thermometer

c. Aluminum IV stand

d. Compressed oxygen cylinder

Key: D

Rationale: A compressed oxygen cylinder is typically composed of ferrous metal, which the MR magnetic will attract.  MRI “safe’ oxygen cylinders made out of aluminum would not pose a problem. A titanium prosthesis or aluminum IV pole are not ferrous metals and are not attracted to a magnet. A mercury thermometer also will not be attracted to a magnet.

## MEASUREMENT OF RADIATION EXPOSURE

Which device is most commonly used to measure the cumulative occupational radiation exposure of veterinary radiology personnel over time?

a. Ionization chamber survey meter

b. Thermoluminescent dosimeter (TLD)

c. Geiger–Müller counter

d. Scintillation detector

Key: B

Rationale: They contain crystalline materials (such as lithium fluoride) that store energy when exposed to radiation; this energy is later released as light when heated, proportional to the absorbed dose.

Which instrument provides the most accurate measurement of radiation exposure or air kerma from an x-ray beam during equipment calibration or quality control testing?

a. Film badge dosimeter

b. Ionization chamber survey meter

c. Geiger–Müller counter

d. Thermoluminescent dosimeter (TLD)

Key: B

Rationale: Ionization chambers measure the ion pairs produced in air by x-ray photons and provide a quantitative reading of exposure or air kerma (in units of gray or coulombs/kg). They are the reference standard for beam output, exposure rate, and calibration measurements.

# D: PHYSICS AND MATHEMATICS

## MODALITY APPLIED PHYSICS

Increasing which ultrasound parameter would result in the lowest axial resolution?

a. Depth

b. Frequency

c. Wavelength

d. Spatial pulse length

Key: B

Rationale: Axial resolution is the minimum reflector separation required along the direction of the sound (scan line) to produce separate echoes. Axial resolution can be calculated as:

Axial resolution (mm)=spatial pulse length (mm)/2.

The smaller the value of the axial resolution, the finer the detail. To improve axial resolution (lower numerical value), SPL has to be reduced. This can be achieved by changing the wavelength or the number of cycles in each pulse. Wavelength is reduced by increasing frequency ($c = \lambda f$).

What is k-edge?

a. The kV peak for the majority of photons produced by the tube.

b. A photoelectric effect peak at the binding energy for electrons.

c. An incident photon energy peak prior to Compton interaction.

d. The binding energy peak for ejected outer shell electron pairs.

Key: B

Rationale: he K-edge refers to the sharp increase (“edge”) in x-ray attenuation that occurs when the photon energy just exceeds the binding energy of K-shell (innermost) electrons of an atom. At photon energies slightly above this binding energy, photoelectric absorption suddenly increases because photons now have enough energy to eject K-shell electrons. This results in a distinct “jump” or peak on a graph of attenuation coefficient versus photon energy — the K-edge.

If a mAs of 2 was used at a distance of 40cm, what is the mAs needed at a distance of 60cm.

a. 2.25
b. 3
c. 4.5
d. 6.75

Key: C

Rationale: mAs2 =mAs1 ×[(D1/D2 )^2 ]= 2 x [(60/40)^2]

Which type of electromagnetic radiation has the largest wavelength

a. Gamma-ray
b. X-ray
c. Visible light
d. Radiowave

Key: D

Rationale: Radio wavelength has the greatest wavelength and lowest frequency. The energy is also the lowest