Radiography of the Dog and Cat

Guide to Making and Interpreting Radiographs

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1. More detailed information is available in the Musculoskeleton, Thorax, and Abdomen chapters (chapters 4 through 6).
- **a.** Normal radiographic anatomy is described in chapters 4 through 6.
- **b.** Possible etiologies for radiographic findings described below are listed in the Differential Diagnoses section in chapters 4 through 6.
- **c.** Clinical correlations and radiographic findings are more thoroughly discussed in the Diseases and Disorders section in chapters 4 through 6.

2. A glossary is available for definitions and quick information.

Musculoskeleton

"Bone is deposited and removed according to the stresses placed on the frame" (Wolff's Law).

Evaluation of bone

1. Different bone diseases commonly present with similar radiographic findings.

2. Diagnosis usually requires information in addition to radiographs (e.g., complete blood count, cytology, histopathology).

3. Current disease may be obscured by preexisting conditions (i.e., degenerative joint disease).

Box 1.1 Checklist for interpreting orthopedic radiographs.

- ✓ At least two orthogonal radiographs
- ✓ Radiographs are those of the animal being evaluated
- ✓ Technique:
  - ✓ Exposure
  - ✓ Positioning
- ✓ Animal's age, body condition, and conformation
- ✓ Bones:
  - ✓ Margination
  - ✓ Opacity
  - ✓ Geometry
  - ✓ Lesion distribution
- ✓ Joints:
  - ✓ Alignment
  - ✓ Width of joint space
  - ✓ Periarticular findings
  - ✓ Lesion distribution
- ✓ Soft tissues:
  - ✓ Thickness
  - ✓ Opacity
- ✓ Reassess based on clinical, physical, and laboratory findings
- ✓ Prioritize list of differential diagnoses
- ✓ Make follow-up radiographs (assess rate of change)

Margination

The less distinct the bone margin, the more active and aggressive the disease process.

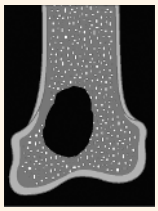
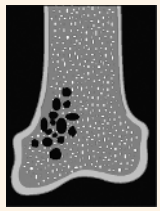
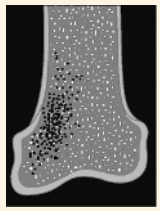
Sharpness of bone margin is not the same as shape of bone border. An irregular border does not equal an ill-defined margin and a smooth border does not equal a well-defined margin. Assess how easily the bone margin can be traced with a pencil to determine its sharpness.

Opacity

- ✓ At least 30%–50% of bone must be altered before a change is visible on radiographs.
- ✓ Active bone destruction may be visible in 5 to 7 days on radiographs.
- ✓ Active bone production may be visible in 10 to 14 days, possibly sooner in rapidly growing, immature animals.

1. Decreased bone opacity (bone loss):
- **a.** Osteopenia (radiologic term for "too little bone").
  - **1)** Bone to soft tissue contrast is poor.
  - **2)** Cortices become thin and faint.
  - **3)** Corticomedullary contrast is poor.
  - **4)** Trabeculae in cancellous bone appear larger and more porous ("coarse trabecular pattern") due to loss of fine boney structures.
  - **5)** A "double cortical line" may be visible due to intracortical resorption of bone.
  - **6)** May be general (i.e., systemic disease) or regional (i.e., disuse atrophy of a limb).
  - **7)** General osteopenia (e.g., hyperparathyroidism, nutritional deficiency) typically affects vertebrae first, followed by mandible and then long bones.
  - **8)** Regional osteopenia (e.g., limb immobilization) tends to be more severe in distal portion of limb.
- **b.** Osteolysis
  - **1)** Pattern of osteolysis reflects aggressiveness of disease process.
    - **a)** Geographic pattern (least aggressive).
    - **b)** Moth-eaten pattern (more aggressive).
    - **c)** Permeative pattern (most aggressive).
  - **2)** Osteolytic pattern is assessed by several criteria (Table 1.1):
    - **a)** Size, number, and location of lesions.
    - **b)** Margination (less distinct margin = more aggressive disease process).
    - **c)** Zone of transition between normal and diseased bone (longer and less distinct zone = more aggressive disease).
    - **d)** Rate of change on subsequent radiographs (greater change = more aggressive).

Table 1.1 Patterns of osteolysis

Pattern	Geographic	Moth-eaten	Permeative
Radiographic appearance			
Size, number of lesions	Large, solitary (over 10 mm)	Small, multiple (3–10 mm)	Tiny, numerous (1–2 mm)
Margination	Well-defined	Poorly-defined	Ill-defined
Zone of transition	Short, well-defined	Long, poorly-defined	Diffuse, nondefined
Cortical remodeling	Normal or thinned	Irregular thinning, sometimes disrupted	Thin, indistinct, often disrupted
Osteosclerosis	May surround lesion	Absent	Absent
Type of lesion	Benign, nonaggressive	Aggressive	Very aggressive
Examples	Bone cyst, pressure remodeling	Tumor, osteomyelitis	Malignant tumor, severe osteomyelitis

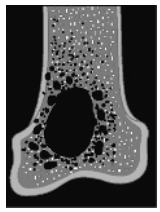


Figure 1.1 Mixed pattern of osteolysis. An aggressive disease process causing peripheral permeative osteolysis with an inner moth-eaten pattern and central geographic pattern (latter due to coalescence of moth-eaten osteolysis).

3) Mixed patterns of osteolysis are common, especially with aggressive diseases. As long as disease is active and unchecked, bone destruction will continue and bone margins will remain ill-defined.

a) Aggressive diseases typically begin as a permeative pattern of osteolysis and progress to moth-eaten and a central geographic pattern (Figure 1.1).

4) Some diseases may not present with visible osteolysis on intitial radiographs (e.g., rib tumors). Serial radiographs aid in characterization of disease process.

2. Increased bone opacity (bone production):

a. Osteosclerosis (hardening or increased density of bone).

1) May be localized (e.g., degenerative joint disease) or diffuse (e.g., osteopetrosis).

2) Localized osteosclerosis typically appears as a thin rim of increased opacity adjacent to a lesion (as body attempts to wall-off disease) or subchondral near a joint surface.

3) Osteopetrosis results in thickened long bone cortices and a narrowed medullary space.

b. Periosteal response:

Periosteal response is an attempt to heal bone, not a reaction to disease.

1) Whenever periosteum is separated from cortex (and maintains blood supply) it will produce mineral in an attempt to fill the subperiosteal space. Mineral is produced perpendicular to periosteum (Stages of periosteal response are described in the Diseases and Disorders section of chapter 4).

2) Margin of periosteal response reflects activity of disease process (less distinct margin = more active disease process).

3) In addition to margination, periosteal new bone is assessed for:

a) Size and shape.

b) Maturity (more organized bone = more chronic disease process).

c) Rate of change on serial radiographs.

4) If periosteum is only mildly elevated, as may occur with a benign process (e.g., bone bruise, stable healing fracture) or in early stages of disease, mineral deposits quickly fill the subperiosteal space.

a) New bone appears smooth-bordered and even in shape (Figure 1.2).

b) Disease process may be active (ill-defined margins) or inactive (well-defined margins; Figure 1.3).

5) With a more aggressive disease process (e.g., neoplasia, severe osteomyelitis), periosteum is continuously pushed away from cortex and there is insufficient

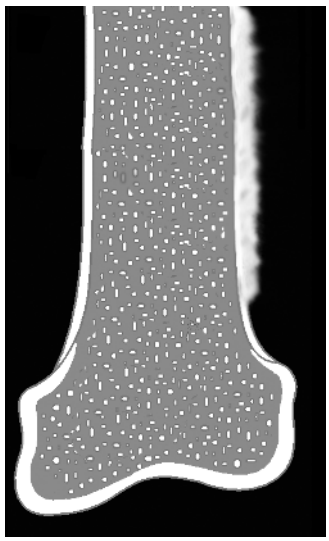


Figure 1.2 Active mild or early periosteal response. Smooth but ill-defined new bone production is visible along right cortex of long bone diaphysis; margins of new bone are hazy and ill-defined (difficult to trace with a pencil).

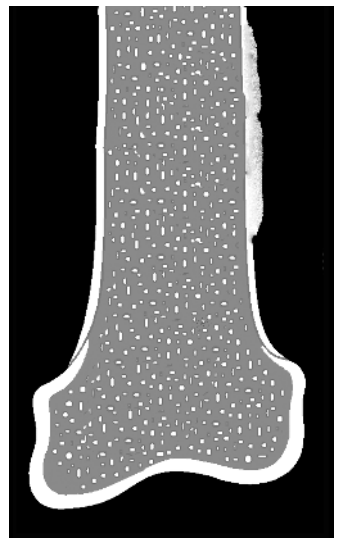


Figure 1.3 Inactive periosteal response due to benign disease. Smooth new bone production is visible along right cortex of long bone diaphysis; margins of new bone are well-defined (easy to trace with a pencil).

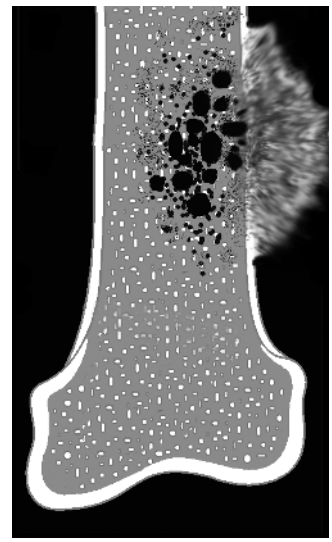


Figure 1.4 Active periosteal response with aggressive disease. Irregular new bone is visible along right cortex of long bone diaphysis; margins are ill-defined. Mixed pattern of osteolysis is present in adjacent bone.

time for mineral deposits to fill the subperiosteal space; margins remain irregular, ill-defined, and often are disrupted (Figure 1.4).

6) As long as disease is active, mineral deposits remain ill-defined, forming perpendicular to periosteum.

a) When disease becomes less active and healing can proceed, mineral deposits become more opaque, better defined and begin to blend with cortex (Table 1.2).

b) Over next few weeks (if disease remains inactive) mineral deposits continue to mature into organized, woven bone with a trabecular pattern and a well-defined margin.

c) Normal stresses can then act to gradually remodel new bone to eventually resemble parent bone.

Geometry

1. Alterations in shape, length, angulation, and diameter may result from numerous etiologies (see Differential Diagnoses and Diseases and Disorders in chapter 4).

2. Normal anatomic variations must be differentiated from pathology. Knowledge of normal anatomy, comparison radiographs of contralateral limb (or a known normal limb), and references (books, anatomic models, box of bones) aid in diagnosis.

Lesion distribution

1. Monostotic (all in same bone) or polyostotic (multiple bones affected).

2. Unilateral or bilateral.

3. Symmetrical or asymmetrical.

4. Epiphyseal, physeal, metaphyseal, diaphyseal.

5. Sites and extent of lesions provide clues to underlying etiology (see Differential Diagnoses in chapter 4).

Evaluation of joints

Alignment of bones

1. Subluxation is partial loss of contact between articular surfaces (i.e., partial dislocation).

2. Luxation is complete loss of contact between articular surfaces (i.e., dislocation).

Joint space width

1. On radiographs, joint space width typically represents thickness of articular cartilage as opposed to volume of joint fluid.

2. Widened joint space in non-weight-bearing images may result from joint effusion, intra-articular mass, or loss of subchondral bone.

3. Narrowed joint space most commonly results from loss of articular cartilage.

4. Joint space width is most accurately assessed with animal weight-bearing and x-ray beam directed perpendicular to joint.

a. Distribution of lesions:

1) Single joint (monarticular).

2) Multiple joints (oligoarticular = 2 to 5 joints, polyarticular = 6 or more joints).

3) Unilateral or bilateral.

4) Pelvic limbs only.

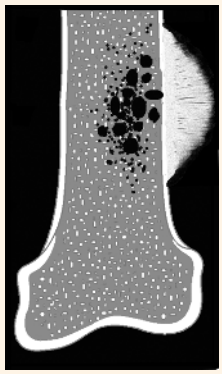
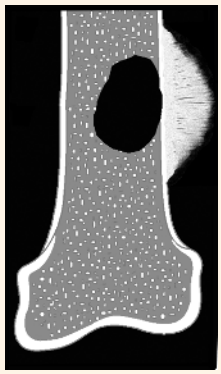
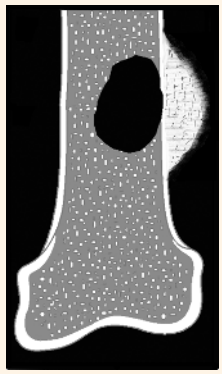
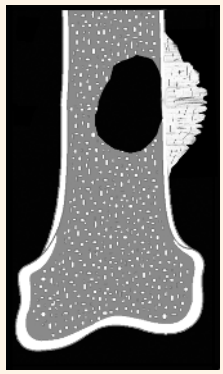
5) Tarsi and/or carpi only.

6) One limb only.

7) Symmetry (bilateral lesions may be symmetrical or asymmetrical).

b. Periarticular findings:

Table 1.2 Activity and aggressiveness of bone disease

Lesion	Active and Aggressive	Active and Nonaggressive	Active and Chronic	Inactive and Nonaggressive
Radiographic Appearance				
Margination	Ill-defined	Ill-defined	Ill-defined	Well-defined
Size and shape of new bone*	Large; irregular	Medium; smooth or irregular	Organized (maturing)	Small; smooth
Osteolysis	Often severe; ill-defined	Well-defined or absent	Well-defined or absent	Usually absent
Appearance of cortex	Destructive remodeling	Displaced, thinned, or normal	Normal, displaced, or thinned	Normal
Soft tissue swelling	Moderate to Severe	Mild	Mild or absent	Absent
Rate of change	Rapid	Slow	Minimal	None
Zone of transition	Long and poorly demarcated	Indistinct but visible	Well-defined	Well-defined
Osteosclerosis	Absent	Ill-defined	Well-defined	Well-defined
Examples	Malignant neoplasia, severe osteomyelitis	Healing fracture, low grade osteomyelitis	Healing fracture, low grade osteomyelitis	Healed fracture

*NOTE: All lesions start small, but active and aggressive lesions tend to grow quickly, while active and chronic lesions tend to enlarge slowly over a long period of time.

1) Osteophytes and enthesophytes are common with chronic disease (Figure 1.5):

a) Appear as well-defined, sharply marginated, bony projections ("bone spurs").

b) Osteophytes form at peripheral margins of articular cartilage, in non-weight-bearing areas.

c) Enthesophytes occur at damaged attachment sites of tendons, ligaments, joint capsules, or fascia, forming in direction of natural pull.

d) Osteophytes and enthesophytes are slow to change, but will grow over time.

e) Conditions that may be mistaken for a bone spur:

1) Normal prominence of bone (especially in chondrodystrophic breeds, usually bilateral).

2) Normal bony protrusion at attachment site of tendon or ligament.

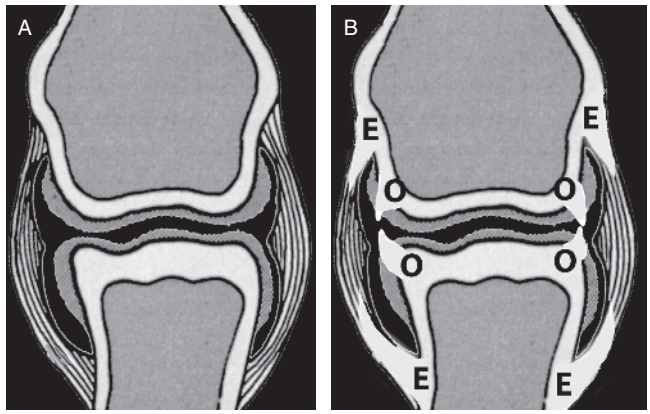


Figure 1.5 Osteophytes and enthesophytes. **A.** Normal joint. **B.** Degenerative joint disease with osteophytes **(O)** forming at periphery of articular cartilage and enthesophytes **(E)** forming at attachments of joint capsule.

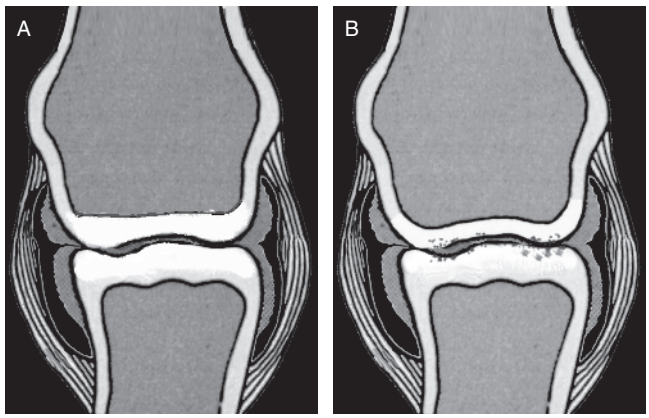


Figure 1.6 Degenerative joint disease. Joint space is narrowed due to loss of articular cartilage. **A.** Subchondral bone is increased in opacity (osteosclerosis). **B.** Focal osteolysis (cystlike lesions) in subchondral bone due to erosion. Normal joint is depicted in Figure 1.5A.

c. Alterations to subchondral bone (e.g., osteosclerosis, osteolysis/erosions, cystic lesions; Figure 1.6).
d. Soft tissue abnormalities (see Differential Diagnoses in chapter 4):
1) Swelling
a) Intracapsular (e.g., joint effusion, tumor) is confined to limits of joint capsule.
b) Extracapsular (e.g., ligament damage, hematoma, tumor) extends beyond limits of joint capsule.
c) Combination of both.
2) Atrophy may be present due to disuse (compare with contralateral limb).
3) Mineralization
a) May be intra-articular or extra-articular.
b) Possible etiologies include bone or cartilage fragment, chronic inflammation, or tumor.
4) Emphysema may be caused by penetrating wound, infection with gas-producing organism, or vacuum phenomenon.

Evaluation of soft tissue

1. Alterations in soft tissues are useful to characterize bone lesions and differentiate normal anatomy from pathology (see Differential Diagnoses in chapter 4).
2. Soft tissue abnormalities usually accompany and often precede bone disease.
3. Musculoskeletal disorders (e.g., pain, lameness) may be limited to soft tissues (e.g., sprain, strain, bruise, inflammation).
4. Comparison radiographs of contralateral limb often aid in recognition of soft tissue anomalies.
5. Increased thickness (swelling):
a. Swelling accompanies most active bone diseases (due to inflammation, hemorrhage, edema, tumor, etc.) and displaces and obscures fascial planes.

Box 1.2 Radiographic signs of joint disease.

- Malalignment of bones (may be mimicked by poor positioning)
- Joint capsule distension (e.g., joint effusion, synovial thickening)
- Altered width of joint space (widened or narrowed)
- Osteophytes (form at edges of articular margins)
- Enthesophytes (form at attachment sites)
- Subchondral osteosclerosis or osteolysis
- Soft tissue mineralization (periarticular or intra-articular)
- Intra-articular gas (vacuum phenomenon)

Box 1.3 Neoplasia vs. osteomyelitis*: General tendencies regarding osseous remodeling.

- Neoplasia tends to be more destructive (osteolytic) than osteomyelitis.
- Osteomyelitis tends to be more productive (larger periosteal response) than neoplasia.
- Neoplastic periosteal response tends to be more irregular and less defined than osteomyelitis.
- Cortical destruction tends to be more severe with neoplasia than with osteomyelitis.
- Codman's triangle tends to be more common with neoplasia than with osteomyelitis.
- Neoplasia tends to remain local while osteomyelitis often spreads along length of bone.
- Sequestrum formation tends to occur with osteomyelitis but is rare with neoplasia.
- Serial radiographs (10-day intervals) tend to reveal relatively little change with osteomyelitis and more significant change with neoplasia.

*Cytology/histopathology is necessary for definitive diagnosis.

b. Absence of swelling near a suspect bone lesion suggests normal anatomic variation or inactive disease.
c. Localized, well-defined, soft tissue swelling may represent a mass.
1) Most soft tissue masses cannot be differentiated on survey radiographs.
2) Fatty masses (e.g., lipoma, liposarcoma) are an exception because they are less opaque than soft tissue.
6. Decreased thickness (deficit):
a. Disuse atrophy (e.g., pain, immobilization, paralysis) is common with many bone diseases.
b. Absence of tissue occurs with severe trauma or surgery.
7. Abnormal opacity:
a. Mineralization may result from chronic inflammation, trauma, tumor, metabolic disease, or presence of foreign material.

b. Gas (emphysema) may be present at site of a penetrating wound, injection, fistulous tract, or due to infection with gas-producing organism.

Evaluation of axial skeleton

Spine

Technique

1. Proper positioning is essential for accurate interpretation.
- **a.** Lateral radiograph:
  - **1)** Transverse spinal processes are superimposed.
  - **2)** Intervertebral foramina are superimposed.
  - **3)** Rib heads are superimposed.
  - **4)** Ilial wings are superimposed.
- **b.** Ventrodorsal (VD) radiograph:
  - **1)** Dorsal spinous processes are centered on vertebral bodies.
  - **2)** Equal distance from dorsal spinous processes to lateral body walls).
  - **3)** Ilial wings are symmetrical.

Evaluation of spine

1. See Diseases and Disorders and Differential Diagnoses sections in chapter 4 ("Musculoskeletal") for specific conditions.

2. Alignment of vertebrae:
- **a.** Poor positioning may mimic altered alignment.
- **b.** Scoliosis = lateral curvature (TIP: "**S**nake like").
- **c.** Lordosis = ventral curvature (TIP: rhymes with "low," "carrying a **L**oad").
- **d.** Kyphosis = dorsal curvature (TIP: rhymes with "high," "mountain peak **K**2").
- **e.** Fracture/subluxation/luxation.

3. Number of vertebrae:
- **a.** Altered number usually is without clinical significance.
- **b.** Important to consider when identifying anatomic landmarks used in surgical and advanced imaging procedures.
- **c.** Altered number of vertebrae may represent a true increase/decrease or an apparent change.
  - **1)** True alterations are not uncommon in some animals (such as cats and Dachshunds with 6 or 8 lumbar vertebrae).
  - **2)** Apparent alterations are common due to presence of congenital vertebral anomalies:
    - **a)** Absence of ribs on T13 appears as 12 thoracic and 8 lumbar vertebrae.
    - **b)** Riblike structures on L1 appears as 14 thoracic and 6 lumbar vertebrae.
- **d.** Four sacral vertebrae are sometimes present.

4. Shape, margination, and opacity of each vertebra.
- **a.** Normal variations in shape exist along each spinal region (see Normal Radiographic Anatomy in chapter 4).
- **b.** Alterations in shape of vertebrae may represent developmental anomalies (e.g., hemivertebrae, transitional vertebrae) or acquired disease (e.g., fracture, tumor).
- **c.** Altered opacity may be general (e.g., osteoporosis, osteopetrosis) or local (e.g., tumor, infection).

5. Dorsal spinal articulations:
- **a.** These are synovial joints that are subject to degenerative joint disease.
- **b.** Dorsal articular facets normally are smooth, well-defined, and similar between vertebrae.
- **c.** Width of intervertebral joint spaces should be similar between adjacent vertebrae.

6. Spinal canal:
- **a.** Normal widening occurs at cervical and lumbar intumescence.
- **b.** Abnormal widening may result from pressure remodeling (e.g., spinal cord tumor).
- **c.** Abnormal narrowing may represent stenosis (congenital or acquired).
- **d.** Ventral aspect of spinal canal normally is smooth and continuous (NOTE: vertebrae move slightly to allow bending of spine).
- **e.** Increased opacity may occur with herniated disc material.

7. Intervertebral disc spaces:
- **a.** Spaces normally appear similar in width to adjacent spaces (see Normal Radiographic Anatomy in chapter 4). (NOTE: disc spaces at periphery of x-ray beam commonly appear narrowed due to distortion.)
- **b.** Increased opacity most commonly is caused by mineralized intervertebral disc.
- **c.** Decreased opacity may result from vacuum phenomenon.

8. Soft tissues are examined dorsal, ventral, and lateral to spine for alterations in thickness and opacity.

Head and neck

1. Although CT and MRI are used extensively for skull imaging, radiography is still useful.

Technique

1. Radiography of the skull requires high-quality images and careful evaluation.

2. Exposure may need to be adjusted for different thickness of skull or to adequately visualize soft tissues.

3. Symmetry and absence of rotation are important because one side of skull usually is compared with the other. If correct positioning is not possible, take malpositioning into account.

Evaluation of skull

1. Considerable variation exists in normal appearance of skull among the many dog and cat breeds.

2. Reference materials such as anatomy and radiology textbooks, bone specimens, and normal radiographs aid in interpretation.

3. Due to superimposition of many bones and extensive compartmentalization, a systematic approach is essential when evaluating skull radiographs:

a. Region I (Figure 1.7):

1) Mandibles: horizontal and vertical rami, condyloid process, temporomandibular joints (TMJ), teeth, alveolar bone, symphysis.

2) Maxillae: hard palate, teeth, alveolar bone.

3) Zygomatic arch: zygomatic bone, squamous temporal bone, retroglenoid process of TMJ.

b. Region II (Figure 1.8):

1) Nasal cavity and turbinates.

2) Vomer bone (nasal septum).

3) Ethmoturbinates and cribiform plate.

4) Frontal sinuses and supraorbital process.

5) Orbit.

c. Region III (Figure 1.9):

1) Cranial vault: frontal, parietal, occipital, temporal bones.

2) Petrous temporal bone (inner ear).

3) Osseous bullae (middle ear).

4) Occipital condyles and foramen magnum.

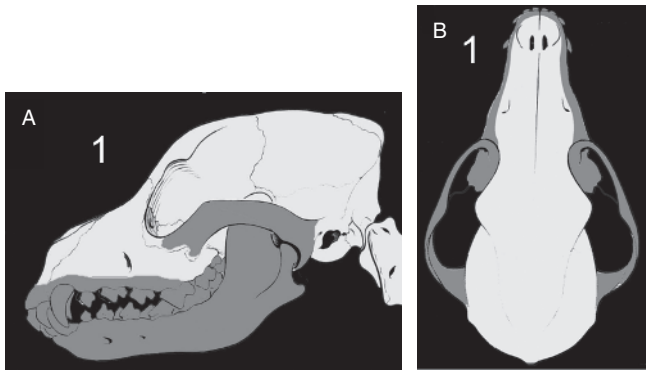


Figure 1.7 Region I for systematic evaluation of skull radiographs. **A.** Lateral radiograph. **B.** DV/VD radiograph.

d. Region IV

1) Soft tissues: skin, subcutaneous, muscles of head.

2) Soft palate.

3) Nasopharynx, oropharynx, pharynx

4) Retropharyngeal space.

5) Larynx: hyoid bones, laryngeal cartilages.

6) External auditory canals.

7) Cervical spine.

Nasal cavity and frontal sinuses

1. Evaluated for alterations in opacity and bony structures (Figure 1.10).

a. Increased opacity may result from presence of foreign material, fluid, or mass, which also tend to obscure normal turbinate patterns.

b. Decreased opacity usually is caused by osteolysis.

2. Adjacent structures may be involved (e.g., frontal sinuses, frontal and maxillary bones, cranial vault, teeth, soft tissues).

3. Findings often are nonspecific but aid in determining location and extent of lesion(s).

4. Aggressive lesions (e.g., neoplasia, severe osteomyelitis):

a. Commonly present with increased soft tissue opacity in turbinates and sinuses due to edema, inflammation, tumor cells, or/and accumulation of fluid.

b. Destruction of nasal turbinates causes loss of fine boney pattern (easiest to see on open mouth ventrodorsal radiograph).

c. Nasal septum may be deviated due to expanding tumor mass.

d. May see osteolysis of overlying nasal, maxillary, or frontal bone(s), often with periosteal response.

e. External soft tissue swelling or mass may be present.

f. In general, unilateral aggressive lesions are more likely to be neoplastic and bilateral lesions are more likely to represent chronic inflammation, but this is not always the case (cytology/histopathology usually is necessary for definitive diagnosis).

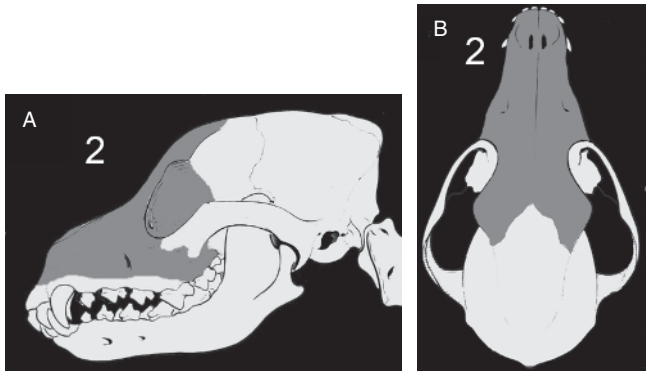


Figure 1.8 Region II for systematic evaluation of skull radiographs. **A.** Lateral radiograph. **B.** DV/VD radiograph.

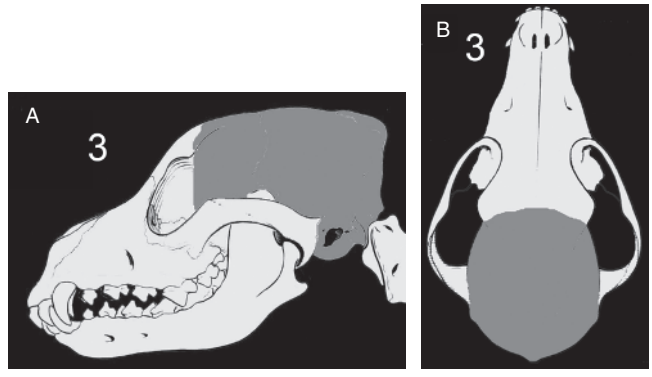


Figure 1.9 Region III for systematic evaluation of skull radiographs. **A.** Lateral radiograph. **B.** DV/VD radiograph.

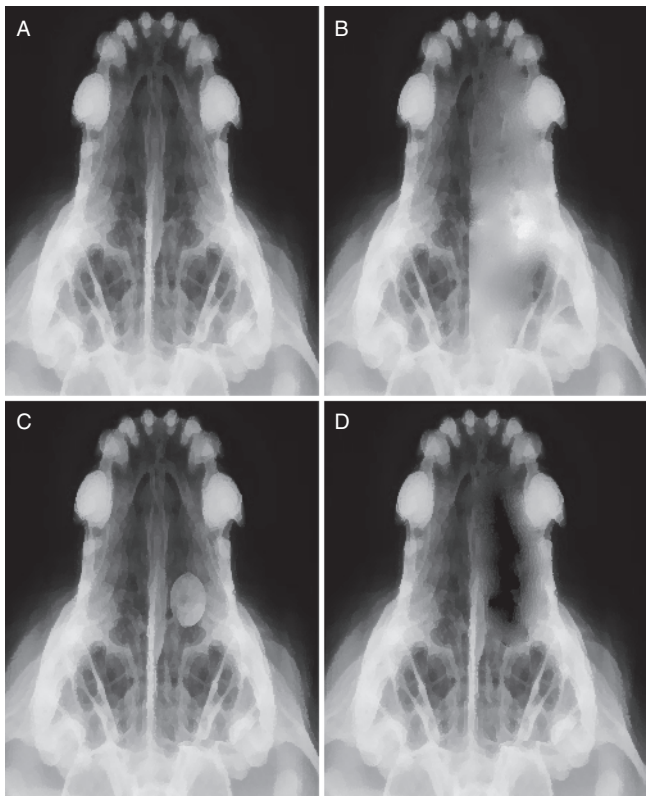


Figure 1.10 Nasal cavity lesions (open-mouth VD radiographs). **A.** Normal. **B.** Unilateral diffuse increase in opacity in left nasal cavity. **C.** Focal increase in opacity in left nasal cavity. **D.** Osteolysis in left nasal cavity.

5. Masses or foreign objects may be visible in nasopharynx (Figure 1.11), caudal to last maxillary molar tooth (true lateral radiograph). Exposure may need to be increased for adequate visualization, and opening the mouth aids in detection (rotates vertical mandibular away from area of interest).

Teeth

1. Congenital and acquired anomalies of teeth (e.g., size, shape, number) are common in dogs and cats and may or may not be clinically significant.
2. Congenital anomalies are more common in brachycephalic breeds.
3. Abnormal number of teeth may be symmetric or asymmetric.

Pharynx and larynx

1. These areas often are included on radiographs of the head.
2. Pharynx and larynx are visible when they contain air.
3. Poor positioning (e.g., flexed neck, rotation) can displace larynx and distort size and opacity of retropharyngeal space. Suspected abnormalities should be confirmed with a well-positioned and properly exposed lateral radiograph.
4. Pharynx and larynx are evaluated for opacity, position, size, and shape.

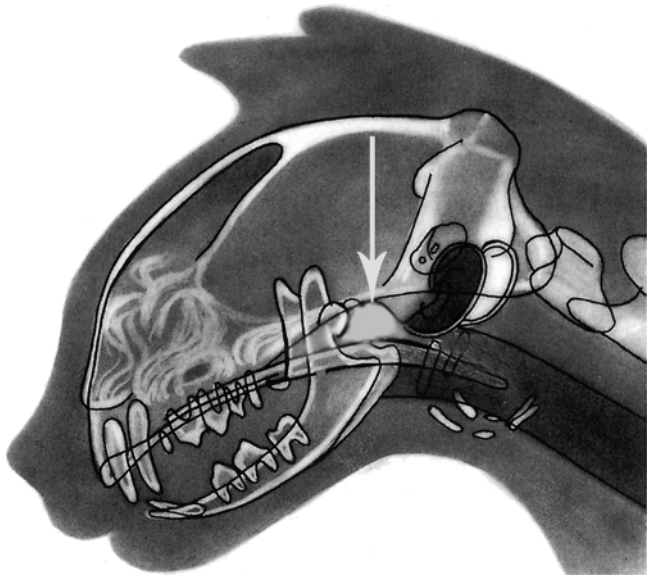


Figure 1.11 Nasopharyngeal mass in a cat (lateral radiograph). Arrow points to increased opacity in nasopharynx, caudal to molar teeth (Adapted from Owens and Biery, *Radiographic Interpretation for the Small Animal Clinician*, 2nd ed. Baltimore: Williams & Wilkins, 1999.)

a. Increased opacity may be caused by presence of swelling, mass, or foreign material.
b. Retropharyngeal disease may displace larynx ventrally.
c. As a rough estimate, normal distance between dorsal edge of cricoid cartilage and ventral aspect of C2 is approximately equal to length of C3 on a properly positioned lateral radiograph (Figure 1.12).

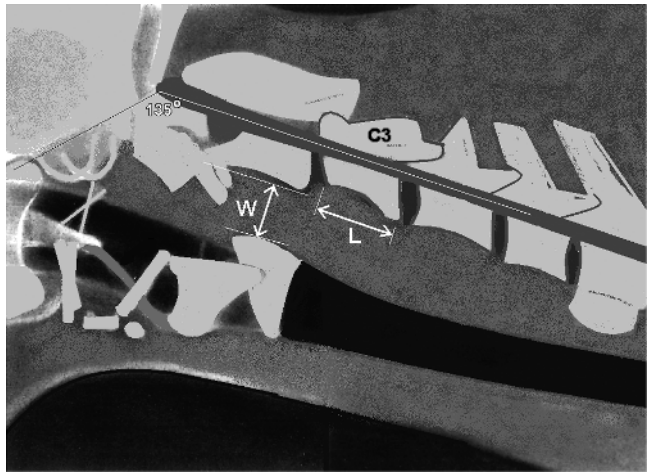


Figure 1.12 Normal width of retropharyngeal space (lateral radiograph). Head is approximately 135° angle to neck. Width of retropharyngeal space **(W)** is measured from dorsal edge of cricoid cartilage to ventral plane of C2. Normal width should not exceed the length of C3 (L). (Adapted from O'Brien, *Radiographic Diagnosis of Abdominal Disorders in the Dog and Cat*. Philadelphia: W.B. Saunders, 1981, p. 124. Special thanks to Dr. T. R. O'Brien.)

Thorax

"Radiography does supplement, not supplant, physical examination."
– Peter Suter, DVM

Effects related to age, body condition, and conformation

1. Obesity may create the appearance of increased lung opacity, cardiomegaly, and widened mediastinum.
2. Emaciation may mimic overinflated lungs and microcardia.
3. Immature animal hearts are relatively large in relation to size of thoracic cavity.
4. Lungs in immature animals may normally be increased in interstitial opacity.
5. Thymic tissue may be visible in cranial mediastinum of dogs up to 6 months of age and in cats up to 2 years of age.
6. Cardiac silhouettes of deep-chested dogs are more upright and narrow.
7. Cardiac silhouettes of barrel-chested dogs are more rounded and wide, with a more dorsally positioned trachea.
8. Lung opacity in heavily muscled animals may appear increased.
9. Wet or dirty hair coat may mimic intrathoracic lesions.
10. Bronchointerstitial markings commonly are increased in older animals.

Box 1.4 Checklist for interpreting thoracic radiographs.

- ✓ At least two orthogonal radiographs
- ✓ Radiographs are those of animal being evaluated
- ✓ Technique:
  - ✓ Exposure
  - ✓ Positioning
  - ✓ Inspiration
  - ✓ Motion artifact
- ✓ Animal's age, body condition, and conformation
- ✓ Extrathoracic structures:
  - ✓ Caudal cervical region and thoracic inlet
  - ✓ Subcutaneous tissues
  - ✓ Cranial abdomen
  - ✓ Thoracic limbs
- ✓ Thoracic wall (including spine, sternum, and ribs)
- ✓ Diaphragm
- ✓ Pleura and pleural space
- ✓ Mediastinum
- ✓ Esophagus
- ✓ Cardiovascular structures
- ✓ Trachea and mainstem bronchi
- ✓ Lungs
- ✓ Reassess based on clinical, physical, and laboratory findings
- ✓ Prioritize list of differential diagnoses
- ✓ Serial radiographs to monitor progress and response to therapy

Thoracic wall

1. Evaluated for symmetry, width, and opacity.
2. Widening may be general (e.g., obesity, edema) or local (e.g., lipoma, tumor).
3. Alterations in opacity may be due to presence of gas, mineral, metal, or superimposition of adjacent structure (see lists of Differential Diagnoses, chapter 5).
4. Ribs are assessed for number, size, margination, opacity, position, and spacing.
   a. Alteration in number of ribs usually is congenital and incidental; however, lysis caused by infection or tumor must be ruled out.
   b. Expansile remodeling may occur with healing rib fracture, tumor, or infection.
   c. Rib margins may be indistinct due to motion artifact or active remodeling.
   d. Abnormal rib opacity may be caused by fracture, osteolysis, or/and periosteal response.
   e. Position and spacing of ribs may be altered by trauma, mass effect, expansion of thorax, or muscle contractions.
   f. Costal cartilages begin to mineralize at a few months of age and can present with a variety of patterns, often nonuniform in appearance (Figure 1.13). Normal costochondral junctions can become quite large and may be mistaken for pathology (also see Normal Radiographic Anatomy in chapter 5).

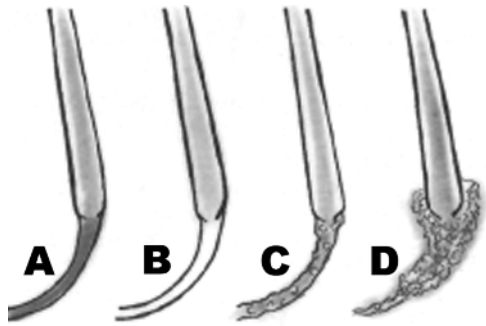


Figure 1.13 Normal costochondral junctions. **A.** Soft tissue opacity costal cartilage in an immature animal. **B.** Mineralization of cartilage, which often begins at a few months of age. **C.** More heterogenous pattern of age-related mineralization. **D.** Large costochondral junction that may be mistaken for pathology. (Adapted from Owens and Biery 1999.)

g. Detection of rib lesions can be difficult, and altering one's viewing perspective may help:

1) Oblique/tangential radiographs can be used to image lesions in profile.

2) Orient radiographs upside down or sideways to draw attention to ribs.

3) Invert black and white scale on digital images to highlight ribs.

4) Serial radiographs may document periosteal response that was not evident on initial study.

5. Sternum is assessed for shape, alignment, opacity, and margination.

a. Abnormal shape may be congenital (e.g., pectus excavatum) or acquired (e.g., fracture, luxation).

b. Alignment may be altered by trauma, mass effect, or overstretching the animal during positioning for radiography.

c. Altered opacity and margination typically is caused by tumor or infection (Figure 1.14).

d. Common aging changes along sternum include bone spurs at edges of sternebrae and mineralization of intersternebral cartilages (more common in large breed dogs).

6. Vertebrae are assessed for alterations in shape, alignment, opacity, and margination (see chapter 4, "Musculoskeletal," for discussion).

Diaphragm

1. Evaluated for margination, position, and shape.

2. Margin may become indistinct or obscured by hernia, pleural fluid, mediastinal disease, or caudal lung disease.

3. Shape and position of diaphragm are affected by animal's position during radiography and pathology in abdominal or thoracic cavity (see lists of Differential Diagnoses, chapter 5).

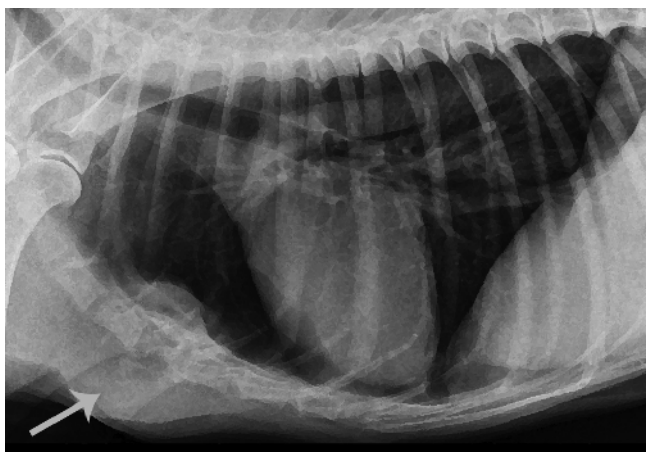


Figure 1.14 Sternal lesion (lateral radiograph). White arrow indicates local soft tissue swelling and osteolysis of 4th sternabra. Intrathoracic soft tissue swelling is evident. Such lesions may result from tumor or infection.

Pleura and pleural space

Pleural effusion

1. Type of pleural fluid cannot be distinguished on radiographs (see Differential Diagnoses in chapter 5).

2. Interlobar fissure lines (pleural fissure lines) are earliest sign of excess fluid in pleural space and appear as thin, curved, soft tissue opacity lines between lung lobes (Figures 1.15 and 1.16).

a. Fluid creates fissure lines that are wider peripherally and taper toward the hilus (Figure 1.17).

b. Pleural thickening creates lines that are uniform in thickness and do not taper.

c. Fat (obese animals) can fill interlobar fissures and create lines that are wider centrally and taper peripherally ("reverse fissure lines").

d. Mineralized costal cartilages may be mistaken for pleural fissure lines (especially in cats).

3. Detection of small pleural effusions may be easier on a VD radiograph or on radiographs made during expiration. Horizontal beam radiography can also aid in detection.

4. Radiographic findings with increasing volume of pleural fluid (Figure 1.18):

a. Lung borders retract from thoracic wall, spine, sternum, and diaphragm (Figure 1.20).

b. With large effusions, lung lobes will be small and may appear leaflike.

c. Vascular and bronchial markings do not extend to thoracic wall.

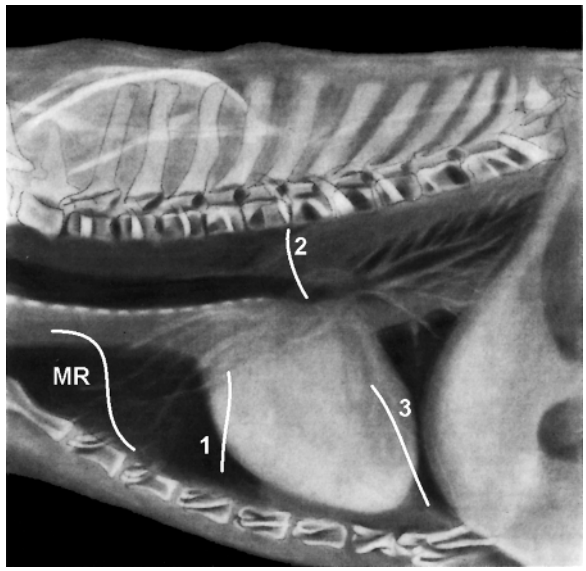


Figure 1.15 Pleural fissure lines (lateral radiograph). White lines indicate interlobar fissures; **(1)** between cranial and middle lung lobes, **(2)** between cranial and caudal lobes, **(3)** between middle and caudal lobes; **(MR)** indicates cranioventral mediastinal reflection. (Adapted from Owens and Biery 1999.)

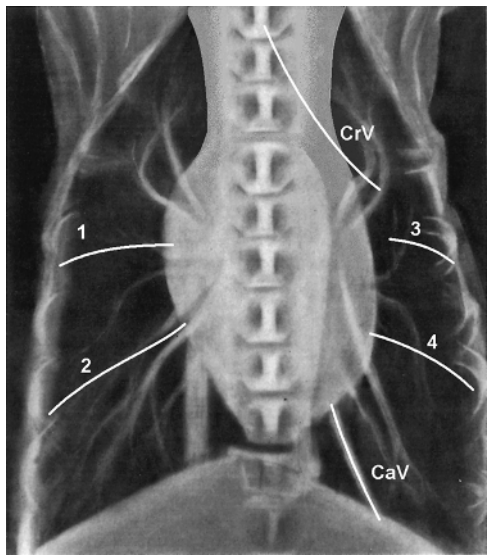


Figure 1.16 Pleural fissure lines (DV/VD radiograph). White lines indicate interlobar fissures; **(1)** between right cranial and middle lung lobes, **(2)** between right caudal and middle lobes, **(3)** between cranial and caudal segments of left cranial lobe, **(4)** between left cranial and caudal lobes. **CrV** = cranioventral mediastinal reflection; **CaV** = caudoventral mediastinal reflection. (Adapted from Owens and Biery 1999.)

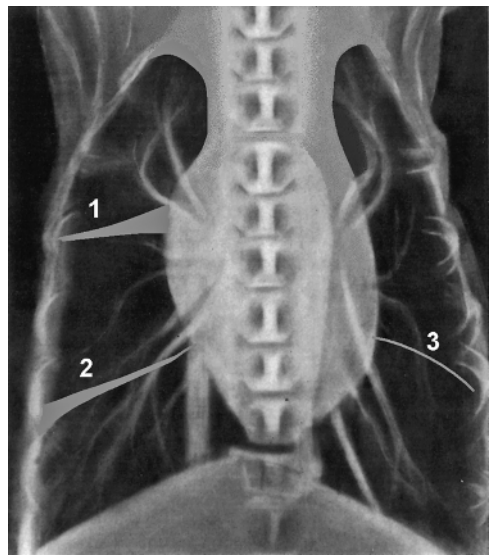


Figure 1.17 Types of interlobar fissure lines. **(1)** Fat between lung lobes is wide centrally and tapers peripherally (sometimes called "reverse fissure line"). **(2)** Fluid in pleural space creates lines that are wide peripherally and taper centrally. **(3)** Pleural thickening creates lines that are uniform and thin (may be indistinguishable from small pleural effusion). (Adapted from Owens and Biery 1999.)

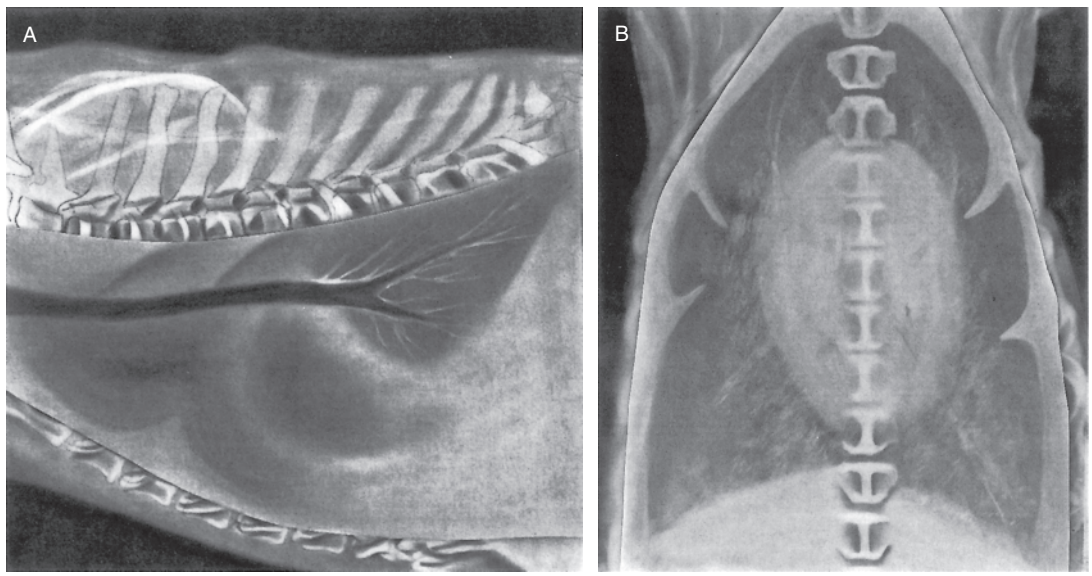


Figure 1.18 Pleural effusion. **A.** Lateral radiograph, a large volume of pleural fluid obscures the heart and other intrathoracic soft tissues; air-filled trachea and large bronchi remain visible. **B.** VD radiograph, bilateral pleural effusion is visible in interlobar fissures and between lung and thoracic wall. (Adapted from Owens and Biery 1999.)

d. Increasing opacity in thoracic cavity.
e. Costophrenic angles become rounded and indistinct.
f. Caudolateral lung margins appear blunted.
g. Ventral lung margin becomes scalloped and outlined by fluid (dorsal to sternum).
h. Cardiac silhouette and trachea are dorsally displaced (depending on volume of fluid).
i. Cranial mediastinum may appear widened due to summation with adjacent fluid.
j. Cardiac and diaphragmatic borders become obscured; diaphragm may be caudally displaced.

5. Rounding of lung lobe borders suggests pleural fibrosis, which restricts lung expansion and can lead to lung rupture during rapid re-expansion.

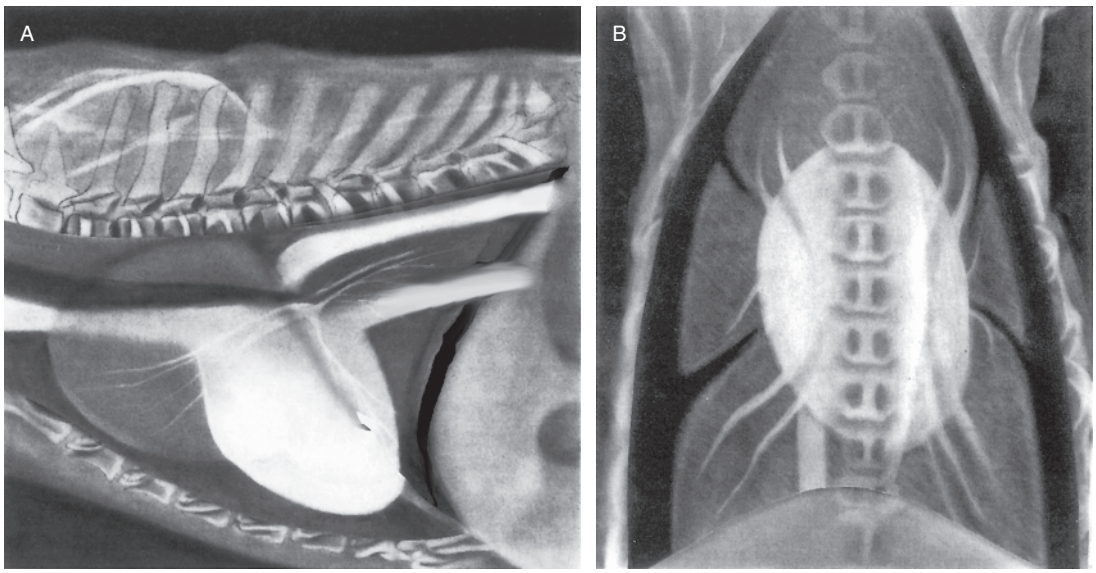


Figure 1.19 Pneumothorax. Lung borders are retracted from thoracic wall and gas opacity is present in pleural space. Lungs are increased in opacity due to partial atelectasis and heart is dorsally displaced away from sternum. **A.** Lateral radiograph. **B.** DV radiograph. (Adapted from Owens and Biery 1999.)

6. Asymmetric or unilateral pleural effusion occurs with inflammatory conditions, which obstruct mediastinal fenestrations and may cause a mediastinal shift away from fluid.
7. Removal of pleural fluid and repeating radiographs aids in detection of lesions.
8. Lung parenchyma may appear increased in opacity due to superimposition of underlying pleural fluid (in lateral recumbency, fluid is dependent and "up" lung is better inflated); however, pulmonary vessels remain well-defined with pleural fluid and are obscured by parenchymal disease.
9. See Pleural Effusion in the Diseases and Disorders section of chapter 5 for additional discussion.

Pneumothorax

1. Lung borders are retracted from thoracic wall and gas opacity is present in pleural space (Figures 1.19 and 1.20).
2. Vascular and bronchial markings do not extend to thoracic wall.
3. Lungs may appear increased in opacity due to inability to expand.
4. Variable separation of cardiac silhouette from sternum, depending on volume of pleural gas.
5. Ventral lung border may appear thin or scalloped (dorsal to sternum).
6. Thoracic cavity may be expanded and decreased in opacity (may require lower exposure technique to produce quality images).
7. Mediastinum becomes more movable and may be displaced (mediastinal shift).

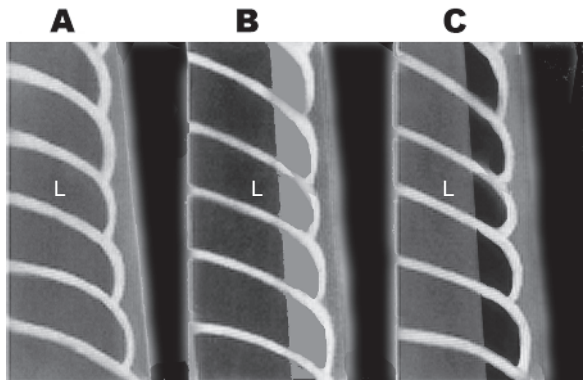


Figure 1.20 Pleural space; **L** = lung. **(A)** Normal; lung borders extend to thoracic wall. **(B)** Pleural effusion; lung border is retracted and fluid opacity is present in pleural space. **(C)** Pneumothorax; lung border is separated from thoracic wall by gas. (Adapted from Owens and Biery 1999.)

8. Diaphragm may be caudally displaced and flattened (depending on volume of pleural gas).
9. Cranial margin of diaphragm usually is sharper due to contrast with pleural gas.
10. Detection of a small pneumothorax may be easier on dorsoventral (DV) radiograph and on radiographs made during expiration. Horizontal beam radiography also aids in detection.
11. See Diseases and Disorders in chapter 5 for further discussion of pneumothorax.

12. Tension pneumothorax is an emergency situation:

a. Thoracic cavity is greatly expanded.

b. Lung lobes are collapsed to a very small size and often are abnormal in shape.

c. Heart and caudal vena cava appear small.

d. Severe caudal displacement of diaphragm ("tented" or "scalloped" diaphragm on DV/VD radiograph).

e. If unilateral, mediastinum is shifted away from tension pneumothorax.

13. Conditions that mimic pneumothorax are included in Differential Diagnoses in chapter 5.

a. In cases of "pseudo-pneumothorax," lungs are not collapsed and pulmonary markings extend to thoracic wall.

Hydropneumothorax

1. Both fluid and gas are present in the pleural space.

2. Soft tissue structures in dependent hemithorax ("down" side) tend to be obscured by fluid, while those in nondependent hemithorax ("up" side) are outlined by gas.

Pleural masses and nodules

1. Localized soft tissue opacity structures in pleural space.

2. Usually easiest to see when x-ray beam is tangential to base of mass.

3. Pleural fluid is common and frequently obscures lesions (repeat radiographs after removing fluid).

4. "Extrapleural sign" occurs with masses on thoracic wall (Figure 1.21):

a. Mass bulges into thoracic cavity and displaces (indents) adjacent lung.

b. May be caused by rib lesions, pleural masses, or trapped pleural fluid (Figure 1.22).

c. Margins of extrapleural mass taper cranially and caudally to blend with thoracic wall.

d. Pleural fluid is absent unless mass breaks through pleura into pleural space.

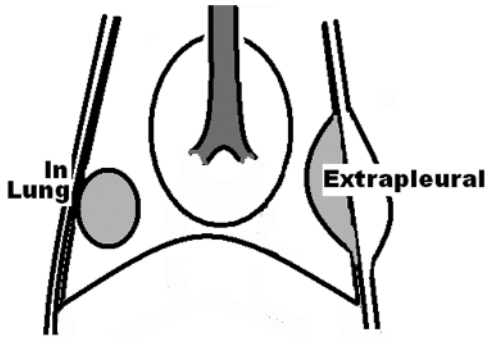


Figure 1.21 Extrapleural sign (VD radiograph). Mass in left thoracic wall (extrapleural) bulges into thoracic cavity; margins of mass blend with thoracic wall. Nodule in lung on right side; margins of nodule form acute angles with thoracic wall.

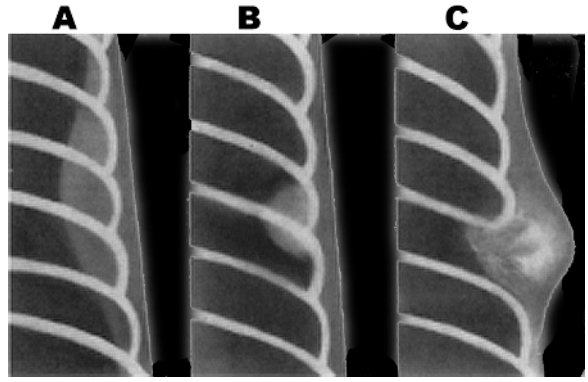


Figure 1.22 Pleural lesions. **(A)** Loculated pleural fluid. **(B)** Pulmonary mass adjacent to thoracic wall. **(C)** Extrapleural mass with periosteal response on rib, extrapleural sign, and extrathoracic mineralized mass. (Adapted from Owens and Biery 1999.)

Mediastinum

1. Mediastinum is evaluated for position, width, and opacity.

2. Altered position of mediastinum (mediastinal shift, Figure 1.23):

a. Lateral displacement (toward right or left side) results from asymmetric lung volume, pleural disease, or an intrathoracic mass.

b. Mediastinal shift is a common physiologic occurrence during radiography due to recumbent atelectasis of dependent (down) lung.

c. Diaphragm usually is asymmetric:

1) Cranial displacement of hemidiaphragm results from poor lung inflation on that side.

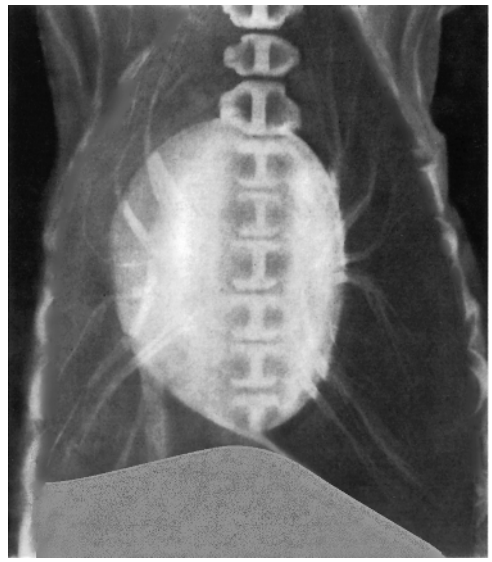


Figure 1.23 Mediastinal shift (VD radiograph). Cardiac silhouette is slightly displaced to the right and right hemidiaphragm is further cranial than left. Increased opacity in right lung is due to partial collapse. (Adapted from Owens and Biery 1999.)

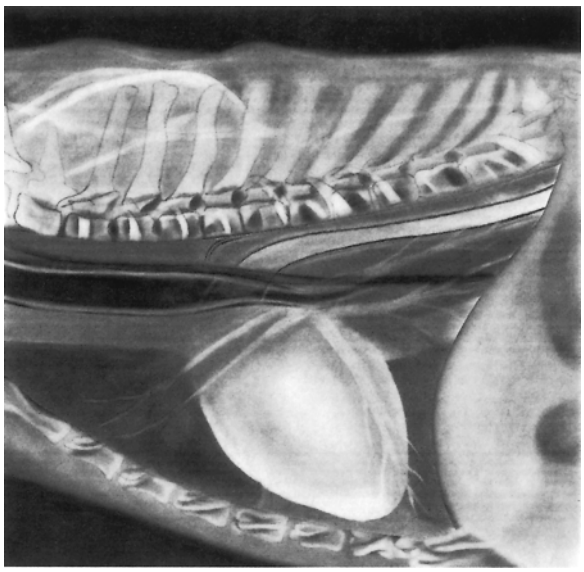


Figure 1.24 Pneumomediastinum (lateral radiograph). Free gas in mediastinum outlines outer tracheal wall, cranial vena cava, and aorta, enhancing their visibility. (Adapted from Owens and Biery 1999.)

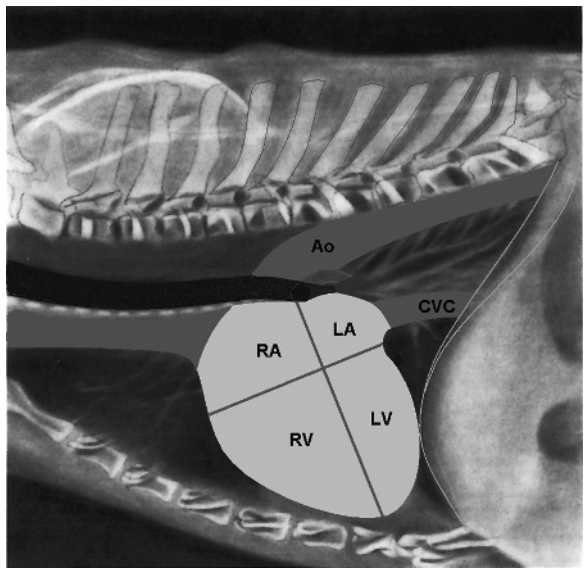


Figure 1.25 Positions of heart chambers inferred by long and short cardiac axes (lateral radiograph). Long axis line extends from tracheal bifurcation to cardiac apex. Short axis line is perpendicular to long axis, near junction of caudal vena cava. **RA** = right atrium, **LA** = left atrium, **RV** = right ventricle, **LV** = left ventricle, **Ao** = aorta, **CVC** = caudal vena cava. (Adapted from Owens and Biery 1999.)

2) Caudal displacement of hemidiaphragm may be caused by large intrathoracic mass or severe unilateral pleural effusion/pneumothorax.

3. Altered width of mediastinum:

a. Obesity is most common cause of mediastinal widening.

1) As a rule of thumb, cranial mediastinum should not be wider than width of thoracic wall at same level (VD/DV radiograph).

b. Widened mediastinum can be caused by mass, fluid, or esophageal enlargement.

c. Free pleural fluid adjacent to mediastinum may mimic widening.

4. Altered opacity of mediastinum:

a. Decreased opacity most commonly is due to pneumomediastinum (Figure 1.24).

1) Mediastinal structures not normally visible become well-defined.

2) Free gas in mediastinum often extends into cervical fascia and subcutaneous tissues.

b. Increased mediastinal opacity may result from inflammation or fluid.

c. Esophageal content may alter mediastinal opacity.

1) Normal caudal esophagus often is visible on left lateral radiographs as a horizontal band of soft tissue opacity between aorta and caudal vena cava.

Cardiac silhouette (heart)

1. Cardiac silhouette represents pericardial sac and its contents.

2. Appearance is influenced by breed, age, phase of respiration, position at time of radiography, and body condition (see Normal Radiographic Anatomy in chapter 5).

3. Radiographs made while animal is healthy can provide a standard to compare with future radiographs of that animal.

4. Heart disease must be differentiated from heart failure.

5. Positions of cardiac chambers can be inferred from cardiac axes (Figure 1.25).

6. Cardiac silhouette is evaluated for size, shape, position, margination, and opacity.

7. Abnormal size and shape of cardiac silhouette:

a. Vertebral heart size is objective means of roughly evaluating size of cardiac silhouette (Figure 1.26).

b. Enlargement may result from increased size of one or more cardiac chambers, excess pericardial fluid, or presence of herniated viscera or mass in pericardial sac.

1) Vertebral heart size is greater than 11.0 in dogs and greater than 8.0 in cats.

2) Trachea is dorsally displaced.

3) Specific heart chamber enlargement occurs at known locations and creates a predictable shape to cardiac silhouette (Figure 1.27; see Diseases and Disorders, chapter 5).

4) Radiographically evident cardiomegaly most often is due to right ventricular or left atrial enlargement.

c. Small cardiac silhouette typically results from hypovolemia:

1) Pulmonary vessels, caudal vena cava, and aorta usually are small.

2) Lungs may be decreased in opacity (hypovascular lung pattern).

3) Peritoneal or pleural fluid may be present (i.e., hemoabdomen).

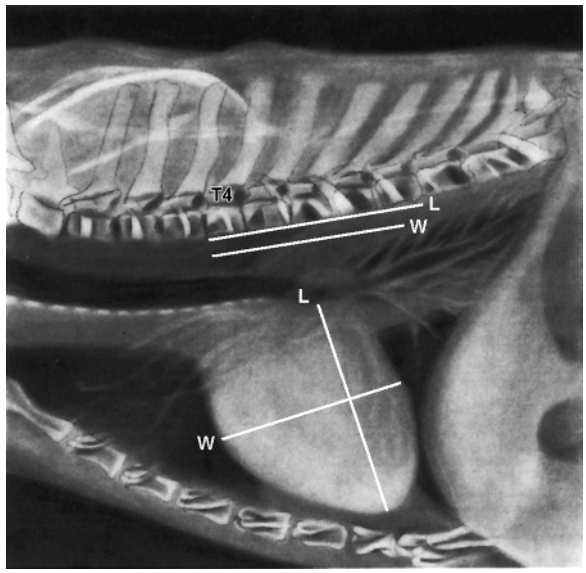


Figure 1.26 Vertebral heart size (VHS, lateral radiograph). Length **(L)** of cardiac silhouette (long axis) and width **(W)** of cardiac silhouette (short axis) are transposed along thoracic spine, beginning at cranial edge of T4. Number of vertebral bodies along each measurement is estimated to 1/10 vertebra and added together to give VHS. (Adapted from Owens and Biery 1999.)

8. Abnormal position of cardiac silhouette:

a. Lung volume determines position of cardiac silhouette.

b. Enlargement of mediastinal structures can cause displacement (e.g., megaesophagus).

c. "Heart follows sternum":

1) Errors in positioning may be mistaken for displacement or abnormal shape of cardiac silhouette.

2) As little as 5-degree rotation can significantly alter appearance of cardiac silhouette.

9. Indistinct cardiac silhouette margins:

a. Margin of cardiac silhouette normally is well-defined due to air in adjacent lungs.

b. Indistinct or obscured margin may be due to motion artifact, excess pericardial fat, pleural fluid, or adjacent lung disease.

10. Abnormal opacity of cardiac silhouette:

a. May result from gas, fat, or mineralization in heart or pericardial space.

1) Gas may be present due to displaced GI structures or pneumopericardium.

2) Fat is common and may mimic cardiomegaly.

3) Mineralization is uncommon:

a) Heart valve mineralization tends to be small, sharp, and linear.

b) Coronary artery mineralization tends to be curvilinear.

11. Pericardial disease:

a. Fluid in pericardial space generally causes a globoid appearance to cardiac silhouette.

1) Type of fluid cannot be distinguished on radiographs.

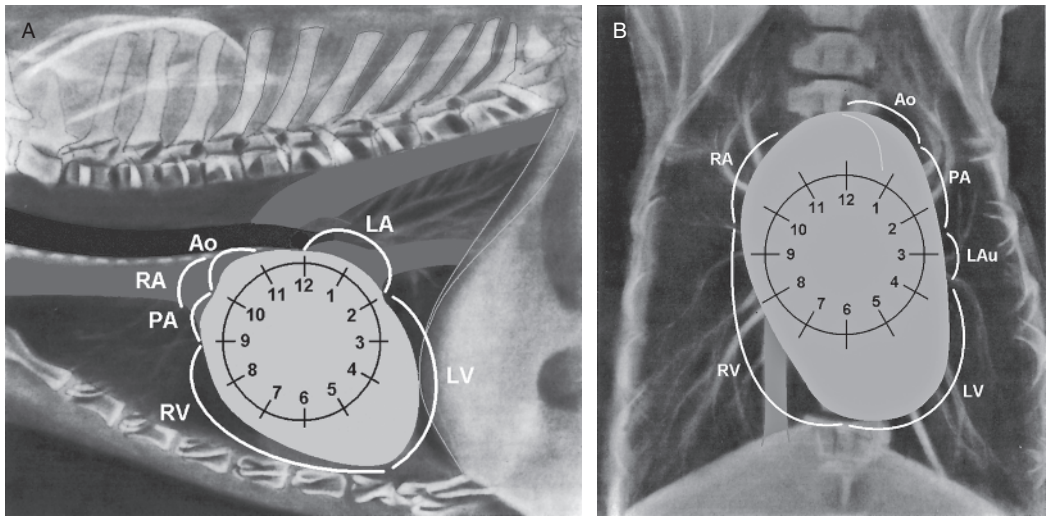


Figure 1.27 Clock face analogy for canine cardiac silhouette. **A.** Lateral radiograph. **B.** VD radiograph. Curved white lines show direction of chamber enlargement. **Ao** = aorta, **LA** = left atrium, **LV** = left ventricle, **RV** = right ventricle, **PA** = pulmonary artery, **RA** = right atrium. (Adapted from Owens and Biery 1999.)

2) Cardiac tamponade (compression of heart by pericardial fluid) can lead to right heart failure, depending on rate and volume of fluid accumulation.

b. Abnormal content in pericardial sac (e.g., tumor, abdominal viscera) may alter size, shape, and opacity of cardiac silhouette.

c. Thickening of pericardium (e.g., constrictive pericarditis) may decrease size of cardiac silhouette.

Trachea

1. Trachea is examined for alterations in diameter, position, opacity, and margination (easiest to evaluate on lateral radiograph).

2. Radiographic findings may not correlate with clinical signs.

3. Abnormal diameter of trachea:

a. Tracheal ratio compares tracheal width to width at thoracic inlet (Figure 1.28):

1) Normal tracheal ratio is 0.20 or greater in nonbrachycephalic dogs.

2) Brachycephalic breeds: tracheal ratio should be 0.16 or greater.

3) Bulldogs: tracheal ratio should be 0.10 or greater.

b. Narrowing of trachea may be uniform (e.g., tracheal hypoplasia) or segmental (e.g., tracheal collapse, stricture, mass).

c. Tracheal collapse syndrome often is a dynamic condition, requiring both inspiratory and expiratory radiographs for detection (Figure 1.29).

d. Trachea may appear falsely narrowed due to orientation to x-ray beam and superimposition of dorsal tracheal membrane (Figure 1.30, Dr. Kichang Lee).

4. Abnormal position of trachea:

a. Trachea is fixed in position at larynx and base of heart but is flexible and easily displaced in between (displacement may be dorsal, ventral, or to the right; aortic arch prevents displacement of the caudal trachea to the left).

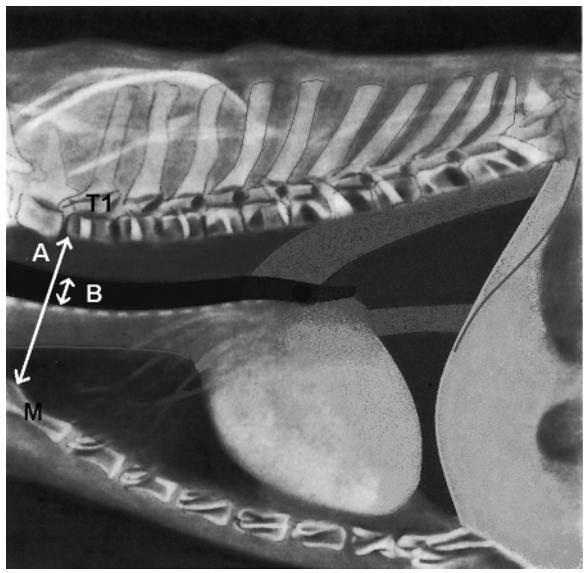


Figure 1.28 Tracheal ratio (TR; lateral radiograph). Width of trachea **(B)** is divided by width of thoracic inlet **(A)** to give TR. **A** = distance between cranioventral edge of T1 and craniodorsal edge of first sternebra (**M** = manubrium). Normal TR: ≥0.20 (nonbulldog brachycephalic breeds: TR ≥0.16; bulldogs: TR ≥0.10). (Adapted from Owens and Biery 1999.)

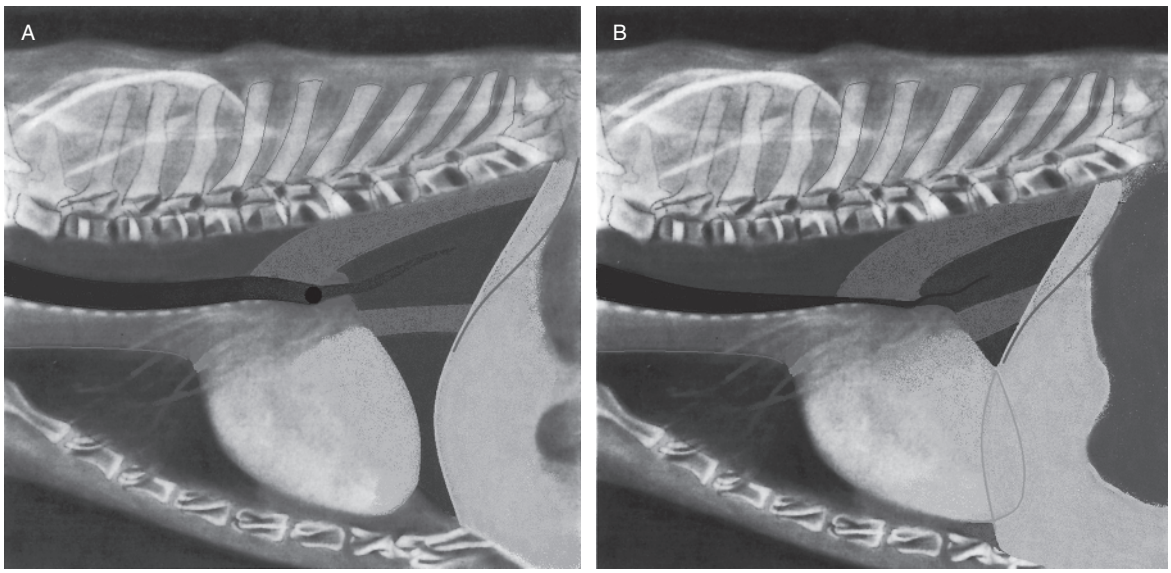


Figure 1.29 Intrathoracic tracheal collapse syndrome (lateral radiographs). **A.** During inspiration trachea and mainstem bronchi are normal in diameter. **B.** During expiration and increased intrathoracic pressure, caudal thoracic trachea and mainstem bronchi narrow (collapse). (Adapted from Owens and Biery 1999.)



Figure 1.30 False narrowing of trachea. **A.** Cross sectional image of trachea (black) with x-rays passing through (arrows). Trachea is slightly obliqued and is not uniform in width to x-ray beam. **B.** Depiction of trachea as seen on lateral radiograph with lower black part of lumen below due to summation of more air and lighter gray part of lumen above (due to less summation of air and which may create false impression of narrowed tracheal lumen). (Adapted from image by Dr. Kichang Lee, with permission and special thanks to Dr. Lee). **C.** Lateral radiograph of normal trachea with false narrowing in cervical region.

b. Flexion of head and neck shortens distance between larynx and heart, causing trachea to bend dorsally and to the right. The trachea is least confined in the cranial thorax, allowing deviation. (Figure 1.31). Repeat radiographs with head and neck extended to confirm positioning artifact.

c. Trachea may be displaced by large mediastinal structures (e.g., cardiomegaly, megaesophagus, mass; see Differential Diagnoses, chapter 5).

5. Increased opacity of trachea:

a. May result from superimposition of esophagus or longus coli muscles, narrowing of tracheal lumen (false or true narrowing), intraluminal foreign material, or mural growths. Cartilagenous tracheal rings may mineralize.

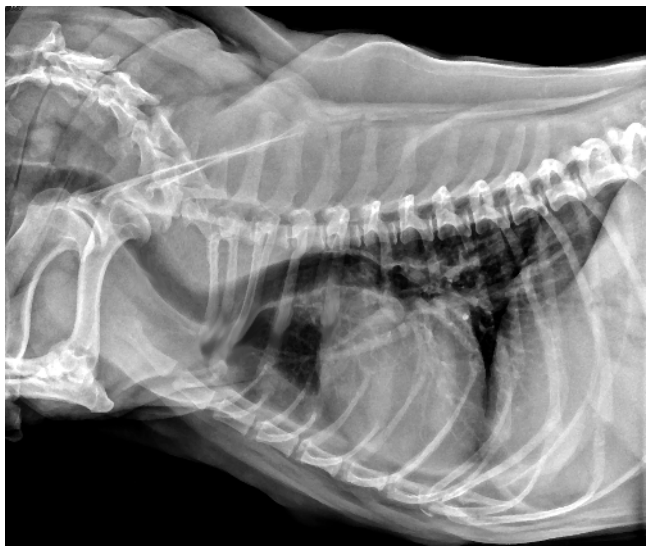


Figure 1.31 Tracheal displacement caused by flexion of head and neck (lateral radiograph).

6. Abnormal margination of trachea:

a. Enhanced visualization of outer tracheal wall is due to presence of adjacent gas:

1) Tracheal stripe sign: Intraluminal air in both esophagus and trachea allows visualization of a thick, well-defined dorsal tracheal margin ("tracheal stripe") due to summation of ventral wall of esophagus summates with dorsal wall of trachea. (Figure 1.32).

2) Pneumomediastinum: outer margins of trachea and other mediastinal structures (e.g., aorta, esophagus, cranial vessels) appear sharp and well-defined (Figure 1.24).

3) If only the "dorsal outer tracheal margin" is visible, gas is present in esophagus (e.g., megaesophagus).

4) If both dorsal and ventral outer margins of trachea are visible, gas is in mediastinum (pneumomediastinum).

b. Loss of visualization of tracheal margins may result from rupture, collapse, severe inflammation, or hemorrhage.

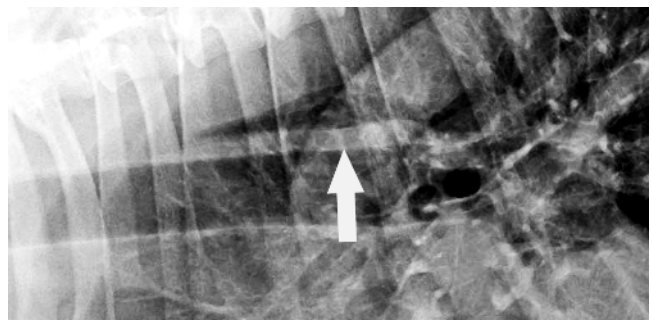


Figure 1.32 Tracheal stripe sign (lateral radiograph, collimated to heart base). Intraluminal air in esophagus and trachea creates the appearance of a thick, well-defined dorsal tracheal margin (white arrow), caused by summation of ventral esophageal wall and dorsal tracheal wall.

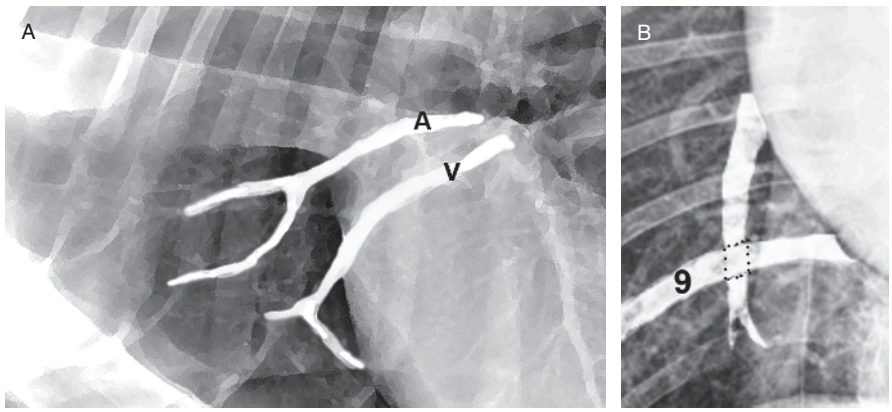


Figure 1.33 Normal pulmonary vessels. **A.** Right cranial artery **(A)** and vein **(V)** on left lateral radiograph. **B.** Right caudal pulmonary vessel on VD radiograph; vessel should be no wider than the 9th rib where they cross (summation of vessel and rib should make a square or "vertical" rectangle, not a "horizontal" rectangle.)

Lungs

1. Lungs respond to pathology in only a limited number of ways; therefore, different pulmonary diseases can produce similar radiographic findings.

2. Lung diseases tend to be dynamic, progressing and regressing over time. Remember, radiographs represent only a single instant in a disease process.

3. Serial radiographs aid in monitoring changing lung patterns, progression of disease, and response to therapy.

4. Lung lesions should be identified on at least 2 orthogonal radiographs and described by:

- **a.** Predominant radiographic pattern:
  - **1)** Vascular.
  - **2)** Bronchial.
  - **3)** Alveolar.
  - **4)** Nodular interstitial.
  - **5)** Unstructured interstitial.
- **b.** Distribution:
  - **1)** Local (confined to a single lung lobe).
  - **2)** Lobar (lung lobe margin is visible).
  - **3)** Diffuse (involving two or more lobes).
  - **4)** General (involving all lung lobes).
  - **5)** Unilateral or bilateral.
  - **6)** Symmetrical or asymmetrical.
  - **7)** Hilar, central, or peripheral.
  - **8)** Cranial or caudal, dorsal or ventral.
- **c.** Opacity:
  - **1)** Gas, fat, soft tissue, mineral, or metal.
  - **2)** Homogeneous or heterogeneous.
- **d.** Nodules are described by:
  - **1)** Number (solitary, multiple, numerous).
  - **2)** Margination (well-defined or ill-defined).
  - **3)** Shape (rounded or irregular).
  - **4)** Opacity (soft tissue or mineral).

Patterns of lung disease

1. Lung patterns rarely are pathognomonic and frequently are mixed.

2. Pattern types are used to describe part of lung that is predominately affected at the time; pulmonary vasculature, bronchi, air spaces (alveoli), or lung intersitium.

Disease of pulmonary vasculature (vascular lung pattern)

1. Alterations in size, shape, distribution, or number of pulmonary vessels result from increased or decreased volume of blood or turbulent blood flow.

2. Most common etiologies include congestive heart failure, hypovolemia, and heartworm disease (see Differential Diagnoses in chapter 5).

3. Right cranial lobar vessels are evaluated on a left lateral radiograph (Figures 1.33A and 1.34).

4. Enlarged pulmonary vessels result from overcirculated (hypervascular) lungs.

- **a.** Right cranial lobar vessels are wider than narrowest part of 4th rib on left lateral radiograph.
- **b.** Caudal lobar vessels are wider than 9th rib where vessel and rib cross on DV/VD radiograph.
- **c.** Enlarged vessels may appear more numerous and to extend further into lung periphery (this finding is significant only if vessels are actually enlarged).
- **d.** Enlarged pulmonary vessels may increase lung opacity due to added soft tissue opacity.

5. Small pulmonary vessels result from undercirculated (hypovascular) lungs.

- **a.** Vessels are smaller than expected and cannot be followed as far peripherally as normal.
- **b.** Lungs may seem to be hyperinflated and less opaque.
- **c.** Cardiac silhouette, caudal vena cava, and aorta often are small.

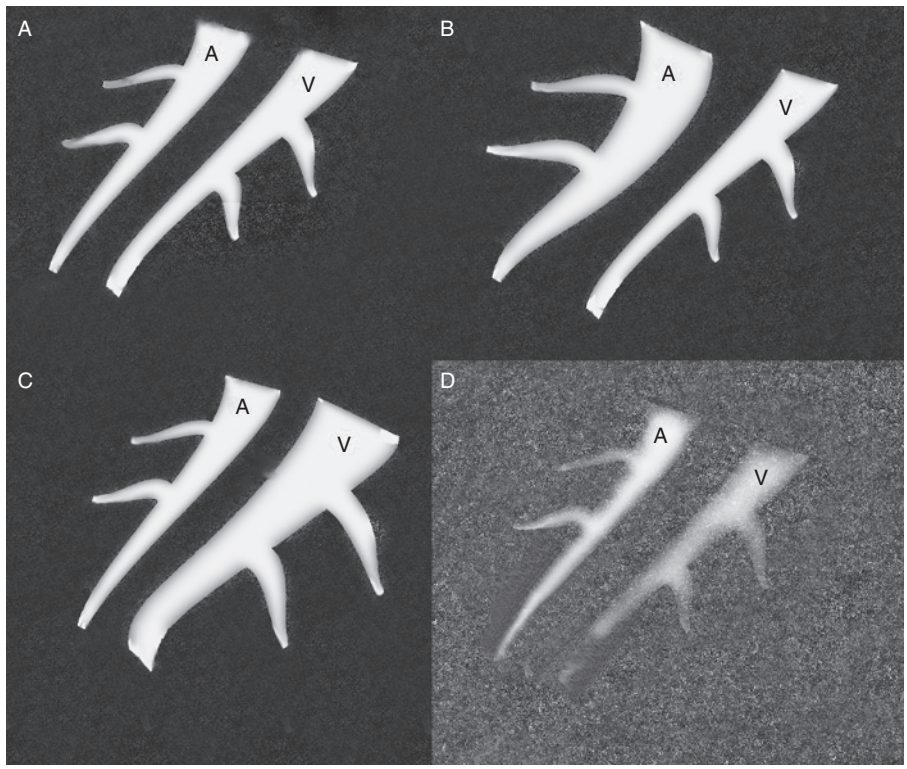


Figure 1.34 Vascular patterns (right cranial pulmonary vessels as seen on left lateral radiograph). **(A) A** = normal artery; **V** = vein. **(B)** Artery larger than vein (heartworm disease). **(C)** Vein larger than artery (left heart failure). **(D)** Indistinct vascular margins (parenchymal lung disease.)

6. Enlarged arteries with normal-size veins most commonly result from heartworm disease.
7. Enlarged veins with normal-size arteries usually is due to left heart failure.
8. Indistinct or obscured vascular margins is due to increased opacity in lung parenchyma.
9. Absence of visualization of vascular margins is due alveolar filling and loss of air in adjacent lung.

Box 1.5 Findings with vascular lung pattern.

- Abnormal size of pulmonary arteries, veins, or both
- Asymmetry in size of paired pulmonary vessels
- Blunted, irregular, or curved shape of vessels
- Vascular margins may be obscured due to perivascular leakage of fluid

Diseases of bronchi (bronchial lung pattern)

1. Alterations in wall thickness, lumen diameter, or opacity of bronchi may result from inflammation or infiltrative disease.
2. Most common etiologies include asthma, tracheobronchitis, tracheal/bronchial collapse syndrome (see Differential Diagnoses in chapter 5).
3. Normal bronchial walls are thin and not well visualized in peripheral lung fields unless thickened, mineralized, or surrounded by excessive fluid or contain secretions.
    a. Newer, high-quality digital radiography systems may enhance visualization of bronchi (familiarity with particular imaging characteristics helps avoid errors in interpretation).
4. Bronchial walls normally are visible near tracheal bifurcation because they are larger (may be mistaken for thickened bronchi).
5. Thickened bronchi viewed on-end appear as thick rings ("donuts"; Figure 1.35).
6. Thickened bronchi often do not taper normally, appearing as parallel lines in profile ("tram lines" or "railroad tracks").
    a. Paired blood vessels can be mistaken for thickened bronchial walls, and therefore "donuts" are a more reliable finding with bronchial disease.
7. Outer bronchial margins may become indistinct due to disease in adjacent lung parenchyma or peribronchial infiltrates ("peribronchial cuffing"; Figure 1.36).
8. Vascular margins usually remain sharp and well-defined if lung disease is confined to bronchi.
9. Bronchi with enlarged diameters and irregular shapes (bronchiectasis) typically result from chronic inflammation.

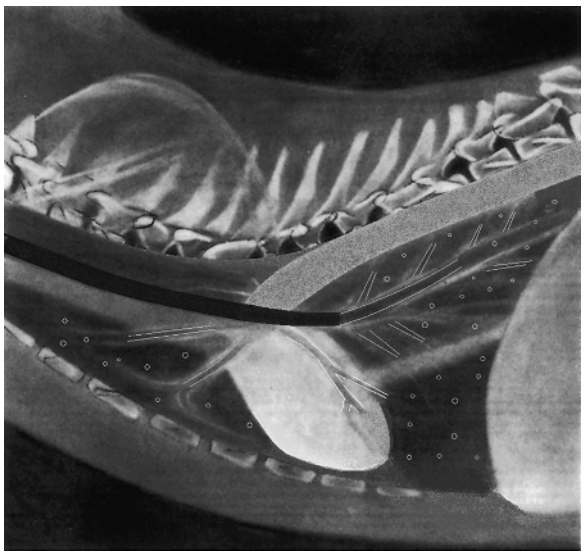


Figure 1.35 Bronchial lung pattern (lateral radiograph). Peripheral bronchial walls are thickened and increased in opacity appearing as "donuts." In addition, lungs are hyperinflated; diaphragm is flattened; caudal lung lobes are less opaque due to air trapping. (Adapted from Owens and Biery 1999.)

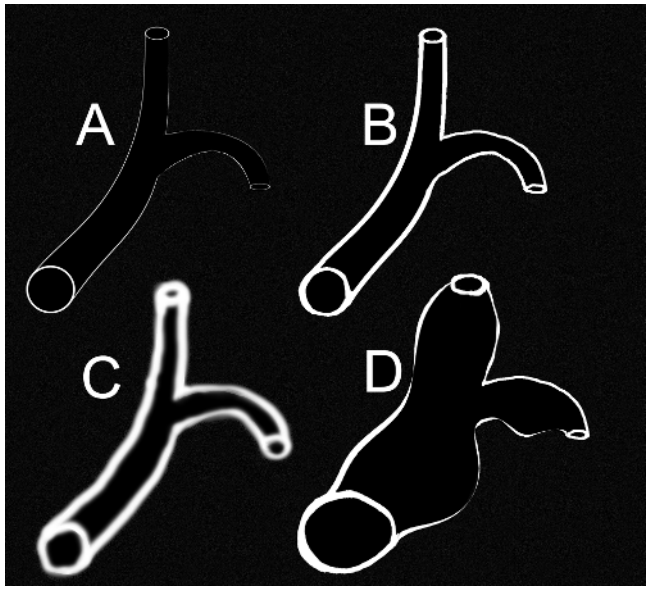


Figure 1.36 Bronchial disease. **(A)** Normal bronchus. **(B)** Thickened bronchial walls with increased opacity. **(C)** Peribronchial infiltrates creating appearance of thickened bronchial wall with indistinct margins. **(D)** Bronchiectasis.

Box 1.6 Findings with bronchial lung pattern.

- Increased bronchial markings in peripheral lung fields ("donuts")
- Loss of normal bronchial tapering
- Uneven and varying bronchial diameters
- Cardiovascular structures remain well-defined

Diseases of lung air spaces (alveolar pattern or alveolar filling)

1. Air normally present in alveoli may be displaced by fluid, cells, or collapse of alveoli.

2. Most common etiologies include pulmonary edema, pneumonia, hemorrhage, neoplasia, and atelectasis (see Differential Diagnoses in chapter 5).

3. Absence of alveolar air results in loss of visualization of pulmonary soft tissues:

- **a.** Blood vessels and adjacent borders of heart and diaphragm no longer are visible.
- **b.** Soft tissue pulmonary masses and nodules may be obscured.

4. Alveolar filling or collapse initially presents as fluffy, ill-defined areas of soft tissue opacity. As filling or collapse progresses, these areas spread and coalesce until all air is displaced from a lung lobe.

5. Lobar margination occurs when alveolar filling or collapse reaches the edge of a lung lobe and is blocked from further spread by pleura. The result is a well-defined soft tissue border that is sharply distinct from adjacent air-filled lung (Figure 1.37).

6. Air bronchograms are a classic feature of alveolar patterns:

- **a.** Appear as linear, gas opacity, branching structures that are sharply distinct from nonaerated, soft-tissue-opacity lung.
- **b.** Caused by air remaining in bronchi after alveoli are filled (Figure 1.38).
- **c.** Present in less than 25% of cases because bronchi may also fill with fluid or cells.
- **d.** Less common in cats than in dogs.
- **e.** Air alveolograms resemble tiny air bronchograms and represent retained air at ends of airways.
- **f.** Normal bronchi with blood vessels on either side may be mistaken for air bronchograms, but close inspection will reveal vascular margins (vessels are obscured with an alveolar pattern).

7. Acute alveolar filling may cause a mottled lung pattern resembling ill-defined pulmonary nodules (usually more severe centrally and fading peripherally).

8. Mediastinum may or may not shift:

- **a.** Lung collapse may result in a shift toward diseased lung.
- **b.** Neoplastic infiltrates may cause a shift away from diseased lung.
- **c.** Usually no shift occurs with pneumonia or pulmonary hemorrhage.

Box 1.7 Findings with alveolar lung pattern.

- Soft tissue opacity in lungs
- Pulmonary vessels are obscured
- Air bronchograms
- Lobar margination
- Border of cardiac silhouette or diaphragm is obscured
- Rapidly changing pattern
- Pulmonary soft tissue lesions may be obscured

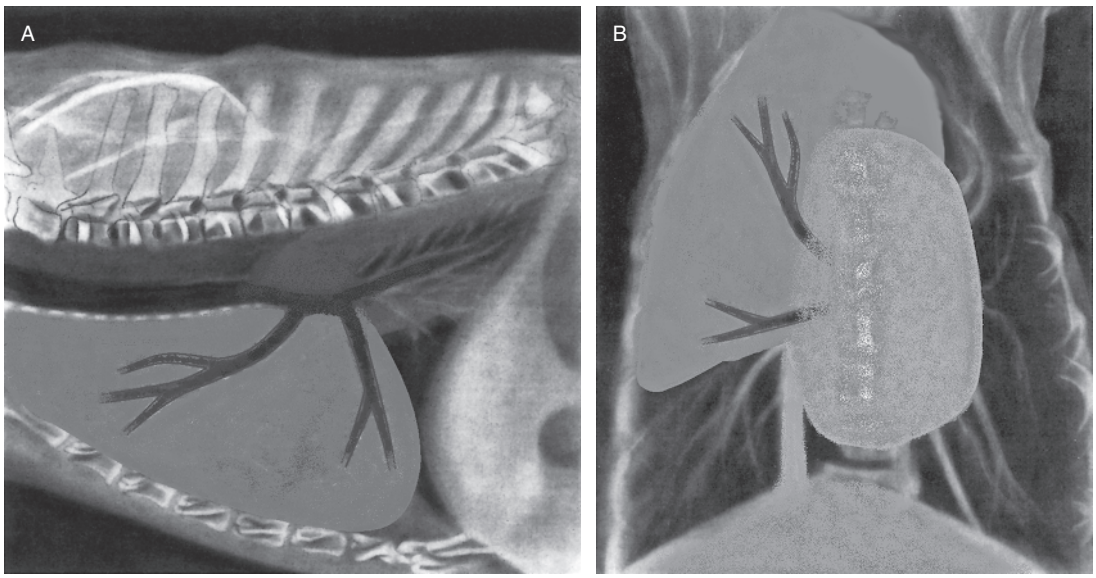


Figure 1.37 Alveolar pattern with prominent air bronchograms and lobar margination (lobar sign) in the right cranial and middle lung lobes. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

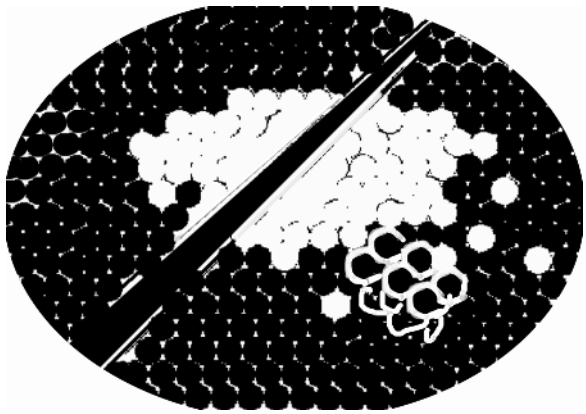


Figure 1.38 Air bronchogram. Alveolar filling (white) adjacent to an air-filled bronchus creates an air bronchogram. The bronchial wall is thickened; however, the wall would not be visible adjacent to the soft tissue in the alveoli. Interstitial thickening in the lower right.

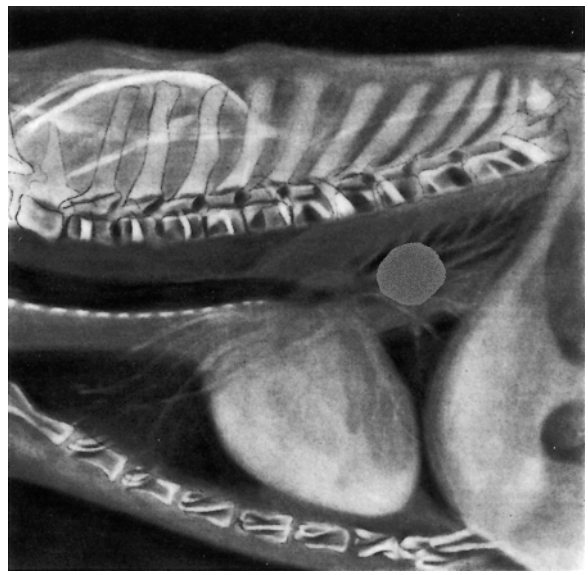


Figure 1.39 Pulmonary mass. A solitary, well-defined, soft tissue opaque mass in dorsocaudal lung field. (Adapted from Owens and Biery 1999.)

9. Alveolar patterns tend to change rapidly over short periods of time.

Diseases of lung parenchyma (interstitial lung patterns)

1. Interstitial tissue is increased or abnormal accumulations of fluid or cellular debris are present.
2. May appear as discrete structures (nodular interstitial pattern) or a general increase in lung opacity (unstructured interstitial pattern).

Nodular lung pattern (structured interstitial lung pattern) (Figures 1.39–1.42)

1. One or more abnormal, discrete opacities in pulmonary interstitium (see Diseases and Disorders in chapter 5).
2. Most common etiologies include neoplasia, mycotic infection (see Differential Diagnoses in chapter 5).
3. At least two orthogonal radiographs are needed to accurately diagnose a pulmonary nodule.
4. Lesions in right lung are better seen on left lateral radiograph and lesions in left lung are better seen on right lateral radiograph (see chapter 2).
5. Pseudo-nodules are discrete soft tissue or mineral opacities that mimic pulmonary nodules (see Diseases and Disorders in chapter 5).

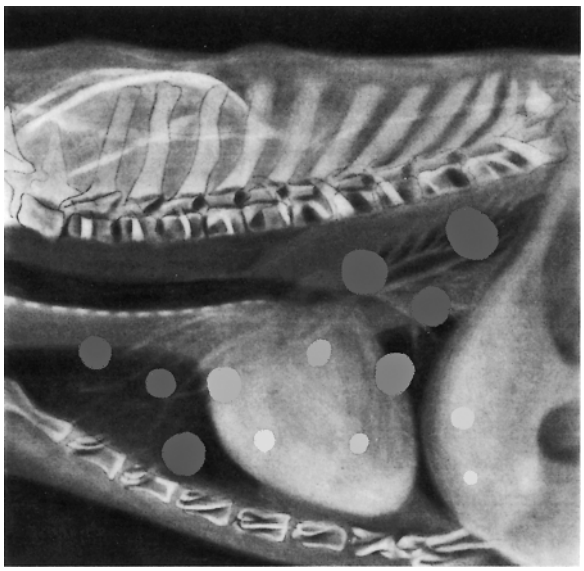


Figure 1.40 Metastatic pulmonary neoplasia. Multiple, variable-size, well-defined, soft tissue opacity nodules are distributed throughout the lungs. (Adapted from Owens and Biery 1999.)

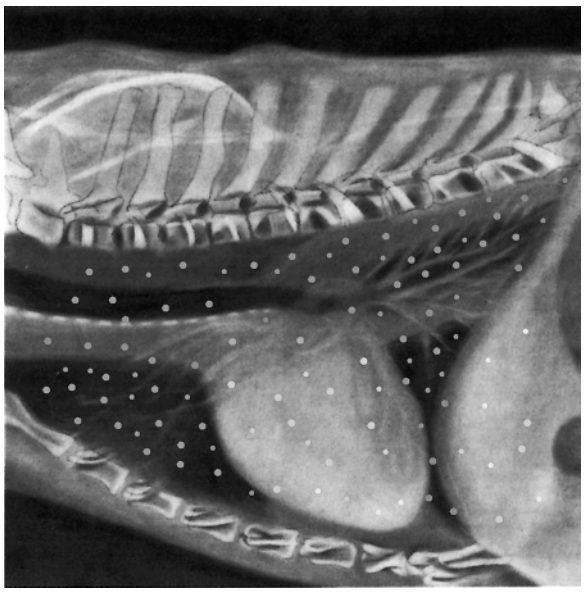


Figure 1.41 Metastatic pulmonary neoplasia. Numerous small, soft tissue opacity nodules scattered throughout the lungs ("snowstorm pattern"). Mycotic infection may produce a similar appearance (due to numerous granulomas). (Adapted from Owens and Biery 1999.)

a. Summation artifacts (e.g., end-on visualization of pulmonary vessels).
b. Superimposed structures not in lung (e.g., cutaneous nodule, nipple, costochondral cartilage).
c. Heterotopic bone formation (i.e., pulmonary osteomas).
d. Neoplastic pulmonary nodules rarely mineralize. If a nodule is more opaque than nearby vessels of same size, it represents focal mineralization or end-on visualization of a vessel (Figure 1.43).

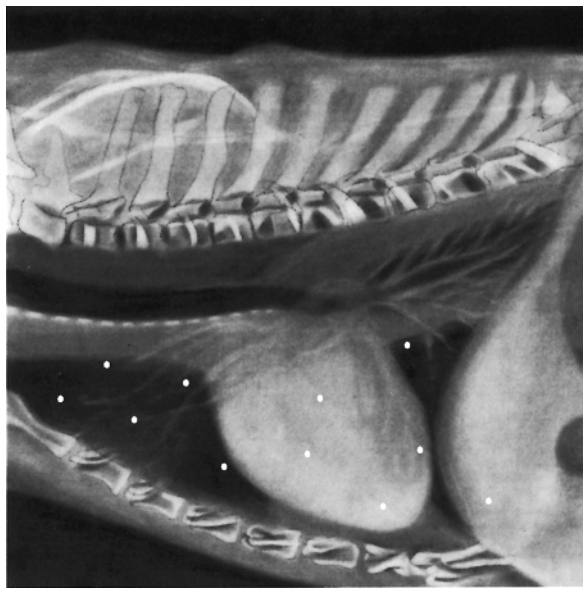


Figure 1.42 Pulmonary microlithiasis. Multiple small, mineral opacity nodules (less than 3 mm in size), predominately distributed in ventral lung fields. Also called pulmonary osteomas or heterotopic bone formation, this finding typically is incidental. Healing granulomas may create a similar radiographic appearance (but some granulomas usually will be larger than 3 mm). (Adapted from Owens and Biery 1999.)

Unstructured or general interstitial lung pattern

1. Nearly all pulmonary diseases involve the interstitium to some degree, making this the most common and least specific lung pattern.
2. Diagnosis of an unstructured interstitial lung pattern usually is made after eliminating other lung patterns.
3. Unstructured interstitial patterns commonly precede and follow alveolar patterns because the separation between alveoli and interstitium is weak. Both patterns may appear concurrently (Figure 1.44).

- Interstitial and alveolar patterns differ only in degree of opacity.
- Alveolar pattern is only lung pattern that can produce soft tissue opacity in lungs and completely obscure pulmonary soft tissue structures.

4. Interstitial lung patterns have been described as "dirty lungs" because margins of intrathoracic structures (e.g., pulmonary vessels, cardiac silhouette, diaphragm, caudal vena cava) remain visible, but are less distinct ("blurred" or "smudged"), similar to looking at lungs through "ground glass" or "bathroom glass" (Figure 1.45).

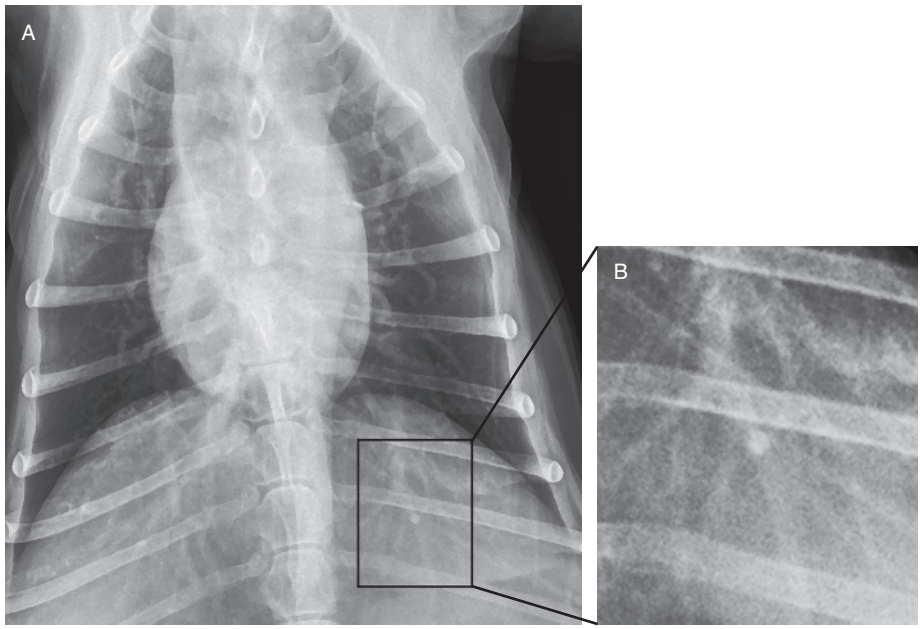


Figure1.43 Pulmonary pseudonodule; end-on visualization of blood vessel. **A.** VD radiograph. **B.** Close up highlighting end-on vessel that appears mineral opaque due to summation (end-on vessel is similar in size to adjacent vessel).

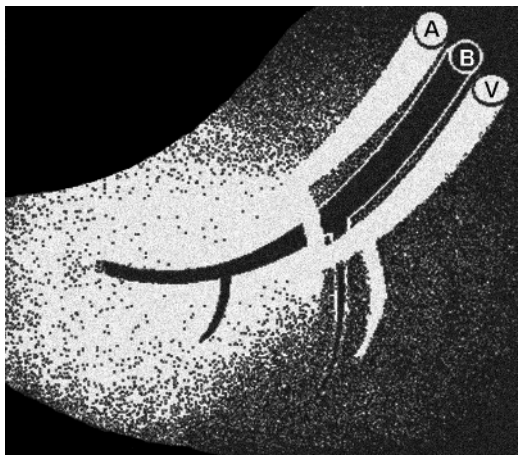


Figure 1.44 Dynamics of lung parenchyma disease. Illustration depicts fluid or cellular material infiltrating lung parenchyma. Normal lung is on upper right side of image, progressing to interstitial disease, and finally severe alveolar filling on lower left (**A** = artery, **B** = bronchus, **V** = vein). As alveoli fill, vascular margins are obscured and air-filled bronchus becomes more distinct as an air bronchogram. Interstitial and alveolar patterns differ only in degree of opacity and confluence.

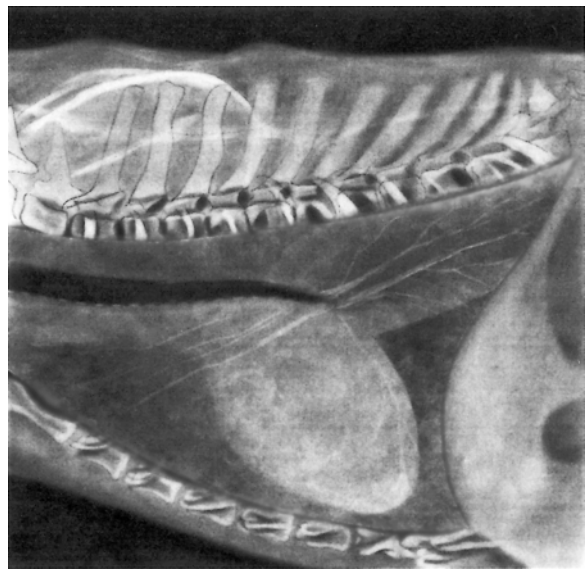


Figure 1.45 Unstructured interstitial lung pattern (lateral radiograph). Lungs are diffusely increased in opacity resulting in a hazy, blurred, or "dirty" appearance to pulmonary structures. (Adapted from Owens and Biery 1999.)

5. Air bronchograms are not present with interstitial patterns, but air in bronchi may have greater contrast against increased interstitial opacity.
6. Lung volume may be smaller because alveoli are unable to fully expand against interstitial infiltrates.
7. Interstitial connective tissues commonly thicken and become more opaque, creating fine, indistinct, linear markings (described as "reticular" or "lacey" in appearance).
   a. As interstitial disease resolves or becomes chronic and less active, reticular markings become thinner and more distinct and vascular margins become better defined.

Box 1.8 Findings with generalized interstitial lung pattern.

- Diffuse increase in lung opacity ("dirty lungs")
- Pulmonary vessels remain visible, but margins are indistinct
- Cardiac and diaphragm borders are visible
- Increased interstitial markings (reticular or lacey pattern of lines)
- No patches of soft tissue opacity caused by alveolar filling

Abdomen

Box 1.9 Checklist for interpreting abdominal radiographs.

- ✓ At least two orthogonal radiographs
- ✓ Radiographs are those of animal being evaluated
- ✓ Technique:
  - ✓ Exposure
  - ✓ Positioning
  - ✓ Motion artifact
- ✓ Effects of age, body condition, and conformation
- ✓ Extra-abdominal structures:
  - ✓ Subcutaneous tissues
  - ✓ Musculoskeleton (body wall, spine, pelvis, pelvic limbs)
  - ✓ Diaphragm
  - ✓ Caudal thorax
- ✓ Peritoneal and retroperitoneal spaces
- ✓ Liver and area of gall bladder (hepatobiliary system)
- ✓ Spleen
- ✓ GI tract (stomach, area of pancreas, small intestine, large intestine)
- ✓ Urinary tract (kidneys, area of adrenal glands, urinary bladder, urethra)
- ✓ Genital system (penis, prostate, area of uterus and ovaries)
- ✓ Reassess based on clinical, physical, and laboratory findings
- ✓ Differential diagnoses

Effects of age, body condition, and conformation

1. Obesity commonly causes abdominal distention.
2. Emaciation results in indistinct serosal margins due to lack of fat:soft tissue interfaces.
3. Positions of abdominal viscera may be altered by amount of intra-abdominal fat.
4. Immature animals have relatively larger liver and kidneys than adults.
5. Wet or dirty hair coat may mimic intra-abdominal lesions.

Extra-abdominal structures

1. Subcutaneous tissues are assessed for thickness and opacity.
2. Musculoskeletal structures (body wall, spine, pelvis, pelvic limbs) are examined for integrity, continuity, opacity.
3. Diaphragm is evaluated for position and margination.
4. Included thorax is examined for abnormalities associated with pleural, pulmonary, or cardiovascular structures.

Peritoneal and retroperitoneal spaces

1. Soft tissue margins are visible only when adjacent to a different opacity:
   a. Usually, fat provides the opacity interface for abdominal viscera, but also gas or contrast medium.
   b. Indistinct or obscured serosal margins may be due to:
      1) Insufficient body fat for opacity interface (emaciation, cachexia; Figure 1.46).
         a) Evaluate body fat status in other parts of animal.
         b) Abdomen often appears tucked.
      2) Immature animal; fat is present, but it is soft tissue opacity (i.e., "brown fat").
         a) Growth plates are open in immature animals.
      3) Increased opacity in abdominal cavity that obscures fat (effusion, inflammation, infiltrative disease).
         a) Abdomen often appears distended.
   c. Enhanced visualization of serosal margins occurs with:
      1) Abundant fat in abdominal cavity (Figure 1.47); however, excessive fat causes more scatter radiation,

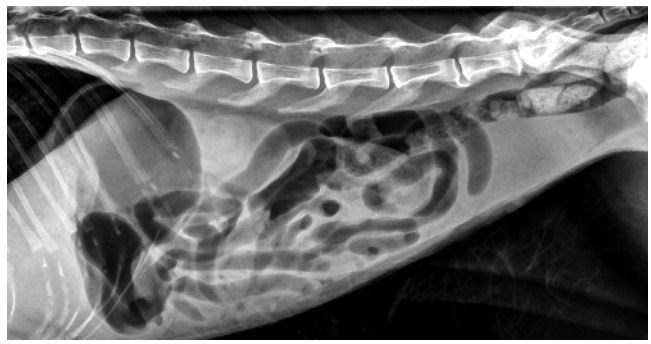


Figure 1.46 Indistinct serosal margins due to insufficient body fat for opacity interface (lateral abdominal radiograph).

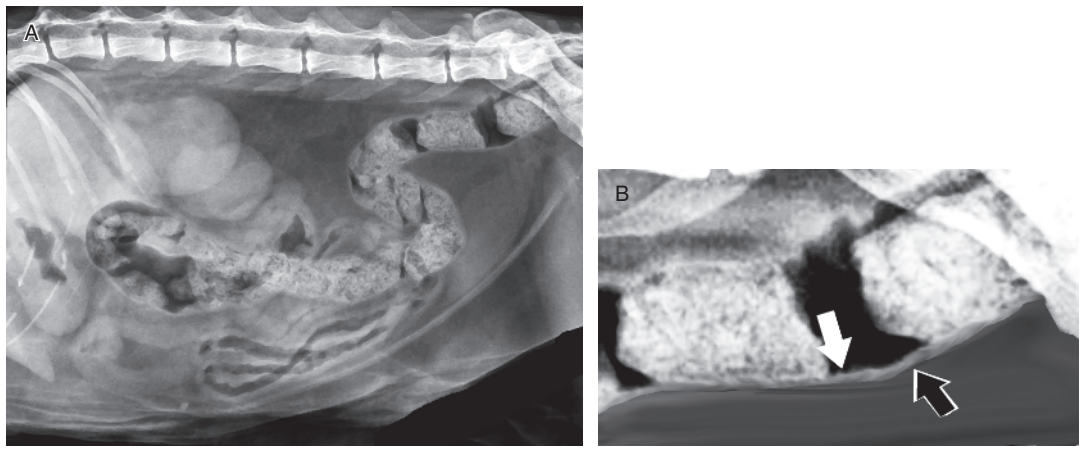


Figure 1.47 **A.** Well-defined serosal margins due to intra-abdominal fat (lateral abdominal radiograph). **B.** Gas in colon lumen allows visualization of mucosal margin (white arrow), and fat in peritoneal space allows visualization of serosal margin (black arrow).

which fogs the image and makes serosal margins less distinct.

2) Free gas in abdominal cavity (e.g., pneumoperitoneum).

2. When soft tissues overlap, their opacities are added or summated, which may mimic an intra-abdominal mass (e.g., overlap of kidneys on lateral radiograph, Figure 1.48). Soft tissue opacity is relative, depending on thickness and adjacent structures (which is why not all "soft tissue" structures are same opacity).

3. Peritoneal and retroperitoneal spaces normally are similar in opacity and definition.

4. Disease in one space usually does not involve the other (i.e., peritoneal effusion will obscure peritoneal serosal margins, but margins of kidneys remain distinct).

Peritoneal fluid and gas

1. Free fluid in peritoneal space is an important radiographic diagnosis.

2. Type of fluid cannot be determined on radiographs (blood, urine, or peritoneal effusion are most common; see Differential Diagnoses in chapter 6).

3. Small volumes of fluid present with:

a. Linear or wispy soft tissue opacities in intra-abdominal fat ("fluid streaking of fat").

b. Localized hazy or mottled appearance with indistinct serosal margins (Figure 1.49).

4. Large volumes of fluid create:

a. More uniform increase in opacity throughout abdominal cavity.

b. Serosal margins are obscured.

c. Gas-filled bowel loops float to top of fluid and tend to localize in center of abdominal cavity.

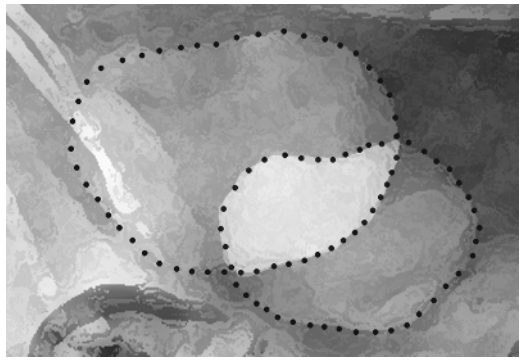


Figure 1.48 Summation. Overlap of kidneys produces increased opacity due to added soft tissue of both kidneys.

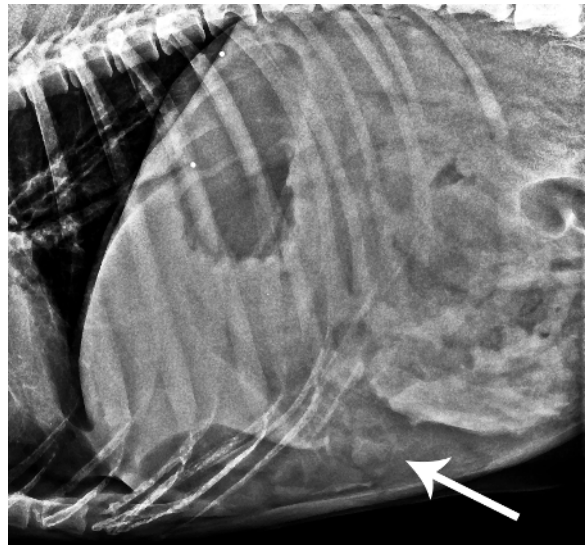


Figure 1.49 Local peritoneal effusion due to splenic hemorrhage (arrow).

d. Retroperitoneal space often is spared and kidney margins remain visible (if adequate fat is present).

e. Abdomen usually is distended and diaphragm may be cranially displaced.

5. Free peritoneal fluid may be difficult to distinguish from other conditions that result in indistinct or obscured serosal margins (e.g., emaciation, immature animal, severe inflammation, disseminated neoplasia/carcinomatosis).

Pneumoperitoneum

1. Free gas in peritoneal space may result from penetrating abdominal wound, ruptured stomach or bowel, or infection with gas-producing organism (see Differential Diagnoses in chapter 6).

2. Pneumoperitoneum decreases opacity in peritoneal space and enhances visualization of serosal margins.

3. Small volumes of gas produce well-defined, triangular or linear areas of decreased opacity (gas bubbles), which commonly collect between bowel loops.

a. Free gas may be difficult to differentiate from intraluminal intestinal gas, but gas in bowel tends to appear more rounded and flowing.

b. Horizontal beam radiographs aid in diagnosis of slight pneumoperitoneum:

1) Position animal in left lateral recumbency for 5 minutes (right lateral is not recommended because air in gastric fundus can be confused with free peritoneal gas).

2) X-ray beam is directed across table (horizontal) to make a VD radiograph, centered at cranial right abdomen.

3) Decrease kVp by 15% to increase gas-to-soft-tissue contrast.

4) Free gas commonly collects in upper part of peritoneal space, between diaphragm and right lateral liver lobes (Figure 1.50).

4. Larger volumes of gas tend to coalesce into bigger bubbles in highest point of peritoneal space, usually caudal to diaphragm and ventral to hypaxial muscles.

5. Iatrogenic pneumoperitoneum is common and must be excluded as an etiology (e.g., laparotomy, abdominocentesis).

a. Normal postoperative gas may persist up to 3 weeks, but in most cases gas is no longer evident within a week.

Pneumoperitoneum: *If no one has "been" there, someone needs to "go" there.*

6. Inflammation or free fluid often accompanies pneumoperitoneum, which makes interpretation of radiographs more difficult.

a. Serosal margins may be obscured.

b. Additional images may be helpful, including VD/DV, opposite lateral, and horizontal beam radiographs.

c. Postoperative peritoneal gas is difficult to differentiate from gastrointestinal perforation and is a common dilemma faced after GI surgery.

d. Abnormal distention of stomach or intestine may indicate rupture, severe inflammation, or obstruction.

7. In addition to gas in peritoneal space, gas may appear within wall or parenchyma of an organ (e.g., splenic or hepatic abscess, emphysematous metritis/cholecystitis/cystitis, pneumatosis coli):

a. Often is easier to detect with obliqued or horizontal beam radiographs.

Retroperitoneal disease

1. Increased opacity and loss of visualization of serosal margins in retroperitoneal space typically results from abnormal accumulation of fluid (urine or blood) or inflammation (Figure 1.51).

2. Enlargement of retroperitoneal space displaces central and caudal abdominal viscera ventrally.

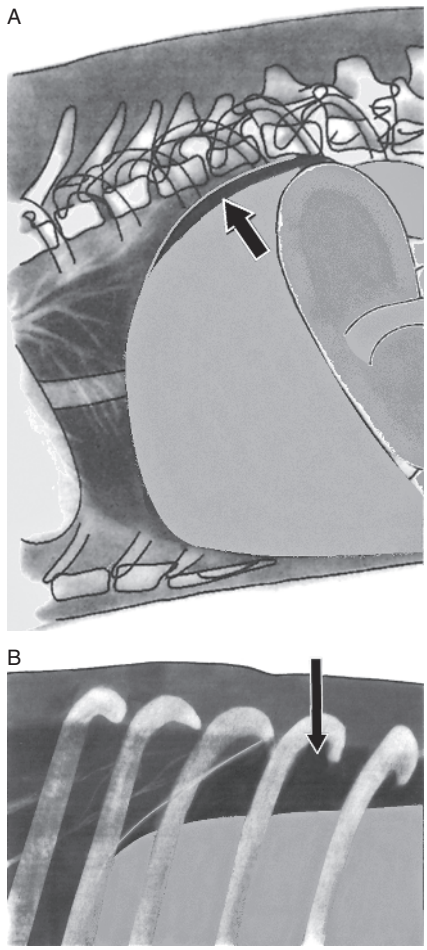


Figure 1.50 Pneumoperitoneum. **A.** Free gas (arrow) is visible dorsally between liver and diaphragm (lateral radiograph). **B.** Horizontal beam radiography documents free gas (arrow) between liver, diaphragm, and body wall (VD radiograph with animal in left lateral recumbency). (Adapted from Owens and Biery, 1999.)

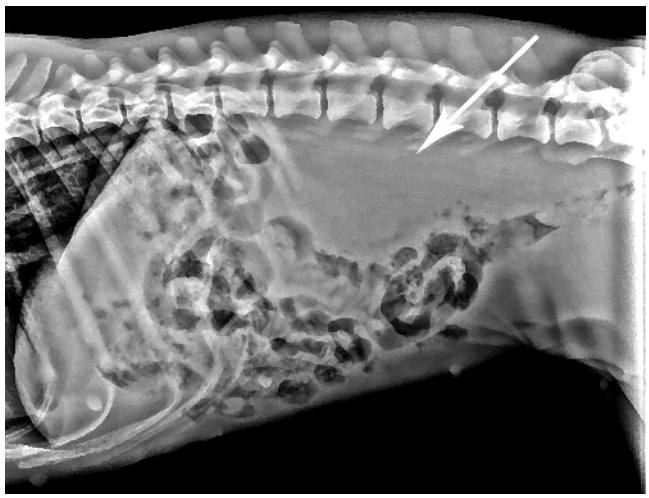


Figure 1.51 Retroperitoneal disease (lateral radiograph). Increased opacity and swelling of retroperitoneal space with indistinct renal margins (arrow).

a. Opacity dorsal to displaced organs may be soft tissue (mass or fluid) or fat (obese animal or lipoma).

3. Periosteal response along ventral borders of lumbar vertebrae may result from retroperitoneal disease (e.g., neoplasia, inflammation/infection):

a. Response differs from spondylosis in that it occurs along middle of vertebral body (spondylosis occurs at ends) and margins tend to be less distinct.

b. Tumors typically affect L5-7 due to metastasis to sublumbar lymph nodes, most commonly from prostatic or cystic neoplasia (Figure 1.52).

c. Migrating plant awns commonly follow diaphragm to affect L3-4.



Figure 1.52 Periosteal response along caudal lumbar vertebrae and cranial margins of pelvis due to metastatic prostatic neoplasia (lateral radiograph). A urethral catheter and pneumocystogram are visible.

1) Ventral margins of L3-4 normally are indistinct due to attachments of diaphragm and should not be confused with disease.

d. Primary vertebral pathology can produce a periosteal response along ventral aspect of vertebral bodies (e.g., spondylitis, trauma, osseous neoplasia).

4. Gas in retroperitoneal space is uncommon.

a. May result from extension of pneumomediastinum, penetrating wound, or infection with gas-producing organism.

b. Enhances visualization of renal and hypaxial muscle margins (lateral radiograph).

c. Severe pneumoretroperitoneum can progress to pneumoperitoneum.

Intra-abdominal mass

1. A local area of increased opacity that displaces adjacent organs and may obscure adjacent serosal margins (Figure 1.53).

a. Differentiation of a mass and localized peritoneal fluid or inflammation may be difficult; however, close inspection often reveals serosal margins associated with mass.

2. Mass may represent organomegaly, tumor, abscess, granuloma, hematoma, cyst, or hyperplasia.

3. To be reliably detected on survey radiographs, small masses must measure at least twice the width of surrounding small intestine.

4. Clues to origin of a mass lie in displacement and/or obliteration of normal structures (Figure 1.54).

a. Altered positions of abdominal viscera may also result from loss of body wall integrity (e.g., hernia) or congenital anomalies (e.g., ectopic kidney).

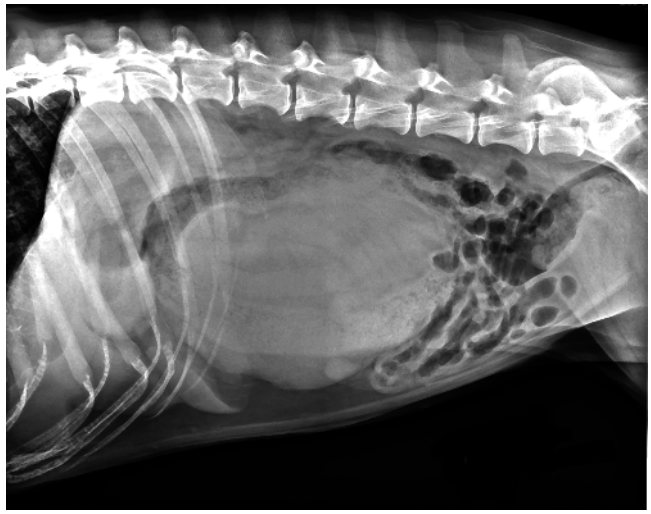


Figure 1.53 Peritoneal mass (lateral radiograph). A well-defined soft tissue opaque mass is visible in the mid-abdominal cavity, resulting in dorsal and caudal displacement of intestines and cranial displacement of transverse colon and stomach.

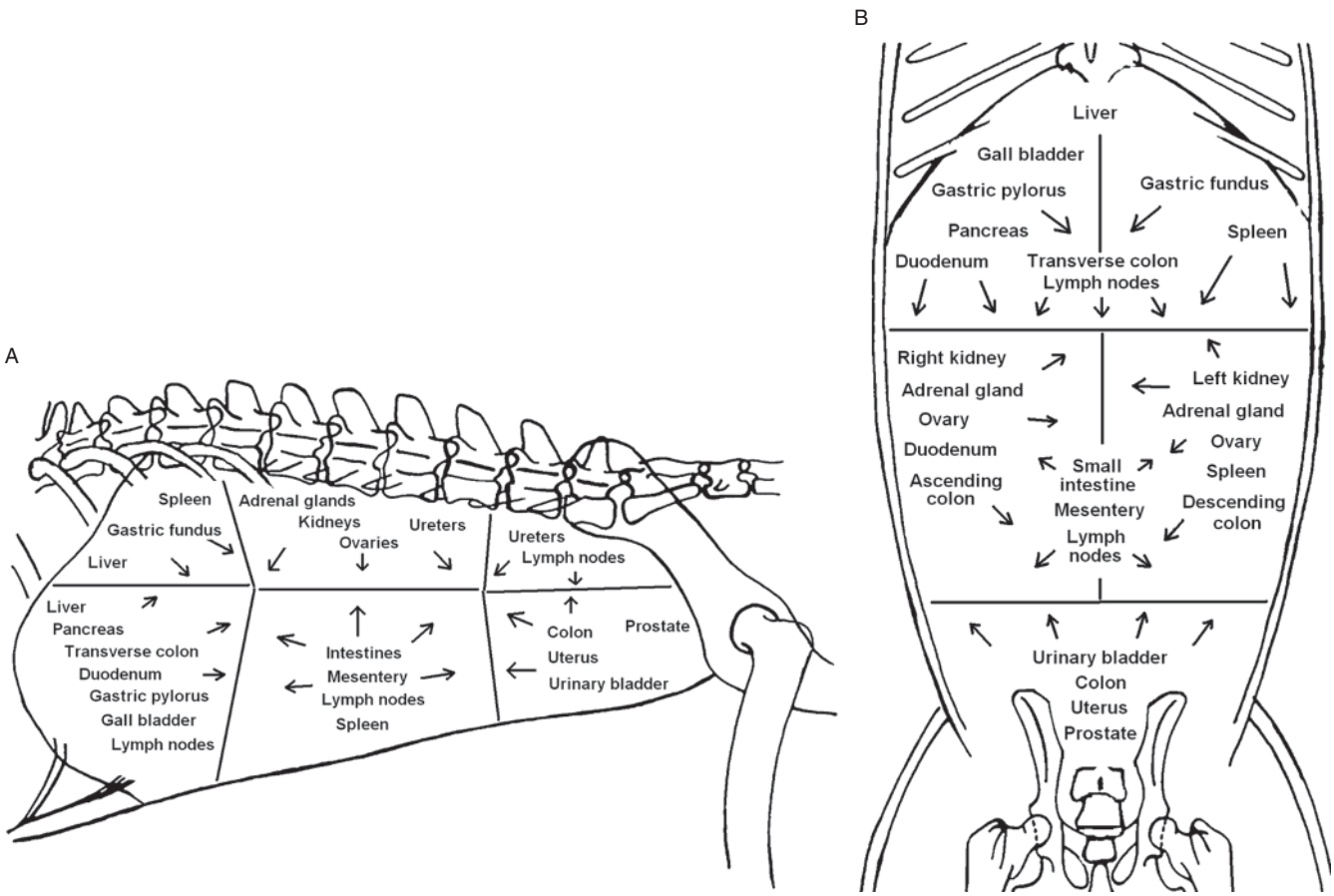


Figure 1.54 Intra-abdominal mass effects. Enlargement of abdominal viscera in areas shown typically displaces nearby structures in directions indicated by arrows. **A.** Lateral abdominal radiograph. **B.** VD abdominal radiograph.

Lymph nodes

1. Lymph nodes are not visible on survey radiographs unless enlarged or mineralized.

2. Enlargement of lymph nodes:

a. May be caused by neoplasia or infection (see Differential Diagnoses in chapter 6).

b. Visceral lymph nodes rarely enlarge enough to be seen on survey radiographs.

1) Moderate to severe enlargement of mesenteric or colic lymph nodes creates a midabdominal mass effect and displaces adjacent intestines (Figure 1.55).

2) Enlarged groups of lymph nodes tend to blend together resulting in an ill-defined, soft tissue opacity mass.

c. Medial iliac lymphadenomegaly presents with increased soft tissue opacity in caudal retroperitoneal space (generally ventral to L6-7).

1) May be large enough to ventrally displace terminal colon and rectum (Figure 1.56).

2) When present, nearby bones should be examined for abnormalities. Bone production other than spondylosis may signal specific neoplastic or infectious disease (Figure 1.52).

3. Mineralization of lymph nodes:

a. Usually dystrophic secondary to necrosis.

b. Oily contrast agents used for lymphangiography may persist in lymph nodes as areas of increased opacity.

Liver

1. Liver is evaluated for size, shape, margination, position, and opacity (Figure 1.57; see Differential Diagnoses in chapter 6).

2. Abnormal size of liver:

a. Position of gastric axis aids in evaluation (see Normal Radiographic Anatomy in chapter 6).

1) If stomach is not visible, consider adding a small amount of air or barium.

b. Enlarged liver (hepatomegaly; Figures 1.58 and 1.59):

1) Gastric axis is angled further caudally (pylorus is displaced caudally).

2) Hepatic margins become rounded.

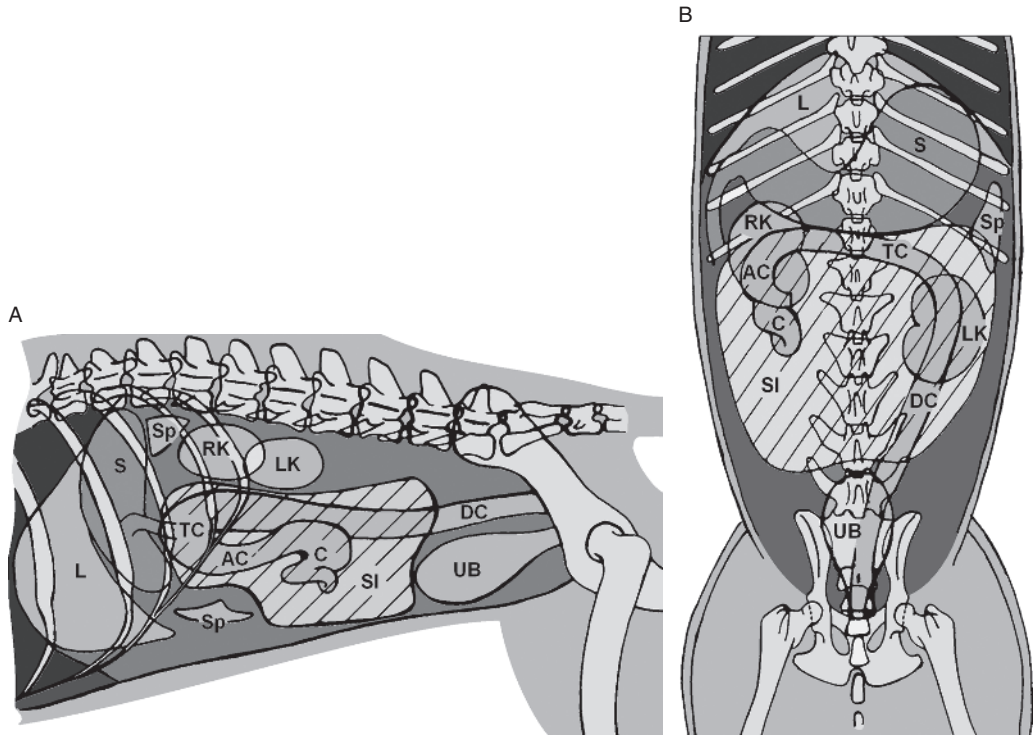


Figure 1.55 Normal abdominal viscera; **L** = liver, **S** = stomach, **RK** = right kidney, **LK** = left kidney, **Sp** = spleen, **SI** = small intestine, **C** = cecum, **AC** = ascending colon, **TC** = transverse colon, **DC** = descending colon, **UB** = urinary bladder. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

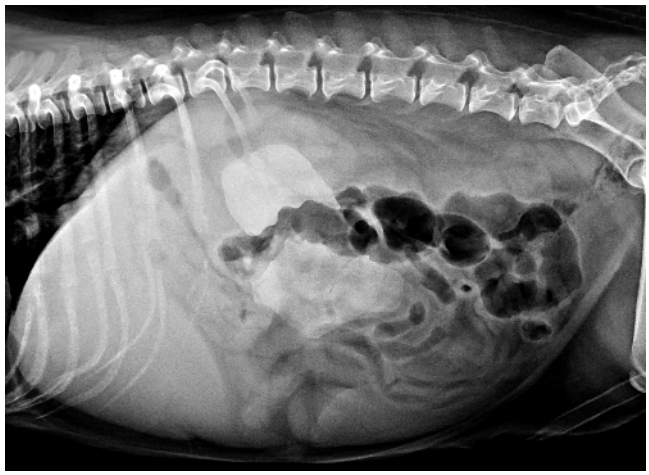


Figure 1.56 Mesenteric lymphadenomegaly (lateral radiograph). A midabdominal mass effect is visible (white area). Hepatomegaly and splenomegaly also are present (lymphoma).

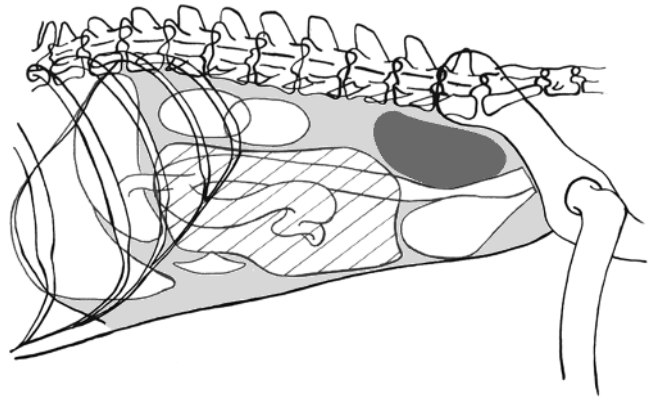


Figure 1.57 Diagram depicting area of enlargement of medial iliac lymph nodes (dark shading) resulting in ventral displacement and compression of descending colon. (Adapted from Owens and Biery 1999.)

3) Caudal border of liver extends beyond costal arch (lateral radiograph).

a) This finding should be interpreted with caution. The concept of liver size in relation to costal arch is based on palpation. It should be noted that skin, subcutaneous tissue, and muscle causes fingers to palpate further caudal than costal arch. A liver extending just caudal to costal arch on radiographs most likely will not be palpable and may be normal. Rounding of hepatic margins is a more reliable indicator of hepatomegaly.

c. Small liver (microhepatia; Figure 1.60):

1) Gastric axis is angled cranially (pylorus is closer to diaphragm).

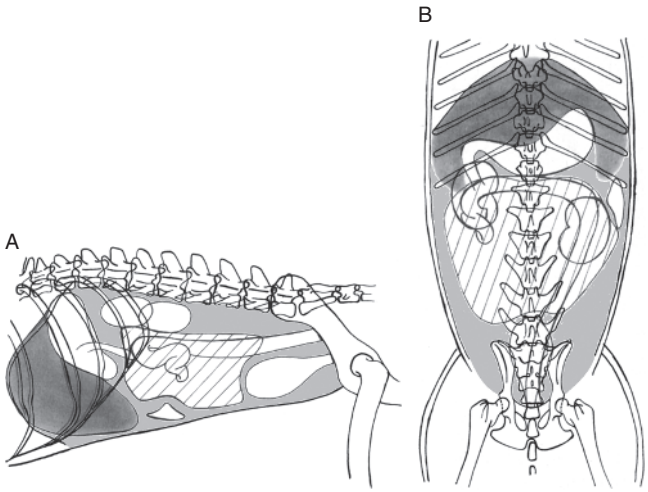


Figure 1.58 General hepatomegaly. Liver enlargement (dark shading) presents with rounded hepatic margins and caudal displacement of stomach. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

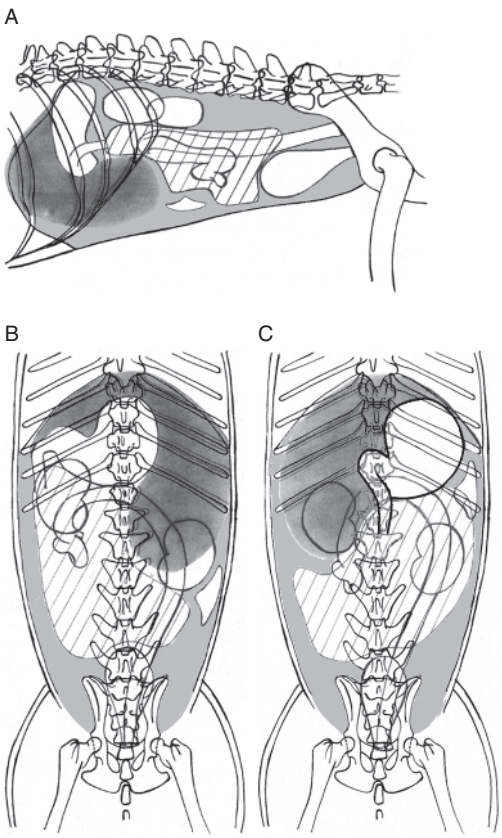


Figure 1.59 Localized hepatomegaly due to liver mass. Liver enlargement (dark shading) presents with rounded hepatic margins and variable displacement of nearby structures. **A.** Lateral radiograph with a ventral hepatic mass extending caudal to stomach and displacing small intestine caudally. **B.** VD radiograph with left hepatic mass displacing stomach and bowel medially, left kidney and spleen caudally. **C.** VD radiograph with right hepatic mass displacing pylorus and duodenum medially and right kidney caudally. (Adapted from Owens and Biery 1999.)

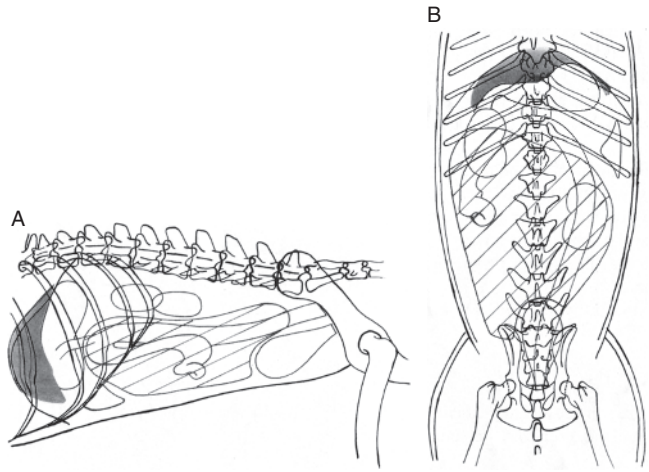


Figure 1.60 Microhepatia. Small liver (shaded area) results in cranial displacement of stomach. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

2) Stomach is separated from diaphragm by less than 2 intercostal spaces.

3) Caudal border of liver does not extend to costal arch (lateral radiograph).

3. Abnormal shape and margination of liver:

a. Rounded margins result from general or local hepatomegaly.

b. Small liver with irregular margins most commonly is due to chronic cirrhosis.

1) Peritoneal fluid often is present with cirrhosis and obscures liver margins.

c. Normal to large liver with irregular margins may be caused by nodules on or near surface of liver (e.g., neoplasia, parasites, hyperplasia).

d. Gall bladder enlargement may create a bulge along ventral border of liver (lateral radiograph).

e. Fluid-filled gastric pylorus may be mistaken for hepatic mass (make left lateral radiograph to position gastric gas in pylorus and confirm identification).

4. Altered position of liver:

a. Cranial displacement may be caused by an abnormal diaphragm (e.g., eventration, hernia) or a large intra-abdominal mass.

b. Caudal displacement is due to an expanded thoracic cavity.

c. Ventral displacement may result from weak abdominal muscles or hernia.

d. Dorsal displacement due to obesity (fat engorged falciform ligament).

5. Abnormal opacity of liver:

a. Mineralization in liver (uncommon) may represent biliary calculi or dystrophic calcification.

b. Gas opacity in liver is rare and may be caused by infection with gas-producing organism, reflux of gas from GI tract, or emphysematous cholecystitis (latter most often occurs with diabetes mellitus).

Gall bladder/biliary system

1. Biliary structures (gall bladder, bile ducts) are not visible on survey radiographs unless they contain mineral or gas, in which case they may be seen in right cranial or cranioventral area of liver.

a. Mineralization may represent calculi or dystrophic mineralization.

1) Biliary calculi vary in opacity, size, and shape.

2) Branching mineralization typically is associated with bile ducts and may represent choledocoliths or chronic inflammation and dystrophic mineralization.

3) Gall bladder wall may mineralize due to chronic inflammation.

4) Costochondral junctions may be mistaken for biliary mineralization.

b. Gas in gall bladder (emphysematous cholecystitis) usually is associated with diabetes mellitus; tends to conform to shape of bladder.

2. An enlarged gall bladder may create a bulge along ventral border of liver, especially in cats (lateral radiograph).

Spleen

1. Spleen is evaluated for enlargement, position, shape, margination, and opacity.

2. Enlarged spleen (splenomegaly; Figures 1.61 and 1.62):

a. A subjective assessment that may or may not be associated with pathology (see Differential Diagnoses in chapter 6).

1) Commonly enlarges during sedation or anesthesia due to smooth muscle relaxation and passive congestion.

2) Relatively larger in some breeds (e.g., German shepherd dog, greyhound, Scottish terrier).

3) In some cases of bone marrow insufficiency, spleen is responsible for production of red blood cells and undergoes compensatory enlargement (removal of spleen in these cases may result in a fatal anemia).

4) Pathology includes neoplasia, hematoma, inflammation, venous congestion.

5) May be associated with immune mediated hemolytic anemia/thrombocytopenia or cardiac arrhythmias (mechanism for development of these conditions is poorly understood).

b. Enlargement may be general or local (see Differential Diagnoses in chapter 6).

c. Splenic margins become rounded.

1) Edges of spleen no longer form acute angles.

2) Lack of rounded margins suggests spleen is not generally enlarged.

d. Splenomegaly frequently is overdiagnosed, especially when a long portion of spleen is visible or tail of spleen is positioned near urinary bladder.

3. Altered position of spleen may or may not be associated with pathology:

a. Spleen is more cranial in deep-chested dogs.

b. Size of liver and stomach affects position of spleen.

c. Displacement of stomach (spleen follows stomach due to gastrosplenic ligament).

d. Intra-abdominal mass may displace spleen in variety of directions.

e. Splenic torsion typically results in ventral displacement (Figure 1.63), but spleen may become quite large and occupy much of the peritoneal space.

4. Shape and margins of spleen may be altered by enlargement, infiltrative disease, mass, or torsion.

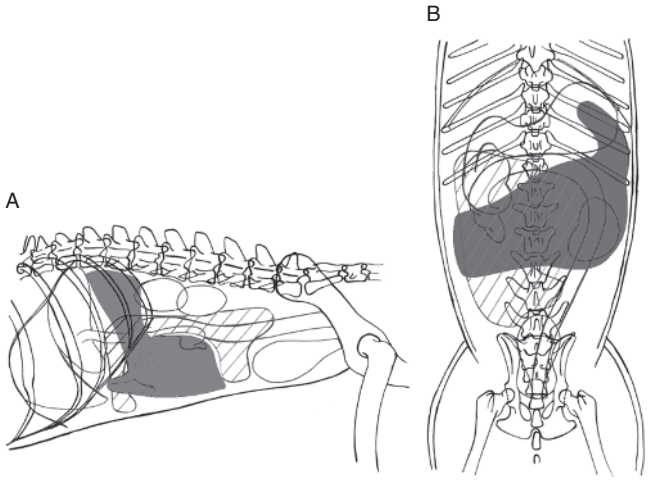


Figure 1.61 Generalized splenomegaly (dark shading) with rounded margins and displacement of intestines. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

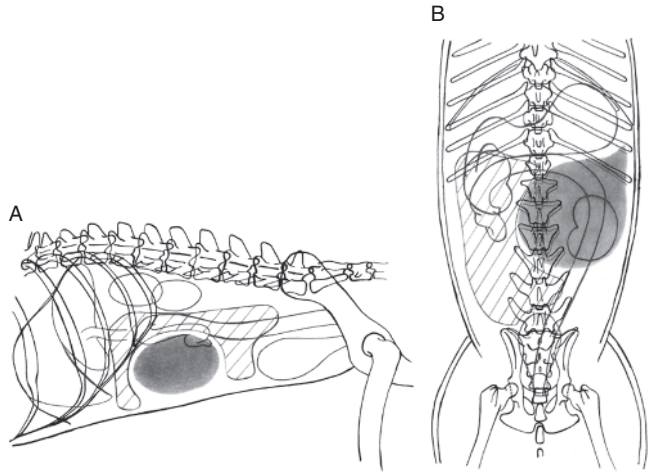


Figure 1.62 Splenic mass (dark shading) with rounded margins and displacement of bowel. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

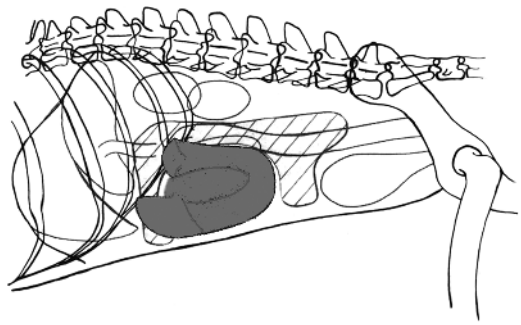


Figure 1.63 Splenic torsion (dark shading on lateral radiograph). Spleen shape resembles a reverse capital letter 'C'. (Adapted from Owens and Biery 1999.)

5. Altered opacity of spleen (mineralization or emphysema) is uncommon but may result from neoplasia or abscessation (Figure 1.64).
6. Peritoneal effusion is common with many splenic disorders and may initially present as fluid streaking of intra-abdominal fat.

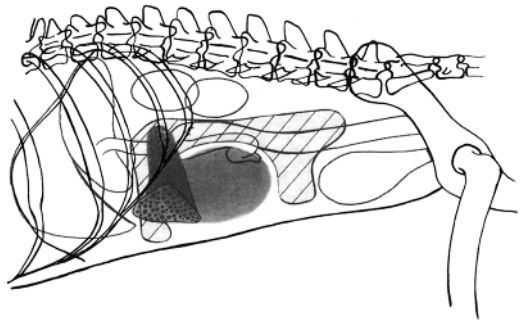


Figure 1.64 Splenic abscess (dark shading on lateral radiograph). Spleen contains multiple foci of gas. (Adapted from Owens and Biery 1999.)

Pancreas

1. Normal pancreas rarely is visible on survey radiographs.
2. May be visible in overweight cats as a poorly-defined, soft tissue opacity structure within triangle formed by stomach, spleen, and left kidney.
3. Pancreatic disease may affect appearance of adjacent tissues:
a. Serosal margins become indistinct due to regional peritonitis (typically in right cranial abdominal quadrant).
b. Duodenum may be displaced ventrally and right laterally by pancreatic enlargement.
c. Gastroduodenal angle may widen due to swelling of pancreas (Figure 1.65).
d. Stomach and transverse colon may be separated by pancreatic enlargement.
e. Peristalsis in stomach, duodenum, and transverse colon may be altered by pancreatic inflammation.
f. Gas may persist in proximal duodenum or transverse colon on serial radiographs (static gas pattern) due to inflammation and localized ileus.

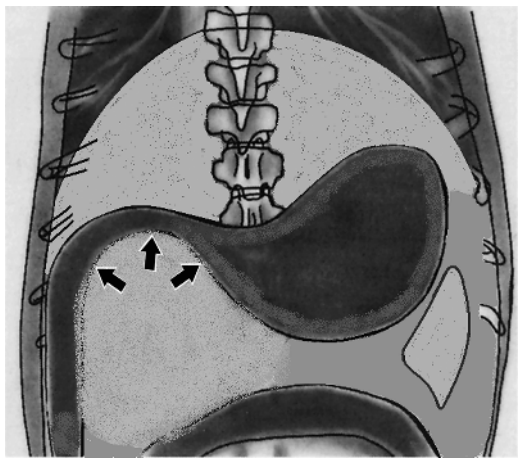


Figure 1.65 Pancreatitis (VD radiograph). Swelling of pancreas causes widening of gastroduodenal angle (arrows), and inflammation obscures serosal margins in right cranial abdominal quadrant. Gas may persist in proximal duodenum and transverse colon on serial radiographs due to adjacent inflammation and localized ileus. (Adapted from Owens and Biery 1999.)

4. Mineralization of pancreas is rare but may result from chronic inflammation, neoplasia, or fat necrosis.

Gastrointestinal tract

Stomach

1. Stomach is evaluated for position, size, shape, content, and margination.
2. Position of stomach:
a. Cranial and caudal displacement of stomach most often is associated with size and position of liver, but cranial displacement may result from a large intra-abdominal mass.
b. Identification of pylorus is important in determining gastric orientation (i.e., gastric dilatation and volvulus) and may require a variety of patient positions and multiple radiographs to take advantage of gravity-dependent movements of gastric fluid and gas (Figure 1.66, Table 1.3).
1) Air in gastric lumen rises to nondependent (up) part of stomach and fluid pools in dependent (down) areas (pattern is dependent on volume of gas and fluid in stomach at time of radiography).
3. Size and content of stomach are extremely variable:
a. Largely distended stomach containing mostly fluid and gas is suggestive of an outflow problem.
1) Borders of an extremely dilated stomach may not be immediately recognized on survey radiographs. Gas bubble in fundus may be mistaken for size of stomach.
2) Frequently with gastric outflow problems, tiny, sandlike mineral opacities will accumulate in dependent portion of stomach due to sedimentation of heavier food particles (Figure 1.67).

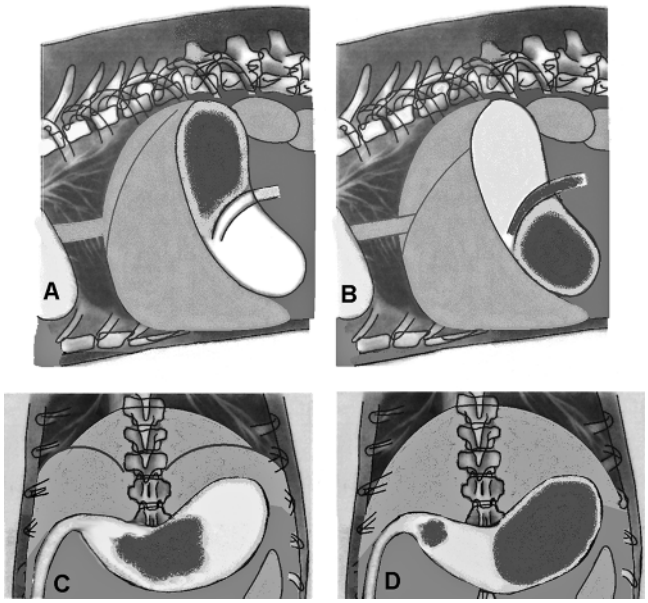


Figure 1.66 Locations of gastric fluid and gas vary with positioning of the animal. **(A)** In right lateral recumbency fluid is in pyloric antrum and gas is in body and fundus; right diaphragmatic crus is cranial. **(B)** In left lateral recumbency gas is in pyloric antrum (and in duodenum) and fluid is in body and fundus; left diaphragmatic crus is cranial. **(C)** In dorsal recumbency (VD radiograph) gas is in body and fluid is in fundus; pyloric antrum contains gas and/or fluid; diaphragm has three humps. **(D)** In ventral recumbency (DV radiograph) fluid is in body and gas is in pyloric antrum and fundus; diaphragm has one hump. (Adapted from Owens and Biery 1999.)

Table 1.3 Locations of gas and fluid in stomach

Recumbent Position	Fundus	Body	Pylorus
Right lateral	Gas	Gas	Fluid
Left lateral	Fluid	Fluid	Gas
Dorsal (VD radiograph)	Fluid	Gas	Gas/Fluid
Ventral (DV radiograph)	Gas	Fluid	Gas

Small intestine

1. Small intestine is evaluated for position, size, pattern, and content.

2. Abdominal radiographs depict appearance of small intestine at a single moment in time, but normal bowel loops are constantly in motion. True lesions of small bowel will be repeatable on serial radiographs.

3. Small intestine containing gas is readily visible on survey radiographs, but fluid-filled bowel is not as apparent. Fluid-filled bowel should be purposefully examined to complete the evaluation of intestinal pattern.

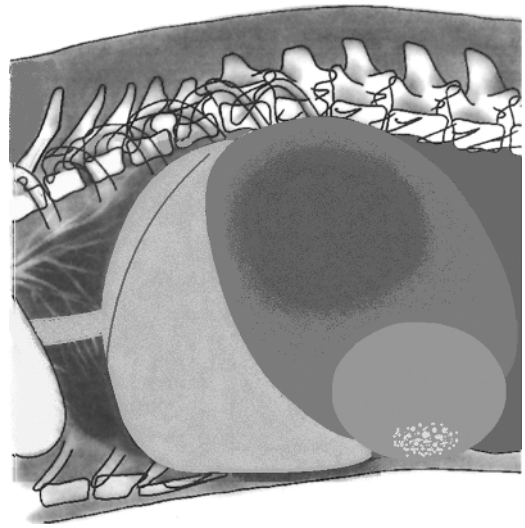


Figure 1.67 Gastric outflow obstruction (lateral radiograph). Stomach is greatly distended with fluid and gas (borders of an extremely dilated stomach may not be immediately recognized on survey radiographs). Accumulation of multiple small, sandlike mineral opacities is due to sedimentation of heavier food particles in pyloric. (Adapted from Owens and Biery 1999.)

4. Small intestine normally fills spaces not occupied by other structures or fat.

- **a.** Majority of small bowel typically is positioned to right of midline.
- **b.** Excessive intra-abdominal fat causes small intestine to "bunch together" in right ventral mid-abdominal cavity (may be mistaken for linear intestinal foreign material).
- **c.** Bowel loops are readily displaced by intra-abdominal masses and organomegaly; pattern of bowel displacement provides clues to origin of mass-effect.

5. All small bowel loops should be similar in width, with no segment measuring more than twice the size of other segments.

- **a.** Intestinal width (serosa to serosa) greater than 2 times the height of the body of L5 indicates abnormally enlarged (distended) bowel (Figure 1.68).
- **b.** Enlargement of small intestine may be due to increased diameter of lumen or less likely thickening of bowel wall (see Differential Diagnoses in chapter 6). Remember to check for dilated fluid-filled bowels, which may not be as obvious as gas-filled bowels.
- **c.** Ileus due to partial or complete physical blockage of bowel lumen (obstructive ileus) is characterized by abnormal distention of one or more bowel segments and more normal-sized intestine distal to obstruction (Figure 1.69).
- **d.** Ileus due to vascular or neuromuscular disease (paralytic ileus) typically presents with more uniformly distended bowel segments, most of which tend to be gas filled.

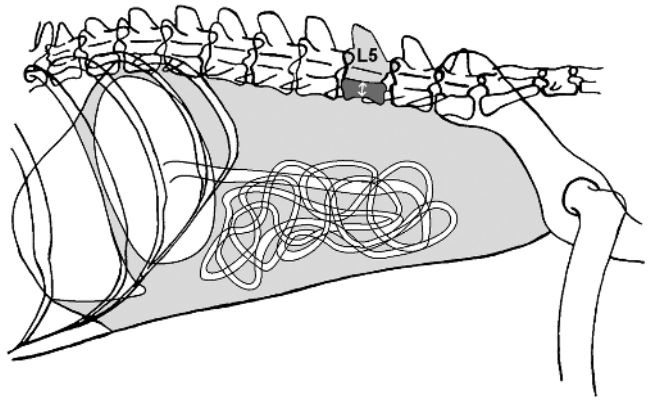


Figure 1.68 Small intestine width (serosa to serosa) normally should not exceed the height of the body of L5 (double-headed arrow in shaded vertebral body). Bowel widths greater than twice L5 body height are likely to be obstructed. (Adapted from Owens and Biery 1999.)

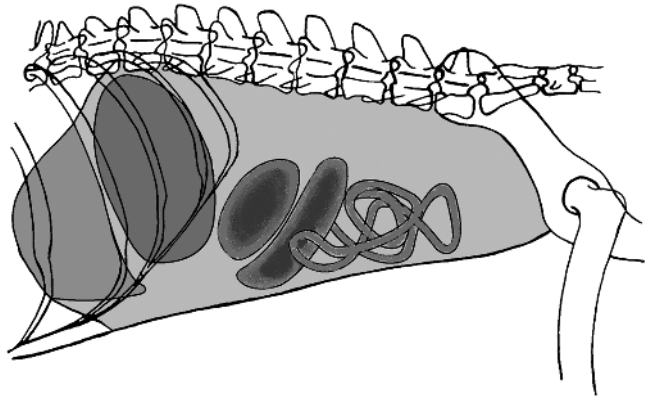


Figure 1.69 Small intestinal obstruction (lateral radiograph). Bowel proximal to obstruction is abnormally dilated and gas filled; bowel distal to obstruction is normal in width. (Adapted from Owens and Biery 1999.)

e. Linear foreign material in small intestine causes bowel to bunch together in a tight, plicated pattern with irregular shaped pockets of gas (comma- or crescent-shaped gas bubbles) and tight turns (Figure 1.70).

f. Bowel wall thickness cannot be reliably assessed on survey radiographs.

1) Fluid and gas in bowel lumen may mimic bowel wall thickening (Figure 1.71).

2) Fluid obscures mucosa margins, and since it is same opacity as bowel wall, intra-luminal fluid may give false impression of wall thickening.

6. It is unusual to see significant quantities of ingesta in small intestine:

a. When present, serial radiographs are recommended to monitor transit and emptying.

b. Gastric content should be evaluated because it will eventually progress into small intestine.

7. Contrast radiography (e.g., upper GI study) aids in evaluating bowel wall thickness, mucosal irregularities, peristaltic activity, intestinal content, and transit time.

Large intestine

1. Large intestine is evaluated for position, size, shape, content, and opacity.

2. Colon wall thickness and mucosal margination cannot be reliably assessed on survey radiographs. Endoscopy (preferred) or barium enema is recommended.

3. Descending colon typically is left of midline but may be positioned right of midline due to a large urinary bladder, ingesta in small intestine, intra-abdominal fat, or redundancy (latter is a normal anatomic variation most often reported in cats and large breed dogs).

4. Width of colon usually is 2 to 3 times width of small intestine and should not exceed 3 times width of small bowel or 1.5 × length of L7.

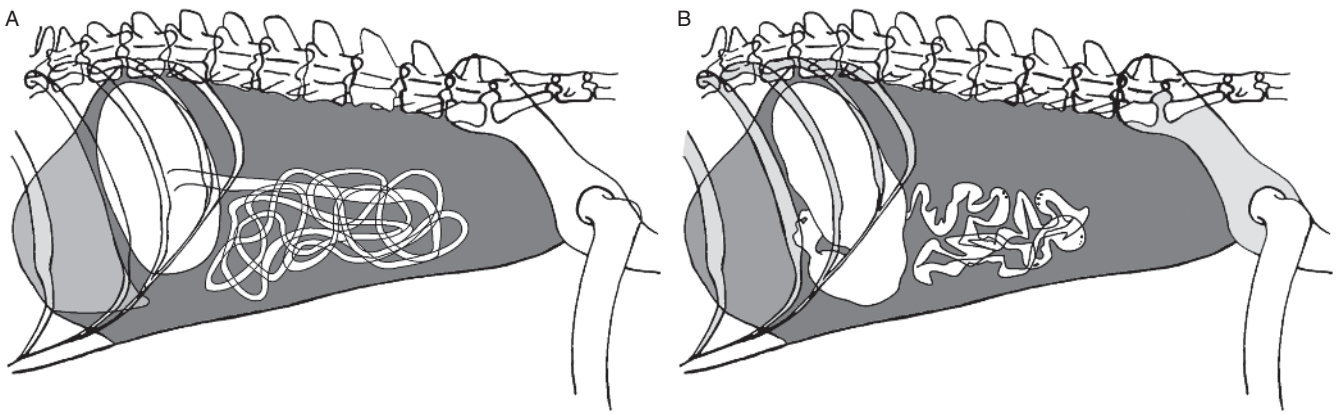


Figure 1.70 Small intestinal linear foreign material (lateral radiograph, barium upper GI study). **A.** Normal bowel pattern with smooth flowing loops. **B.** Small intestine is bunched together (plicated) with hairpin turns and irregular margins. (Adapted from Owens and Biery 1999.)

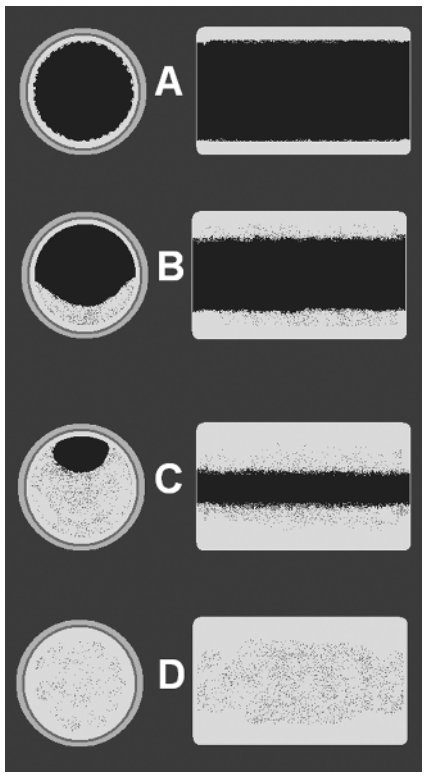


Figure 1.71 Evaluation of small intestinal wall thickness. Left side images depict a bowel loop as seen end-on. Right side images depict the same bowel loop in profile (longitudinal). Radiographic appearance of small intestine is dependent on volume of gas and fluid in the lumen: **(A)** gas filled, **(B)** mostly gas filled, **(C)** mostly fluid filled, **(D)** fluid filled. Unless the bowel lumen is completely filled with gas, intestinal wall thickness cannot be accurately evaluated on survey radiographs. (Adapted from O'Brien 1981, 293. Special thanks to Dr. T. R. O'Brien.)

5. Large intestine contains variable amounts of gas, fluid, and fecal material.

a. Ingesta in colon (feces) typically is heterogeneous or granular-appearing soft tissue opacity with finely dispersed gas pattern.

b. Feces that is more voluminous or more opaque than normal suggests constipation or megacolon.

c. Diffuse, homogeneous soft tissue opacity in colon may represent fluid (diarrhea).

d. Persistence of a local soft tissue opacity in colon may represent a mass or intussusception.

6. Narrowing of pelvic canal by more than 50% frequently leads to colon obstruction.

Urinary tract

Kidneys and ureters

1. Kidneys are evaluated for number, size, shape, margination, position, and opacity (see Differential Diagnoses in chapter 6).

2. Normal appearance of kidneys does not rule out renal disease.

3. Size of kidneys:

a. Visualization of kidneys depends on amount of retroperitoneal fat:

1) Kidneys generally are more visible in cats and overweight dogs.

2) Superimposed intestinal content often obscures kidneys.

3) Right kidney lies in renal fossa of liver and generally is not well seen; caudal pole of right kidney may be visible.

b. Small kidneys result from hypoplasia or renal fibrosis:

1) May be difficult to identify, especially in animals with little body fat.

2) Dog kidneys measure less than 2.5 × length of L2.

3) Cat kidneys measure less than 2 × length of L2.

4) In cats, hypoplasia of kidneys may occur with early neutering.

c. Enlarged kidneys (renomegaly):

1) In dogs, length of kidney(s) is greater than 3.5 × length of L2.

2) In cats, length is greater than 3 × length of L2

a) Feline kidneys tend to enlarge in width more than in length, resulting in a more rounded appearance.

3) Enlarged kidney usually remains in dorsal abdominal cavity (retroperitoneal).

a) Right renomegaly displaces proximal duodenum, ascending colon, and small intestine cranially, ventrally, and to the left (Figure 1.72).

b) Left renomegaly displaces small intestine and proximal descending colon ventrally, caudally, and toward the right (Figure 1.73).

4) Renomegaly may be caused by inflammation, obstruction, infiltrative disease, or cystic disease (see lists of Differential Diagnoses, chapter 6).

5) Older, intact male cats commonly have slightly larger kidneys.

4. Shape of kidneys may be altered by obstruction, infiltrative disease, cystic disease, or inflammation (acute or chronic).

5. Abnormal position of kidneys may be congenital or due to mass effect.

a. Excessive retroperitoneal fat (obesity, lipoma) is a common cause of ventral and cranial displacement.

b. Loss of body wall integrity can affect position of kidney(s).

6. Abnormal opacity of kidneys:

a. Mineralization may occur with renal calculi or dystrophic calcification.

b. Fat in renal pelvis causes decreased opacity (common in overweight cats), which can be mistaken for pathology.

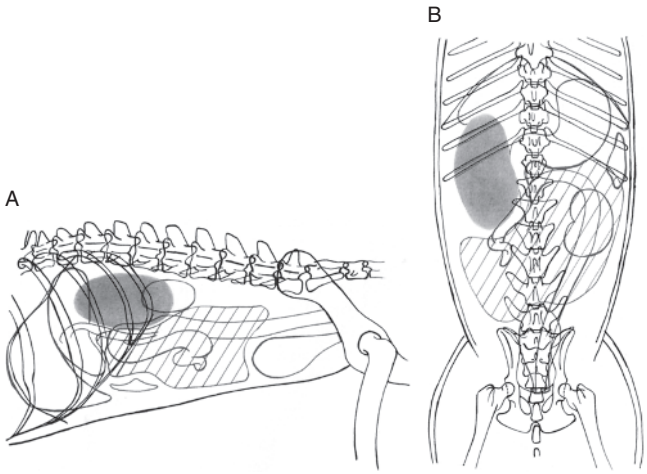


Figure 1.72 Right renomegaly (dark shading). **A.** Lateral radiograph; enlargement of right kidney may ventrally displace proximal duodenum, ascending colon, and small intestine (depending on degree of enlargement). **B.** VD radiograph; enlargement may medially displace ascending colon and small intestine. (Adapted from Owens and Biery 1999.)

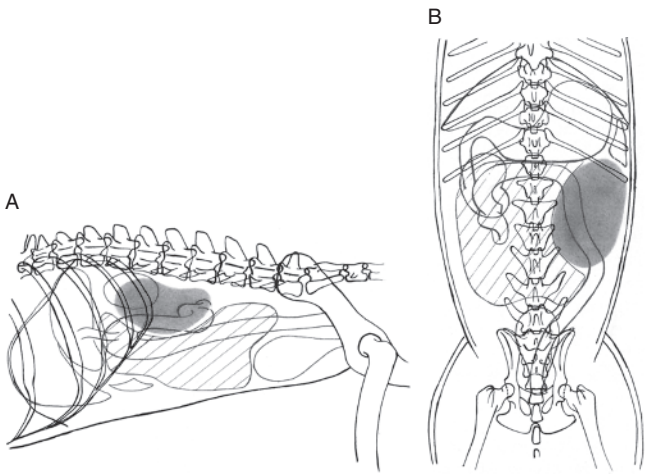


Figure 1.73 Left renomegaly (dark shading). **A.** Lateral radiograph; enlargement of left kidney may ventrally displace descending colon and small intestine. **B.** VD radiograph; enlargement may medially displace small intestine and descending colon. (Adapted from Owens and Biery 1999.)

Urinary bladder

1. Urinary bladder is evaluated for size, position, shape, margination, and opacity.

2. Abnormal size of urinary bladder is subjective assessment:

a. Full bladder normally does not extend cranial to level of umbilicus (Figure 1.74).

b. Overdistention of bladder may result from obstruction or neurologic disease.

c. Empty bladder sometimes is located within pelvic canal and may not be visible on survey radiographs.

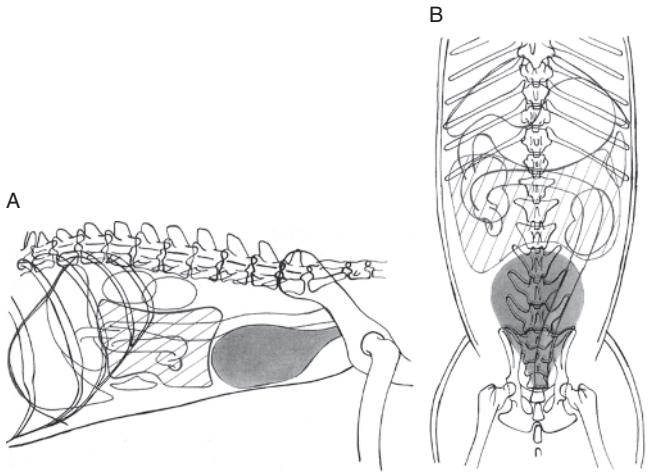


Figure 1.74 Distended urinary bladder (dark shading) commonly displaces small bowel cranially and descending colon dorsally. **A.** Lateral radiograph. **B.** VD radiograph. (Adapted from Owens and Biery 1999.)

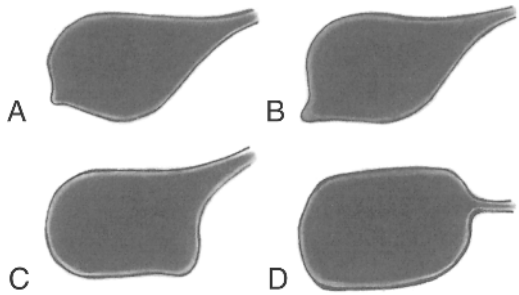


Figure 1.75 Abnormal shapes of urinary bladder. **(A)** Small urachal diverticulum in vertex. **(B)** Large urachal diverticulum in vertex. **(C)** Mucosal hernia along ventral margin. **(D)** Rounded shape due to inflammation or infiltrative disease (may also be a normal variant).

3. Altered position of urinary bladder usually results from pathology in a nearby structure.

a. In dogs, neck of bladder normally is less than 2 cm cranial to pubis.

b. In cats, bladder neck is longer (often confused with urethra), commonly extending up to 3 cm cranial to pubis.

4. Abnormal shape of urinary bladder may result from indentation by adjacent organ or mass, rupture, tumor, or diverticulum (Figure 1.75).

5. Bladder wall thickness cannot be reliably assessed on survey radiographs.

6. Abnormal opacity of urinary bladder:

a. Mineralization commonly represents calculi, but can be associated with neoplasia.

b. Gas in urinary bladder often is iatrogenic (e.g., cystocentesis, catheterization) but can be caused by infection

with gas-producing organism (emphysematous cystitis, usually associated with diabetes mellitus).

7. Contrast radiography is commonly used to evaluate urinary bladder (see chapter 3 for method):

- **a.** Excretory urogram.
- **b.** Positive contrast cystogram.
- **c.** Negative contrast cystogram (pneumocystogram).
- **d.** Double contrast cystogram.
- **e.** Positive contrast urethrogram (voiding or retrograde).

Urethra

1. Urethra usually is not visible on survey radiographs due to its small size and similar opacity to adjacent tissues.

2. Contrast radiography generally is required to assess urethral size, position, and integrity.

3. Urethral calculi (Figure 1.76) may be obscured by superimposed pelvic bones or pelvic limbs, requiring altered positioning of animal for visualization (see chapter 2, "Making Quality Radiographs").

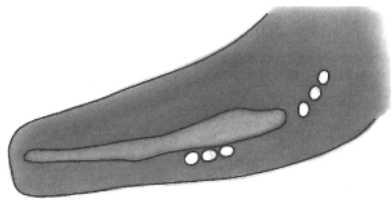


Figure 1.76 Penile urethra and os penis with urethral calculi (white; lateral radiograph). (From Owens and Biery 1999.)

Adrenal glands

1. Adrenal glands are not visible on radiographs unless greatly enlarged or mineralized.

2. Enlargement can be caused by tumor or hyperplasia.

- **a.** Adrenomegaly may displace a kidney caudally and/or medially.
- **b.** Adrenal masses can grow larger than a kidney and may be mistaken for a mass in another organ (i.e., splenic mass).

3. Mineralization of adrenal glands can occur with neoplasia but may be idiopathic:

- **a.** Neoplastic mineralization tends to be unilateral, ill-defined, and patchy.
- **b.** Idiopathic mineralization is age related and most often reported in cats.
  - **1)** Typically bilateral
  - **2)** Appears as small, well-defined, mineral opacities, sometimes dumbbell shaped.

Male genital system (prostate gland)

1. Prostate gland is evaluated for size, shape, margination, and opacity.

2. Abnormal size of prostate gland:

- **a.** Prostatomegaly occurs to some degree in most prostatic diseases (Figures 1.77 and 1.78).
  - **1)** Easiest to recognize on lateral radiographs.
  - **2)** Normal height of prostate gland should not exceed 70% of diameter of pelvic inlet.
    - **a)** Greater than 70% is abnormal enlargement.
    - **b)** Greater than 90% suggests a mass.
  - **3)** Enlarged prostate may be displaced cranially into abdominal cavity.

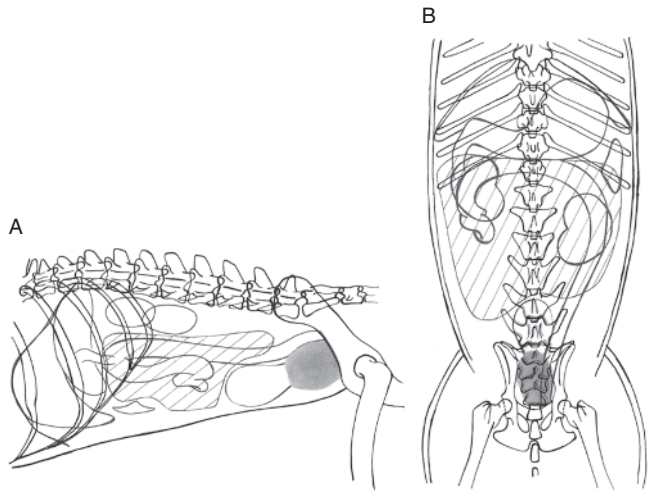


Figure 1.77 Prostatomegaly (dark shading). **A.** Lateral radiograph; enlargement of prostate gland displaces urinary bladder cranially and descending colon dorsally. **B.** VD radiograph; prostate is visible cranial to brim of pelvis through pelvic canal. (From Owens and Biery 1999.)

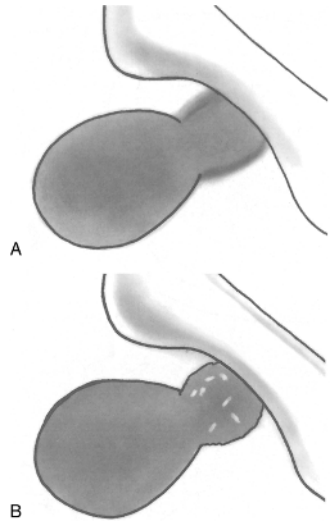


Figure 1.78 Prostatomegaly (close up lateral radiograph). **(A)** Enlarged prostate gland with ill-defined margins is caused by inflammation due to infection or neoplasia. **(B)** Prostatomegaly with focal mineralization most commonly is caused by neoplasia but may result from chronic inflammation or benign hypertrophy and calculi. (From Owens and Biery 1999.)

4) Typically causes cranial displacement of urinary bladder and dorsal displacement of rectum (urinary bladder can be displaced dorsally, ventrally, or laterally if there is asymmetric prostatomegaly).

b. Opacity of prostate gland:

1) Mineralization most often is due to neoplasia but can result from chronic inflammation or presence of calculi.

2) Gas in prostate may result from reflux during pneumocystogram or infection with gas-producing organism.

3. Diseases of testicles, scrotum, and penis are better evaluated by clinical inspection and ultrasonography than with radiography.

Female genital system

1. Ovaries normally are not visible on survey radiographs.

a. Area of ovaries is examined for mass effect or change in opacity.

2. Uterus is evaluated for size, position, and opacity:

a. Size of uterus varies with age, body size, and previous pregnancies.

1) Normal, nongravid uterus is less than 1.5 cm wide and rarely visible on survey radiographs.

2) Mild uterine enlargement is difficult to distinguish from nearby small intestine:

a) Uterine width must be at least twice that of small bowel to be reliably detected.

3) In obese animals, uterine body sometimes is visible as a linear soft tissue opacity between rectum and urinary bladder (lateral radiograph).

4) Enlarged uterine horns commonly produce convoluted, tubular, soft tissue opacity structures in caudoventral abdominal cavity:

a) On lateral radiograph, uterine horns typically are dorsal and cranial to urinary bladder and displace small intestine cranially and dorsally (Figure 1.79).

b) On VD/DV radiograph, an enlarged uterine horn may resemble a kidney.

b. Abnormal location of uterus may result from hernia or mass effect.

c. Alterations in uterine opacity may be due to normal or abnormal pregnancy, infection, or tumor.

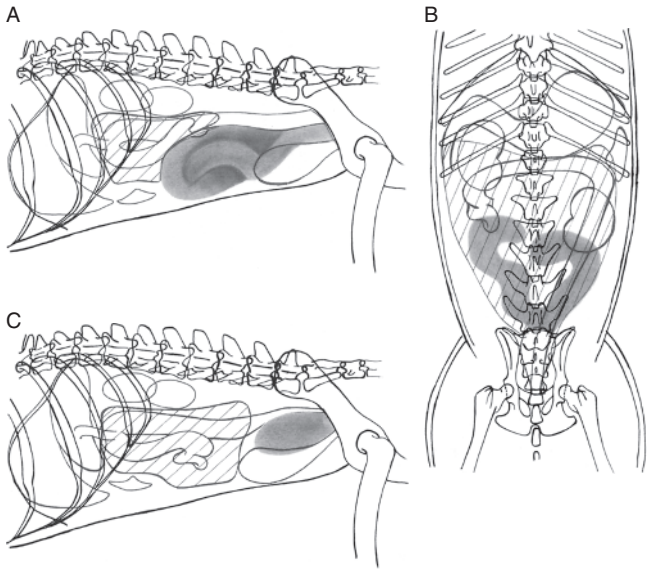


Figure 1.79 Enlargement of uterus (dark shading). **A.** Lateral radiograph; uterus is partially superimposed over urinary bladder and displaces small intestine cranially. **B.** VD radiograph; uterus in caudal abdominal cavity, superimposed over or displacing small bowel. **C.** Lateral radiograph; a cervical mass displacing urinary bladder ventrally and descending colon dorsally. (From Owens and Biery 1999.)