ACVR | Diagnostic Imaging

DI 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

Thank you to the exam committees and all the Diplomates and residents whose input was critical in the development of this material.

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KEY CONCEPTS

E: ANATOMY, PHYSIOLOGY, AND PATHOPHYSIOLOGY (80%)

A variety of imaging modalities are employed to evaluate disease in veterinary patients, including radiography, fluoroscopy, and computed tomography. Consequently, thorough knowledge of normal and abnormal anatomy and physiology is a fundamental component of the veterinary radiologist's daily practice.

The listed diseases are examples to guide study and the exam may not be limited to these topics.

RESPIRATORY SYSTEM

- Anatomy and physiology
    - Upper and lower airway
    - Mediastinum
    - Pulmonary parenchyma and vasculature
        - relationship between lung perfusion and lung health
        - relationship between the blood gas profile and respiratory health
    - Relationship between respiratory systems and other bodily systems
    - Processes involved in the production and resorption of pleural fluid
- Pathophysiology of common respiratory, mediastinal, and pleural diseases
    - Infectious/inflammatory
    - Neoplasia
    - Edema
    - Trauma

DIGESTIVE SYSTEM

- Anatomy and physiology
    - Pancreas
    - Endocrine vs exocrine
    - Ductal and vascular anatomy
    - Species differences
    - Esophagus
    - Gastrointestinal tract
    - Normal anatomic relationships of gastrointestinal tract with all other abdominal organs
- Pathophysiology of common disorders
    - Pancreatitis
    - Swallowing disorders

- Gastrointestinal obstruction
- Neoplasia

HEPATOBILIARY SYSTEM

- Anatomy and physiology
  - Liver
  - Gallbladder
  - Biliary tree
  - Vascular structures
  - Embryology of the hepatobiliary system to understand the development of common malformations
- Pathophysiology of common disorders
  - Inflammatory disease
  - Cirrhosis
  - Biliary obstruction
  - Neoplasia
  - Congenital anomalies (biliary, vascular, embryology, etc.)
  - Acquired vascular anomalies (portal hypertension, etc.)

MUSCULOSKELETAL SYSTEM

- Anatomy and Physiology
  - General principles of bone anatomy
  - Normal variants
  - Endochondral ossification and physeal closures
  - Bone response to injury or disease
  - Species differences
  - Radiographic technique for the skeletal system
- Pathophysiology
  - Bones
    - Aggressive versus non-aggressive bone lesions
    - Congenital/developmental conditions
    - Metabolic disease
    - Vascular conditions
    - Traumatic injuries
  - Joints, muscles, tendons, ligaments and other soft tissues
    - Congenital/development conditions
    - Erosive and non-erosive disease
    - Traumatic injuries
    - Metabolic disease
    - Infectious or other inflammatory disease

        - Neoplasia

URINARY SYSTEM

- Anatomy and physiology
    - Kidney (including renal function assessment)
    - Ureters
    - Urinary bladder
    - Urethra
    - Relationship between urinary system and other bodily systems
- Pathophysiology
    - Renal disease (e.g. renal failure, GFR, pyelonephritis, etc.)
    - Obstructions
    - Neoplasia
    - Urolithiasis
    - Congenital malformations

CARDIOVASCULAR SYSTEM

- Anatomy and physiology
    - Cardiac anatomy and cycle
    - Embryology of the cardiovascular system to understand the development of common malformations of the heart and vascular system
    - Differences between fetal and neonatal circulation
    - Major arterial supplies, venous drainage and portal systems
- Pathophysiology
    - Effects of common cardiac diseases including developmental anomalies
    - Hemodynamics, flow, timing, and pressure relationships
    - Congenital and acquired cardiovascular diseases
    - Mechanisms and pathophysiologic effects of congestive heart failure
    - Pericardial disease and effect on cardiac function
    - Cardiac malformations
    - Thoracic and abdominal vascular malformation
    - Thromboembolic disease

NEUROLOGIC SYSTEM

- Anatomy and physiology
    - Embryonic derivation of spinal and vertebral components germane to clinically encountered congenital disease
    - Anatomical relationships of spinal cord, spinal nerves and meninges and vertebral canal
    - Brachial and lumbosacral plexus
    - Major components and innervations of the nerves that originate from these plexus
    - Distribution of nerves in the distal extremity of the thoracic and pelvic equine limbs as related to common nerve blocks performed
    - Anatomy of the brain, brain stem, including the cranial nerves and spinal cord that can be recognized with cross-sectional imaging
    - Ventricular system of the brain including CSF flow dynamics
    - Origin of cranial nerves and their function
    - General understanding of neurologic examination and lesion localization
    - Anatomy of the organs of special sense
    - Vascular supply to the brain and spinal cord
- Pathophysiology
    - Common spinal cord and brain disorders
    - Neoplasia
    - Infectious/inflammatory disease
    - Malformations
    - Degenerative disease
    - Intervertebral disc disease
    - Vascular
    - Trauma

ENDOCRINE SYSTEM

- Anatomy and physiology
    - Adrenal glands
    - Thyroid and parathyroid glands, including ectopic locations
    - Pituitary gland
    - Relationship between endocrine systems and other bodily systems
- Pathophysiology
    - Thyroid iodine trapping and imaging significance in functional and non-functional disease processes
    - Parathyroid feedback loop and discriminating between different types of hyperparathyroidism
    - Expected imaging findings with hyperfunctional or hypofunctional endocrine diseases
    - Preferred imaging modalities and parameters for suspected disease processes
    - Neoplasia

LYMPHATIC SYSTEM

- Anatomy and physiology
  - Lymph nodes
  - Lymph production, flow/drainage
  - Central lymphatic system (thoracic duct, cisterna chili)
  - Spleen
  - Techniques for evaluation of the lymphatic system (lymph node mapping, lymphangiography)
- Pathophysiology
  - Neoplasia
  - Inflammatory/infectious
  - Lymph flow disturbances (lymphangiectasia, lymphedema, chylothorax)
  - Hyperplasia

REPRODUCTIVE SYSTEM

- Anatomy and physiology
  - Gonadal structures
  - Embryonic urogenital organ development
  - Radiographically identifiable fetal ossification intervals
  - Relationships between urogenital tissues, hormones and minerals
- Pathophysiology
  - Malformations of the urogenital system
  - Infectious/inflammatory disease
  - Neoplasia
  - Structural diseases
  - Intersex
  - Imaging indicators of fetal death

F: IMAGING MODALITIES (16%)

URINARY CONTRAST RADIOGRAPHY

- The indications and contraindications, technical aspects (including choice of contrast media) complications, standard imaging protocols (including positioning) and principles of interpretation for the following contrast procedures.
- Kidney/ureteral urinary contrast radiography

    - Quality of the nephrogram versus persistent opacification versus clearance of the contrast medium
    - Contrast radiographic signs of common conditions of the kidney and ureter
- Bladder/urethral urinary contrast radiography
    - Type of cystographic procedure (e.g. positive, negative, double contrast)
    - Contrast radiographic signs of common conditions of the urinary bladder (e.g. luminal disease, mural disease, etc.)

GI CONTRAST RADIOGRAPHY

- The indications and contra-indications, technical aspects (including choice of contrast media) complications, standard imaging protocols (including positioning) and principles of interpretation for the following contrast procedures.
- Esophagography (including evaluation of swallowing)
- Gastrography (positive, negative and double contrast)
- Upper GI series
- Colonography (positive and negative)

FLUOROSCOPY

- The principles of fluoroscopic image systems
    - Image intensification and flat-panel technology
    - Automatic Brightness Control (ABC)
- Principles of radiation safety specific to fluoroscopy (e.g. dose considerations, image quality vs. dose tradeoff, etc.)
- Fluoroscopy imaging artifacts (e.g. motion blur, veiling glare, pincushion and S-distortion lag artifacts in digital systems, etc.)
- Clinical applications (technique, protocol, interpretation)
    - Know the standard imaging protocols (including positioning) and principles of interpretation
    - Gastrointestinal studies (e.g. swallowing disorders, esophageal motility, etc.)
    - Airway evaluation (e.g. tracheal collapse, laryngeal function, dynamic airway obstruction, etc.)
    - Cardiovascular applications (e.g. selective angiography, non-selective angiography)
    - Orthopedic applications (e.g. arthrography)

G: DIGITAL IMAGE MANAGEMENT (4%)

DIGITAL IMAGE STORAGE

- How images are digitally stored by computers (e.g. conversion of analog to digital including methods of conversion, transfer of digital information)
- The principles of image storage (e.g. RAID types, data storage options)
    - The quality of a stored image based on the properties of the image
- Picture Archival and Communication System (PACS) software (e.g. security measures, DICOM, RIS, HIS, information required to connect systems, etc.)
    - Computers and computer networks (e.g. ethernet, LAN, WAN, internets speed, transmission speed and bandwidth, VPN use in radiology, etc.)
- DICOM standards
    - DICOM transmission of images
    - DICOM images and metadata
    - Modality worklist
    - DICOM tags and their use
    - Image compression (lossy, lossless)
    - Temporal compression
- The types of digital images and the metrics use to indicate image size and effects on storage of data (e.g. matrix size, bits per pixel)
- Security software that can be used to store digital records.

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.
  - Ziemer, Lisa S., et al. "ACVR and ECVDI consensus statement for teleradiology." *Veterinary Radiology & Ultrasound* 65.3 (2024): 288-293.

- 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 journals 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
- Journal of the American Veterinary Medical Association
- Veterinary Clinics of North America
- American Journal of Veterinary Research
- Journal of Veterinary Internal Medicine

- Equine Veterinary Journal
- Journal of Feline Medicine and Surgery.
- Journal of Veterinary Internal Medicine.
- Veterinary Radiology and Ultrasound.

STUDY GUIDE SAMPLE QUESTIONS

E: ANATOMY, PHYSIOLOGY, AND PATHOPHYSIOLOGY

RESPIRATORY SYSTEM

Which species does not have a right middle lung lobe?

a. Bovine

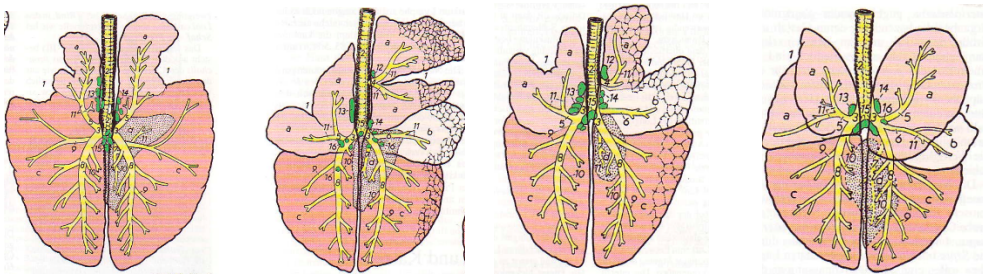
b. Canine

c. Equine

d. Swine

Key: C

Rationale: Basic anatomy - The equine species does not have a right middle lung lobe.



Equine Bovine Swine Canine

a. cranial lung lobes, b. right middle lung lobe, c. caudal lung lobes (images from Nickel Anatomy of the domestic animal)

When performing lateral radiographs of the pharyngeal region of a horse, the position resulting in the narrowest pharyngeal diameter is a:

a. dorsal neck position with the head flexed.
b. dorsal neck position with the head extended.
c. ventral neck position with the head extended.
d. ventral neck position with the head flexed.

Key: A

Rationale: The smallest pharyngeal diameter was found at the dorsal, flexed position, which is a clinically important head position in dressage horses. The largest pharyngeal diameter was found at the extended midway position. At each head level, the pharyngeal diameter decreased with flexing the head and it increased with extending the head. The head angle was not associated with pharyngeal diameter, and neither sedation status nor breathing cycle significantly affected pharyngeal diameter. A decrease in pharyngeal diameter will limit the airflow through the upper respiratory tract, and it may result in turbulence with subsequent dynamic collapse.

DIGESTIVE SYSTEM

On ultrasound, micronodular lesions in some dogs and cats with diarrhea, are located in what layer of the colon?

a. Mucosa

b. Submucosa

c. Muscularis

d. Serosa

Key: B

Rationale: VRUS 2013; 54: 646-651. Micronodular ultrasound lesions in the colonic submucosa of 42 dogs and 14 cats.

Hyperechogenicity of the pyloroduodenal junction in small dogs represents:

a. dilated lacteals.

b. normal anatomical transition zone.

c. collagen and fibrosis.

d. early outflow obstruction.

Key: B

Rationale: VRUS 2024; 65: 238-245. Hyperechogenicity of the pyloroduodenal junction in small dogs: Population prevalence in 175 dogs and histological correlation in 14 specimens.

MUSCULOSKELETAL SYSTEM

In the cat what is the round foramen is visible on the distomedial humerus?

a. Trochlear

b. Supracondylar

c. Medial condylar

d. Oval

Key: B

Rationale: The supracondylar foramen is a normal variant in cats transmitting the brachial artery and median nerve. References: Thrall, 2018; Dyce et al., 2010.

Humeral intracondylar fissures in dogs are:

a. known to spontaneous heal with minimal intervention.

b. commonly observed in the contralateral elbow of dogs with unilateral humeral condylar fractures.

c. rare in small breed dogs.

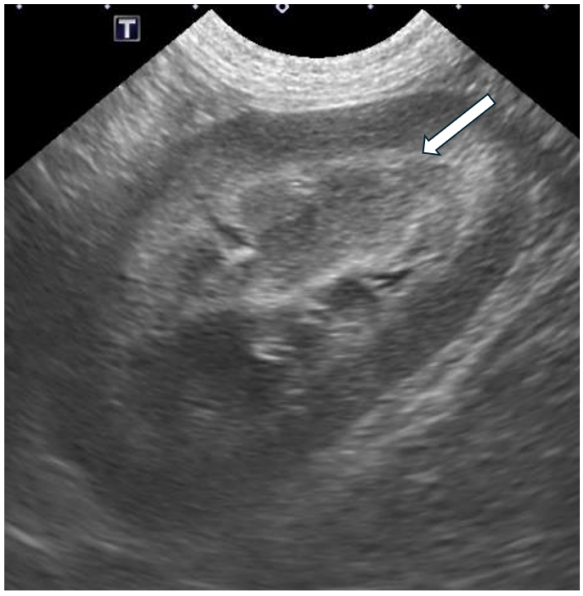
d. always associated with obvious lameness at initial detection.

Key: B

Rationale: HIFs are commonly observed in the contralateral elbow of dogs with unilateral humeral condylar fractures. Humeral intracondylar fissures (HIFs) are stress fractures that can predispose dogs to humeral condylar fractures, even with minimal trauma. In a study by Davenport et al. (2023), HIFs and intracondylar sclerosis were commonly observed in the contralateral elbows of French Bulldogs and spaniel breeds presenting with unilateral humeral condylar fractures.

URINARY SYSTEM

This image was taken from a 4-year-old clinically normal small breed dog. The hyperechoic region noted in the kidney (arrow) most likely represents:



a. normal outer medulla.

b. hemorrhage, edema, and necrosis associated with Leptospirosis.

c. mineralization associated with chronic diffuse nephropathy.

d. fat deposition within the collecting ducts and thin limbs of the loop of Henle.

Key: A

Rationale: VRUS 2013; 54: 652-658: Ultrasound appearance of the outer medulla in dogs without renal dysfunction.

Unidirectional flow of urine from ureter to bladder is aided by:

a. ureteral ileus.

b. oblique path of intramural ureter.

c. overdistension of bladder.

d. caudal location of ureteral papillae.

Key: B

Rationale: Unidirectional flow of urine is aided by ureteral peristalsis, oblique path of intramural ureter and compliant bladder. Ettingers Textbook of Veterinary Medicine, 9th Ed. Chapter 306: Ureteral Disorders

ENDOCRINE SYSTEM

In a dog with a nodule in the region of the thyroid gland, which finding is more consistent with a parathyroid adenocarcinoma than a hyperplastic nodule?

a. Basihyoid bone lysis

b. Nodule is located caudoventral to the thyroid gland

c. Nodule measures 0.8 cm

d. Nodule has homogeneous echotexture

Key: C

Rationale: In each thyroid lobe, there are two parathyroid glands; the external parathyroid gland is located at the cranial and dorsolateral aspect of the thyroid lobe and the internal is embedded within the mid to caudal aspect of the thyroid lobe. Normal parathyroid glands would not be found caudoventrally. Basihyoid lysis is a feature of ectopic thyroid carcinoma. Neoplastic nodules are larger than non-neoplastic nodules. While there is some overlap, adenocarcinomas and adenomas are larger than hyperplastic nodules, with suggested cutoffs of 0.3-0.4 cm. In a 2019 VRU paper, neoplastic nodules were significantly more likely to have heterogeneous echotexture, making choice D incorrect.

Seacrest S. Grimes J. Ultrasonographic size of canine parathyroid gland may not correlate with histopathlogy. Vet Radiol Ultrasound. 2019; 60: 729-733.

REPRODUCTIVE SYSTEM

Which imaging modality is used for early gestation detection in domestic animals?

a. CT

b. MRI

c. Radiography

d. Ultrasound

Key: D

Rationale: Ultrasound allows real-time, non-invasive detection of gestation around day 21-35 in small animals and around day 20-30 in large animals.

What is the cause of a uterus masculinus?

a. Lack of production of anti-Mullerian hormone
b. Prostatic duct occlusion
c. Prostatic retention cyst dilation
d. Retained testicular progesterone secretion

Key: A

Rationale: Failure of normal regression of Mullerian ducts in the male fetus has been attributed to absence or insensitivity to anti-Mullerian hormone (aka Mullerian inhibiting substance)

F: IMAGING MODALITIES

URINARY CONTRAST RADIOGRAPHY

A good initial nephrogram followed by persistent of increasing opacity is most likely due to:

a. insufficient dose of contrast medium.
b. systemic hypotension prior to contrast administration.
c. contrast medium induced renal failure.
d. primary polyuric renal failure.

Key: C

Rationale: The incorrect distractors all result in a poor nephrogram. Contrast induced renal failure produces a good nephrogram initially, but no, or delayed pyelogram phase.

The possibility of gas embolization from negative contrast cystography can be minimized by:

a. the use of nitrous oxide instead of room air as a negative contrast agent.

b. maintaining the patient in dorsal recumbency.

c. adding positive contrast agent along with the negative contrast agent.

d. adding the negative contrast slowly, over a 5-minute period.

Key: A

Rationale: Nitrous oxide is more soluble in blood than room air, resulting in decreased chance of gas embolization.

FLUOROSCOPY

In fluoroscopy, which component most significantly enhances the image brightness compared to using only a fluorescent screen?

a. Flat-panel detector

b. Image intensifier

c. Charge-coupled device (CCD) camera

d. Lead collimator

Key: B

Rationale: Image intensifiers dramatically increase image brightness through a combination of flux gain and minification gain, making the image visible even under normal lighting—far beyond what a faint fluorescent screen could achieve.

Which advantage is commonly associated with flat-panel detectors over image intensifiers in modern fluoroscopy systems?

a. Increased geometric distortion

b. Higher radiation dose rate

c. Elimination of glare and spatial distortion

d. Lower dynamic range

Key: C

Rationale: Elimination of glare and spatial distortion; Flat-panel detectors offer several benefits including improved stability, lower dose rates, broad dynamic range, and importantly — elimination of glare and geometric distortions like vignetting, which are common disadvantages of image intensifiers.

G: DIGITAL IMAGE MANAGEMENT

DIGITAL IMAGE STORAGE

What is an advantage of lossless compression?

a. It is a bit-preserving form of compression.

b. It contains fewer artifacts than uncompressed images.

c. It does not require utilization of DICOM-viewing software.

d. It provides the fastest method of image transfer.

Key: A

Rationale: Lossless compression is preserved bit-by-bit. With irreversible compression (i.e. lossy, nonrecoverable compression), information is lost. Medical images have redundancy, so when reversible compression is used, there is no loss of information. Regardless of compression type, decompressing an image is not instantaneous. Depending on the image quality and study type, images that have been decompressed, such as lossless images, can be used for medical use.