Abstract

Radiography is one of the foremost diagnostic tools for orthopedic conditions in small animal medicine. However, gaining efficiency and accuracy in obtaining images can take many years. Orthopedic radiographs require great precision to be useful in a perioperative setting, and a comprehensive guide may be necessary in many veterinary clinics/hospitals. Patient positioning, collimation, appropriate positioning of a calibration marker, and knowledge of orthopedic landmarks are important factors in obtaining orthopedic radiographs. This guide focuses on the pelvic limbs and shows positioning for each view.

RADIOLOGY/IMAGING

A Positioning Guide to Orthopedic Radiography of the Pelvic Limb

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Since its inception in the 1920s, radiography has become one of the most common diagnostic tools in veterinary medicine.[1] When orthopedic injury or disease is suspected following physical examination, radiography is often the first tool used to determine a definitive diagnosis. However, despite its crucial role and frequent use, mastering the skill of obtaining appropriately positioned orthopedic radiographs can take years of practice.

Although radiography can be used to image any orthopedic anatomy, this article focuses on positioning of the pelvic limbs. These tips are useful options for patients with many common orthopedic conditions, such as cranial cruciate ligament disease, patellar luxation, and hip dysplasia. Specialized hip dysplasia monitoring series, such as the University of Pennsylvania Hip Improvement Program, require extensive training to achieve proficiency and are beyond the scope of this article.

RADIOGRAPHIC TECHNIQUE

Appropriate technique (e.g., exposure settings) and positioning are important for producing diagnostic-quality images while minimizing errors. Exposure relies on kilovoltage peak (kVp) and milliampere-seconds (mAs). Together, these 2 factors affect the quality and sharpness of the image. Imaging of soft tissue anatomy typically uses a higher kVp and lower mAs. For orthopedic imaging, a lower kVp and higher mAs are typically more beneficial.

At least 2 orthogonal views of the affected limb should be performed. For more complicated

Take-Home Points

- Orthopedic radiographs require at least 2 orthogonal views to be effective. It can be useful to obtain 2 orthogonal views of the contralateral limb for comparison.
- A calibration marker at the appropriate position is necessary for perioperative planning.
- Anatomical knowledge of long bones is needed to prevent image distortion during imaging.
- Use of chemical and mechanical restraint allows for decreased staff radiation exposure, increases ability to make patient positioning adjustments, and is advantageous to the patient's overall wellbeing.
- Knowledge of orthopedic landmarks is necessary to identify appropriate positioning and image evaluation.
- Stressed views must be labeled appropriately to ensure accurate diagnosis of tarsal joint instability.

orthopedic disease processes, radiographs of the contralateral limb may be indicated. When contralateral images are obtained, positioning should be identical to the affected limb to provide an accurate basis for comparison. Likewise, any following radiographic series or postoperative recheck radiographs for the affected limb should use the same positioning. Consistent, accurate positioning and orientation allow for easier interpretation of images to increase the likelihood of finding abnormalities or healing complications. When surgical intervention is indicated, postoperative radiographs should be taken immediately after surgery to confirm reduction, implant placement, and alignment using the same positioning.[2]

Common Errors

A study performed in human medicine showed that 84% of repeated radiographs were due to positioning errors.[3] Positioning errors can create several effects that result in nondiagnostic radiographs. Distortion and magnification are the most common of these effects.

Distortion is caused when the bone is not parallel to the exposure cassette and can present as elongation or foreshortening of the whole image or part of the image. Distortion can be prevented with anatomical knowledge of the bones being radiographed.

Magnification refers to the difference in size between imaged and actual anatomy caused by the distance of the anatomy from the radiation capture cassette. Magnification naturally occurs in radiographs at a rate of 1% of magnification for every 10 mm of distance between the anatomy and the capture cassette during radiation exposure.[4,5] Magnification can be accounted and corrected for through the use of a calibration marker placed parallel to the capture plate and adjacent to, and at the same vertical level as, the anatomy being imaged. Most long bones have a landmark that can be used for the calibration marker to ensure identical placement each time the same positioning is utilized. Deviations in height or plane will skew the calibration marker's effectiveness. If the disease or injury warrants surgical intervention, a calibration marker assists with perioperative planning.

Motion is another common error when taking radiographs. Motion can hide or mask minute disease processes or trauma and can directly affect measurements. In addition, patients struggling against restraint can exacerbate orthopedic injuries, causing

GLOSSARY

Calibration marker An item that represents a known length (100-mm cylinder) or diameter (25.4-mm ball bearing) used during radiography to assist with correction of magnification of the anatomy in the final image

Caudocranial view A radiographic view in which the x-ray beam passes caudal to cranial through the desired limb

Collimation Limitation of the x-ray beam to the desired area of interest to reduce scatter radiation

Contralateral Relating to the opposite side of the body (e.g., if a patient sustained a fracture of the right femur, the contralateral area would be the left femur)

Craniocaudal view A radiographic view in which the x-ray beam passes cranial to caudal through the desired limb

Kilovoltage peak (kVp) Energy and strength of the x-ray beam

Lateral view A radiographic view in which the x-ray beam is moving medial to lateral through the desired object (e.g., nomenclature dictates that a right lateral femur view would have the patient in right lateral recumbency)

Milliamperage (mA) Current passing through the x-ray machine

Milliampere-seconds (mAs) Amount of radiation produced over a set amount of time

Orthogonal Projection made at a 90° angle from the original view (e.g., right lateral and craniocaudal views)

Valgus A skeletal deformity characterized by a lateral (outward) turn of the distal limb

Varus A skeletal deformity characterized by a medial (inward) turn of the distal limb

Ventrodorsal view A radiographic view in which the x-ray beam passes ventral to dorsal through the desired limb

BOX 1

Fundamentals of Radiation Safety

While radiography is a useful diagnostic tool, exposure of patients and radiographers to ionizing radiation means that it is not benign. Following the ALARA (as low as reasonably achievable) principle, a radiographic examination should be limited to as few exposures as possible and radiographers should wear appropriate personal protective equipment (PPE) if they must be present during exposure.

At minimum, radiographic PPE should include a protective apron, a thyroid shield, gloves, and glasses (all made with lead or other appropriate material) to prevent direct exposure, plus a radiation dosimeter.

To ensure these safety standards, radiographers should be familiar with the basic equipment and terminology associated with radiographic examinations prior to performing an exam. Additionally, radiographers can maintain the ALARA principle while achieving useful radiographic images by understanding proper anatomical positioning and exposure setting techniques, how to use anatomic identification and magnification markers, how to minimize technical errors, and how to use hands-free (passive restraint) radiography practices.

further damage and discomfort. Motion can be minimized or prevented with appropriate patient restraint. Hands-free restraint using passive or chemical methods helps reduce radiation exposure to staff. Passive restraint includes tape, ties, sandbags, and other restraining devices. Chemical restraint, when determined safe by the veterinarian, allows for the added benefit of analgesia in trauma patients and further prevents motion artifact. A combination of dexmedetomidine (4 µg/kg) and butorphanol (0.1 mg/kg) can be safely used for chemical restraint in most dogs and cats.[6,7] When manual restraint is necessary, staff should wear appropriate personal protective equipment, including a lead apron, thyroid shield, gloves, and glasses (**BOX 1**).[2]

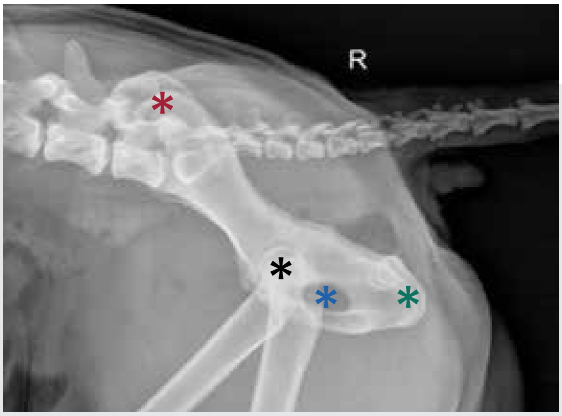

FIGURE 1. Right lateral view of the canine pelvis. The iliac wings **(red asterisk)**, femoral heads **(black asterisk)**, obturator foramens **(blue asterisk)**, and ischial tuberosities **(green asterisk)** are all superimposed. The left ilium is larger than the right due to magnification.

Labeling

Appropriate labeling is necessary to enable accurate interpretation of radiographs. Using physical right and left markers during the imaging process, rather than adding digital display markers after the fact, can prevent mislabeling or misidentification of the anatomy in the image and may reduce the risk of mistakes during the diagnosis and treatment process. Positional terminology (e.g., medial/lateral, cranial/caudal, dorsal/palmar) should be used in relation to the direction of the x-ray beam. Obliqued or stressed radiographs should be labeled with the obliqued direction and which area stress was applied to, respectively.

POSITIONING

Pelvic Radiography

Pelvic radiographs most often comprise 2 views: a right lateral view and a ventrodorsal view. Occasionally, the splay-leg ventrodorsal, or frog-legged, view is needed.

The right lateral view shows the iliac wings superimposed, with the left ilium larger than the right due to magnification (**FIGURE 1**). The femoral heads, obturator foramens, and ischial tuberosities should all be superimposed.

The ventrodorsal view requires the patient to be positioned in dorsal recumbency with the entire pelvis laying parallel to the table (**FIGURE 2A**). The limbs should be pulled caudally and rotated internally. Tape should be applied over the stifle joints and adhered to the table to maintain internal rotation and consistent anatomic distance from the capture plate. The radiographic image should reflect the femurs running parallel to each other with the patellas sitting squarely in the femoral trochlea bordered by the femoral condyles (**FIGURE 2B**). The obturator foramens should be identical in size with the spine running through the middle. The calibration marker should sit adjacent to the point of the greater trochanter of the femur. Collimation should extend to include the iliac crests and stifle joints.

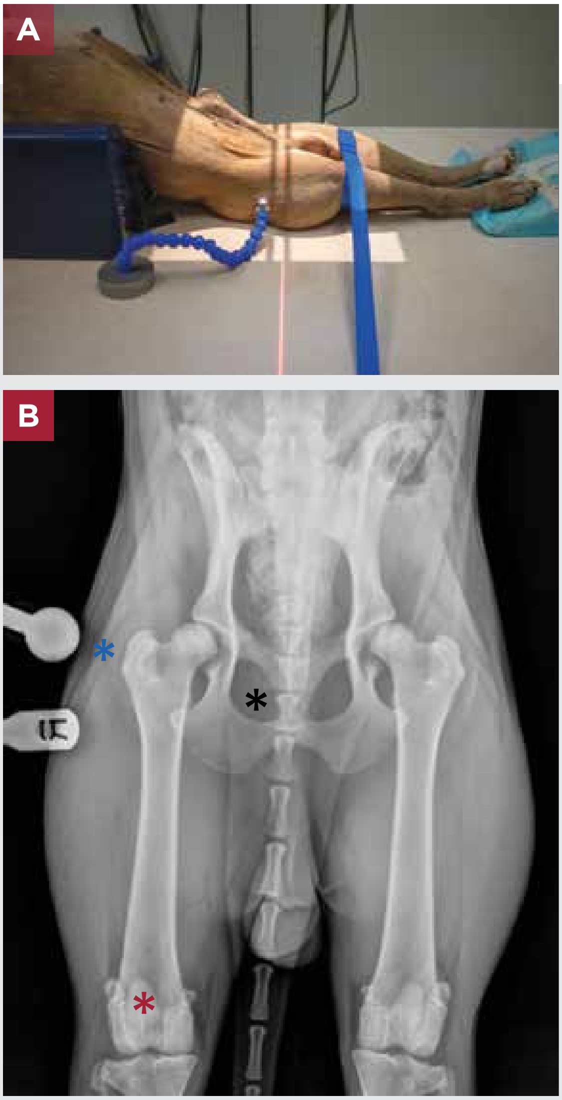

FIGURE 2. Ventrodorsal view of the pelvis. **(A)** The patient is in dorsal recumbency with the pelvis parallel to the table. The pelvic limbs are extended and rotated internally and restrained with tape. **(B)** Image with the femurs parallel to each other with the patella sitting in the femoral condyles **(red asterisk)** and the obturator foramens **(black asterisk)** identical in size. The calibration marker is at the level of the greater trochanter **(blue asterisk)**.

The frog-legged view is a variation of the ventrodorsal view. The patient should be positioned similar to the standard ventrodorsal view, with the exception that the femurs should be abducted laterally (**FIGURE 3A**). The radiographic image should reflect a view of the femurs held perpendicular to the pelvis (**FIGURE 3B**). The collimation marker should be placed at the level of the right ischial tuberosity.

Femoral Radiography

Femoral radiography includes lateral and craniocaudal views of the affected limb. The lateral view requires the unaffected limb to be restrained dorsally to allow an

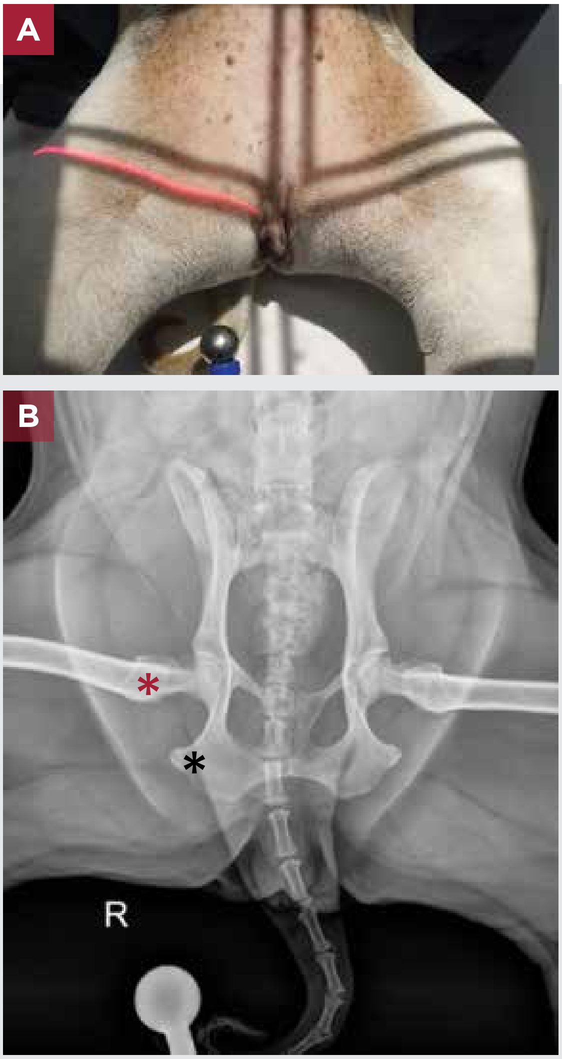

FIGURE 3. Frog-legged view of the pelvis. **(A)** The patient is in dorsal recumbency with the pelvis parallel to the table. The pelvic limbs are abducted laterally. **(B)** Image with the femurs horizontal **(red asterisk)**. The calibration marker is at the level of the ischial tuberosity **(black asterisk)**.

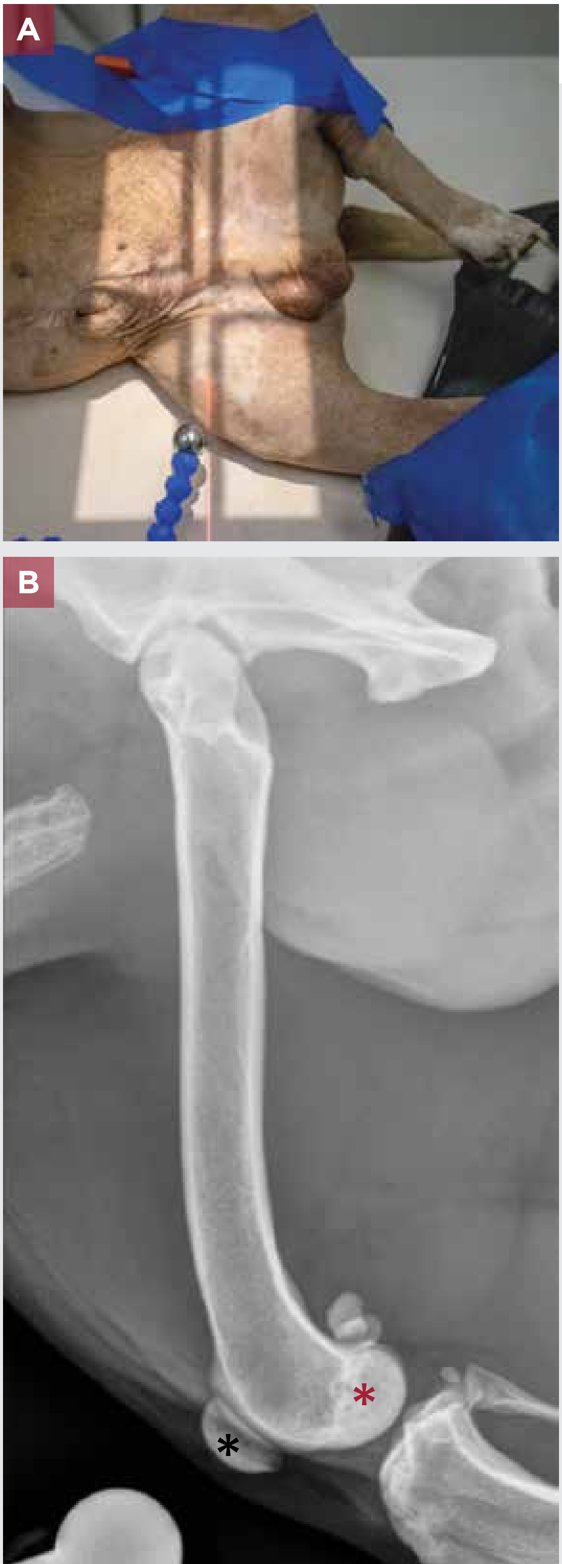

FIGURE 4. Lateral view of the femur. **(A)** The patient is in lateral recumbency with the unaffected limb restrained dorsally with tape. **(B)** Image with the central axis vertical. The femoral condyles **(red asterisk)** are superimposed and the calibration marker is positioned at the level of the patella **(black asterisk)**.

unobstructed view of the desired femur (**FIGURE 4A**). Tape can be applied to the limb and held in place against a weight. For obese patients, a foam wedge placed under the thorax can help rotate the limb further back. The radiographic image should show the central axis of the femur to be vertical and the femoral condyles superimposed (**FIGURE 4B**). The calibration marker should be positioned adjacent to, and at the level of, the patella.

Although the craniocaudal view is easier to obtain with a mobile x-ray unit, it can be accomplished with a fixed unit. In practices with a fixed unit, the craniocaudal view can be obtained in 2 different ways. The first requires manual restraint with the patient positioned in inclined dorsal recumbency, typically using a large wedge (**FIGURE 5A**). The affected limb is fully extended. The second option has the patient positioned in ventral recumbency (**FIGURE 5B**). The affected limb is fully extended and elevated under the stifle joint to allow the femur to be completely parallel to the film.

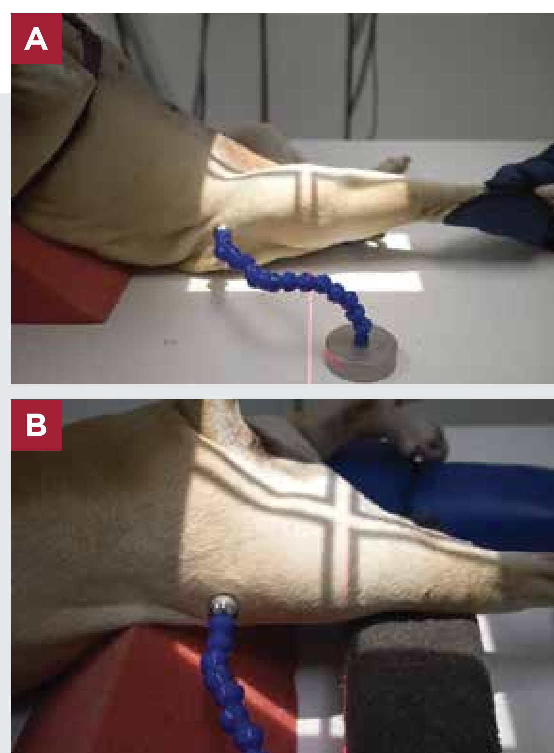

FIGURE 5. Craniocaudal view of the femur using a fixed unit. **(A)** The patient is in inclined dorsal recumbency. The affected limb is fully extended. Manual restraint is used while staff wear appropriate personal protective equipment. **(B)** The patient is in ventral recumbency. The affected limb is fully extended and elevated to ensure the femur is parallel to the film.

If a mobile unit is available, the patient is positioned in lateral recumbency with the affected limb on top (**FIGURE 6A**). The affected limb is pulled so that the femur is parallel to the film cassette. The resulting image should have the central axis of the femur vertical with the patella sitting squarely in the femoral trochlea bordered by the femoral condyles (**FIGURE 6B**). The proximal aspect of the femur (femoral head and greater trochanter) should be close in width to the distal aspect of the femur (lateral and medial condyles). If 1 aspect is visibly larger than the other, the femur needs to be repositioned to be parallel to the film. The calibration marker sits at the level of the greater trochanter.

Stifle Radiography

Stifle radiography studies often include the entire tibia (not just the joint), and in many practices, stifle radiography is considered interchangeable with radiography of the entire tibia. Stifle radiography includes lateral and caudocranial views. Both views require the distal aspect of the femur and the tarsus in the collimation.

Stifle radiography studies often include the entire tibia (not just the joint), and in many practices, stifle radiography is considered interchangeable with radiography of the entire tibia.

The lateral view requires the unaffected limb to be restrained craniodorsally with a tie or tape (**FIGURE 7A**). This view should reflect the central axis of the tibia vertical on the radiographic image, with the femoral condyles superimposed (**FIGURE 7B**). The central axis of the femur and tarsus should be horizontal, creating 90° angles in both the stifle and tibiotarsal joints. The calibration marker should be positioned adjacent to, and at the level of, the patella. In patients with cranial cruciate ligament disease for which tibial tuberosity advancement surgery is being considered, the angle of the stifle joint should be roughly 135° instead of 90°.

FIGURE 6. Craniocaudal view of the femur using a mobile x-ray unit. **(A)** The patient is in lateral recumbency. The affected limb is on top, fully extended, and restrained with tape and sandbags. **(B)** Image with the central axis of the femur vertical and the patella **(red asterisk)** between the femoral condyles. The width of the proximal end of the femur **(green asterisk)** should be similar to the width of the distal end of the femur **(black asterisk)**. The calibration marker sits at the level of the greater trochanter **(blue asterisk)**.

FIGURE 7. Lateral view of the stifle/tibia. **(A)** The patient is in lateral recumbency. The unaffected limb is restrained craniodorsally. The affected limb is restrained with tape and a weight is used to create right angles in the stifle and tibiotarsal joints. **(B)** Image with the femoral condyles **(red asterisk)** superimposed. The angles of the stifle joint **(blue asterisk)** and tibiotarsal joints **(yellow asterisk)** are 90°. The calibration marker is at the level of the patella **(white asterisk)**.

FIGURE 8. Caudocranial view of the stifle/tibia. **(A)** The patient is in sternal recumbency with the affected limb fully extended and restrained with a sandbag. The unaffected limb has been elevated with a foam block. **(B)** Image with the patella **(red asterisk)** between the femoral condyles and the medial aspect of the calcaneus **(blue asterisk)** in the middle of the tibiotarsal joint.

FIGURE 9. Lateral view of the tarsus. **(A)** The patient is in lateral recumbency with the affected limb flexed to produce a 90° angle in the tibiotarsal joint. Foam and a sandbag weight are used to assist with phalangeal positioning. **(B)** Image with the calcaneus **(red asterisk)** and metatarsals **(black asterisk)** vertical. The tibia is horizontal with a 90° angle at the tibiotarsal joint **(yellow asterisk)**. Digits 2 and 5 **(green asterisk)** are superimposed, as are digits 3 and 4 **(blue asterisk)**. The calibration marker is at the level of the calcaneus.

FIGURE 10. Caudocranial view of the tarsus. **(A)** The patient is in sternal recumbency with the affected limb fully extended. Collimation includes the distal tibia and the entire paw. **(B)** Image with the medial aspect of the calcaneus **(red asterisk)** in the middle of the tibiotarsal joint. The metatarsals **(black asterisk)** are vertical. A crooked phalange **(blue asterisk)** is present and is likely an incidental finding. The calibration marker is at the level of the calcaneus.

FIGURE 11. Lateral stress (valgus-stressed) view of the tarsus. **(A)** Tape has been applied to the distal tibia and the metatarsals. The tape is pulled to open the medial aspect of the tarsal joint. **(B)** Image with the stress from the tape opening the medial aspect of the joint.

For the caudocranial view, the patient should be in sternal recumbency with the affected limb fully extended (**FIGURE 8A**). The unaffected limb should be elevated to allow the affected limb to rest on the patella. If the patient has a long tail, it can be tucked under the unaffected limb. The image should reflect the patella squarely between the femoral condyles and the central axis of the tibia positioned vertically (**FIGURE 8B**). The medial aspect of the calcaneus should be aligned with the center of the tibiotarsal joint.

Tarsal Radiography

Tarsal radiography should include lateral and caudocranial views. When both tarsi are affected, each tarsus should be imaged separately. Collimation for all tarsal views should include the distal aspect of the tibia and the entirety of the digits.

Positioning of the lateral view requires the unaffected limb to be restrained craniodorsally with a tie and the affected limb extended caudoventrally with tape (**FIGURE 9A**). Foam can be used with a weight or sandbag to provide pressure against the paw to create a neutral, weight-bearing stance. The radiographic image should represent the calcaneus and metatarsals in a vertical position with the tibia horizontal, creating a 90° angle at the tibiotarsal joint (**FIGURE 9B**). Digits 2 and 5 and digits 3 and 4 are superimposed, respectively. The calibration marker should be placed at the level of the calcaneus.

The caudocranial view requires the patient in sternal recumbency with the affected limb fully extended (**FIGURE 10A**). The radiographic image should reflect the medial aspect of the calcaneus aligned with the center of the tibiotarsal joint, with the metatarsals

FIGURE 12. Medial stress (varus-stressed) view of the caudocranial tarsus. **(A)** Tape has been applied to the distal tibia and the metatarsals. The tape is pulled to open the lateral aspect of the tarsal joint. **(B)** Image with the stress from the tape opening the lateral aspect of the joint.

pictured vertically (**FIGURE 10B**). Crooked phalanges are common and may be incidental findings. The calibration marker should be placed at the level of the calcaneus.

Due to the nature of tarsal injuries, stressed views are commonly needed and must be labeled appropriately to enable accurate diagnosis. Lateral and medial stress views for the tarsus are performed in the caudocranial position.

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For a lateral stress (i.e., valgus-stressed) view, tape should be applied to the distal aspect of the tibia, with the tail of the tape extending medially (**FIGURE 11A**). Tape should then be applied to the metatarsals, with the tail of the tape extending laterally. The 2 tape tails should then be pulled in their respective directions, allowing an opening on the medial aspect of the joint to be seen on the image (**FIGURE 11B**).

For a medial stress (i.e., varus-stressed) view, tape should be applied to the same locations, with the tape over the distal tibia extending laterally and the tape over the metatarsals extending medially (**FIGURE 12A**). Again, the tape tails are pulled in their respective directions. An opening on the lateral aspect of the joint can be seen on the resulting radiographic image (**FIGURE 12B**).

Digit Radiography

Radiography of the digits includes lateral and craniocaudal views, and positioning is very similar to that for tarsus radiography. A splayed lateral view is common to help separate the digits. For this view, the patient is positioned in lateral recumbency. Tape should be applied to the nail of digit 5 and pulled cranially while tape should be applied to the nail of digit 2 and pulled caudally (**FIGURE 13A**). Often, tape needs to be applied proximally to the metatarsophalangeal joints to prevent the digits slipping into an obliqued view. The resulting radiographic image allows evaluation of the individual digits (**FIGURE 13B**). The calibration marker should be placed at the level of the affected digit.

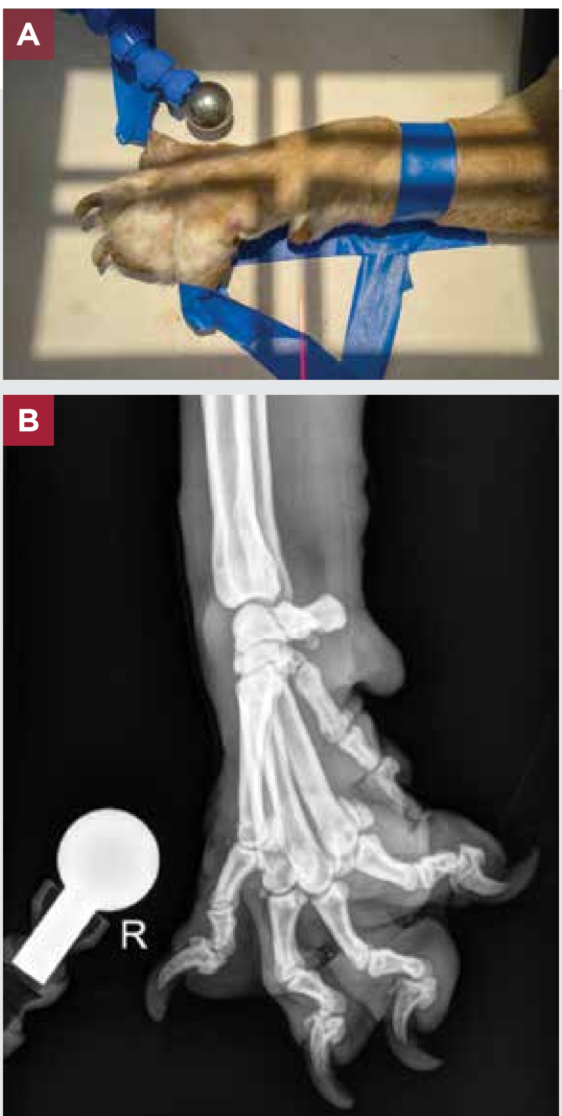

FIGURE 13. Splayed lateral view of the digits. The right thoracic paw is shown, but the positioning is the same for the pelvic limbs. **(A)** The patient is in lateral recumbency. Tape is used to splay the digits apart. **(B)** Image with the digits separated for evaluation. The calibration marker is at the level of the affected digit.

SUMMARY

Becoming skilled at orthopedic radiography requires knowledge of radiography techniques, orthopedic landmarks, and a lot of practice. Despite standard anatomy, variation in patient size and shape calls for critical thinking when positioning a patient appropriately for a specific orthopedic radiograph. However, with a strong understanding of the fundamentals of radiography, a radiographer should be able to find a solution to any imaging challenges. **TVN**

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