Diagnostic imaging of orthopaedic problems in small animals: a practical guide

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Author's Profile

Henri van Bree graduated in 1974 from Ghent University in Belgium. Since 1991 he has been a full professor in medical imaging and orthopaedic surgery at the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, University of Ghent, Belgium, and since 2001, the head of the Department of Medical Imaging and Small Animal Orthopaedics. Professor. Dr. van Bree gained his PhD at the University of Utrecht, Holland, Department of Radiology on "Comparative imaging in the canine shoulder". He is a Diplomate of both the European College of Veterinary Diagnostic Imaging (ECVDI) and the European College of Veterinary Surgeons (ECVS) and the author of about 250 publications on medical imaging and orthopaedics. Professor. Dr. van Bree has been an invited speaker at about 150 international conferences on medical imaging and small animal arthroscopy and his research topic is comparative imaging in small animal joint disease.

Introduction

The history of musculoskeletal imaging begins with Roentgen's discovery of X-rays in 1895. Plain radiography has since become the initial, and in many cases, the only imaging modality for the diagnosis and follow up of joint abnormalities. Over the years, however, radiologists and orthopaedic surgeons became aware of the importance of the diagnosis of not only bony conditions but also of a diverse variety of soft-tissue conditions. However, we must be on guard against imaging complacency. The 'perfect' imaging protocol does not exist because imaging parameters will be both patient and disease specific. When assessing image quality, we must consider both contrast resolution and spatial resolution. Contrast resolution refers to the ability to distinguish different normal tissues and normal from abnormal tissue. Spatial resolution refers to the ability to depict and distinguish small objects that are in close proximity.

In humans, musculoskeletal imaging utilising arthrography, scintigraphy, computerised tomography (CT), magnetic resonance imaging (MRI), ultrasound (US) and arthroscopy are used on a daily basis. In veterinary orthopaedics, plain radiography was the routine imaging technique for both diagnostic and follow-up purposes, for decades, and is still routinely used as a common practice. However, more and more, the veterinary profession has access to increasingly sophisticated technology like CT and MRI. Also arthroscopy has become interesting for veterinary orthopaedic surgeons for the diagnosis and treatment of several joint diseases and has become a routine procedure in several orthopaedic clinics. All these imaging techniques have their merits but also their limits (see table 1 at the end of this text).

Scintigraphy

Skeletal scintigraphy is a commonly performed imaging procedure in veterinary medicine mostly in large animal orthopaedics. Whereas conventional techniques like radiography are excellent methods to investigate morphologic changes in bones, radionuclide techniques provide information regarding the metabolic function of the skeleton. The advantages of skeletal scintigraphy are its high sensitivity for detecting early disease and the ease of surveying the entire skeleton. Scintigraphy is a useful technique to localise the cause of obscure lameness or in cases of uncertain radiographic findings. Although it is very sensitive, it is not very specific. Radiography, on the other hand, is less sensitive but more specific. Also the spatial resolution offered by scintigraphy is not well enough to specify anatomic structures. The main drawback to joint imaging using 99mTechnicium-labeled phosphates is the normal uptake at the end of long bones, especially in immature animals (fig 1). This means that in some instances it is difficult to determine whether a difference in counts between two joints represents a meaningful finding. However, comparison of bilateral images, acquired at the same time, and quantitative analysis of joint images by computer, can provide diagnostic guidelines.

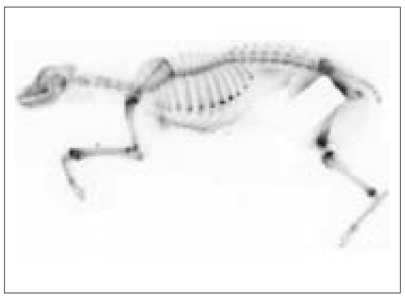

Figure 1. Scintigraphic survey of the skeleton of an immature animal: Notice the uptake at the end of all long bones which is a normal finding. Although the contours of the different bones can be determined, the spatial resolution offered is not well enough to specify anatomic structures.

Conventional radiography

Conventional radiography is an excellent imaging technique for imaging bony structures but is a poor method for imaging soft tissue structures. It displays a greater spatial resolution than either MRI or CT. The disadvantage is that the two-dimensional display of three-dimensional structures results in superimposition that can obscure important findings. Details that can be derived from plain radiographs include information on the size, contour, density, and location of changes that are present in or around a joint. The areas that can be evaluated include the subchondral bone plate, trabecular subchondral bone, articular margins, and areas where ligaments, tendons, and the joint capsule attach. In people, and horses, joint space narrowing has been a well-accepted indicator of articular cartilage degeneration and is considered as a cardinal radiographic feature of disease. In small animals the loss of joint space is not a reliable sign as the radiographs are taken non-weight-bearing.

Individual soft tissue structures are not visualised as easily as the bony structures unless they are bordered by fat (for example, in facial planes or in the cranial aspect of the stifle) (fig 2). Indirect information on articular soft tissues structures can be present in cases of calcification within these structures, mostly a sign of degeneration but can also sometimes be an incidental finding. Sometimes the delineation of the attachment of tendinous structures can be irregular as can be observed in cases of some biceps problems. Also, using stress radiographs, indirect evidence of an articular ligament rupture can be obtained, the most obvious example being a cranial cruciate ligament rupture shown by tibial compression radiographs of the affected knee joint (fig 2).

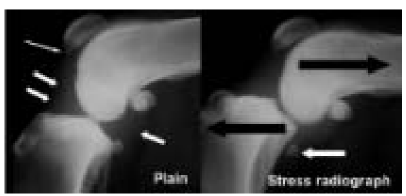

Figure 2. Plain (left image) and stress radiograph (right image) of a stifle joint with a ruptured cranial cruciate ligament (CCL): on the plain radiograph new bone formation, as there is on the distal end of the patella, is visible (thin white arrow), also joint effusions can be appreciated (thick white arrows): on the stress radiograph a caudal displacement of the femur relative to the tibia is seen. Distal displacement of the popliteal muscle's sesamoid bone (white arrow) is a sign of CCL disease and can also be seen in this stress view.

Arthrography

Arthrography is seldom used in small animal orthopaedics but is an interesting and simple technique readily available to most veterinarians. Although probably not as accurate as the newer imaging techniques (arthroscopy, MRI, and ultrasound), it provides information on intra-articular structures not seen on survey radiographs. Within the shoulder joint, articular cartilage, biceps tendon, the extent of the joint capsule, and the synovial surface outline can all be roughly visualised on arthrograms. One to 4 ml of preferably a non-ionic, low osmolar contrast medium, has to be injected intra-articularly. Exposures have to be made within 5 minutes post-injection because of the rapid absorption of the contrast medium by the synovial membrane. Cartilage fissuring and fragmentation, such as occurs with osteochondritis dissecans (OCD) can be demonstrated and identified as contrast material infiltrates beneath the articular cartilage (fig 3). A distinction can be made between clinical and non-clinical lesions and this can help in making therapeutic decisions. Synovial proliferation may be demonstrated as a thick, irregular synovial outline or as a small filling defect within the joint capsule. Finally, arthrography can be used to visualise joint mice and can also help in the diagnosis of bicipital tendon problems.

Figure 3. An example of an arthrogram of a dog's shoulder with osteochondritis dissecans (OCD): notice contrast material infiltrating beneath the articular cartilage outlining a cartilage flap (black arrows) which was invisible on the plain radiograph.

Computerised tomography (CT)

Computerised tomography (CT) has several advantages over plain radiography. It is a cross-sectional imaging technique using x-rays and computers. Better soft-tissue differentiation and absence of superimposition are the major advantages of CT over conventional x-ray techniques. CT enables more detailed and specific morphological diagnosis than radiography. CT greatly facilitates examining complex joint structures like the elbow and tarsus. Another advantage is that the transverse CT images can be reformatted in multiple anatomic planes. Although the spatial resolution of CT images is poorer when compared with classical film-screen radiography, the cross-sectional image display and superior discrimination of tissue attenuation offered by CT enables differentiation of soft tissue structures that can not be perceived on conventional radiographs. Subtle new bone formation and bone lysis are better identified on CT images when compared with conventional radiography because of their greater physical density discrimination, the ability to manipulate the grey scale of the digital image, and the elimination of overlying structures. CT has been proved to be superior in the diagnosis of a fragmented coronoid process (FCP) of the elbow joint (fig 4). Its use in the diagnosis of elbow incongruity has also been reported.

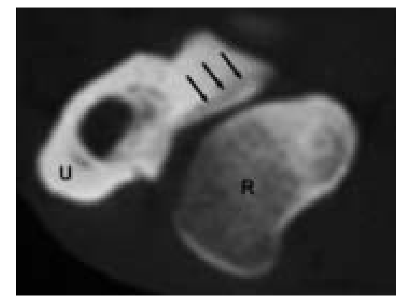

Figure 4. A CT image of a dogs elbow with a fragmented coronoid process (FCP) which was not visible on the corresponding radiograph: notice a fissure line (black arrows) and subchondral sclerosis in the area of the medial coronoid process. The fragment is squeezed in between the radius (R) and the ulna (U).

In tarsocrural OCD, CT is superior in the diagnosis of lateral ridge involvement. In medial tarsocrural OCD, CT allows to assess the exact localisation, and the size and number of the fragments. It helps in decision making when using minimal surgical exposure techniques to treat these lesions. In the treatment of hip dysplasia it can be used to check the status of the dorsal acetabular rim which is an important criterion when triple pelvic osteotomy (TPO) is considered.

In cases where treatment of bone tumours is considered, CT enables a more exact demarcation of the affected tissue and helps to decide to what extent the tumour has to be excised. And finally, degenerative joint changes can be identified at an earlier stage than on conventional radiographs.

The disadvantages of CT are the need for general anaesthesia and the cost for maintaining the equipment.

Magnetic resonance imaging (MRI)

MRI has definite advantages over CT in delineating peri-articular and intra-articular soft tissue structures. When a patient is placed in a strong magnetic field and subjected to short pulses of radio frequency energy, radio signals can be elicited from the patient's body. These signals can be compiled into images that reveal certain characteristics of body tissues. MRI is a very useful imaging method because it can detect several tissue characteristics and combine the resulting signals in different ways to yield images with a variety of appearances. Unlike other imaging modalities such as radiography, arthrography, CT and scintigraphy, MRI is capable of directly visualising all components of the joint simultaneously and can detect a wide variety of joint abnormalities. A major advantage includes its ability to evaluate the various components and surrounding structures of the joint, and not merely the surface as visualised by arthroscopy or outlined by arthrography. With this technique multiplanar reconstructions are possible and by using different sequences, differentiation between different structures and pathologic processes, is possible. MRI is especially sensitive to bone marrow alterations. In people, the current status of MRI suggests that it allows an evaluation of the appearance of normal and abnormal articular cartilage, although the optimal sequencing for the detection of cartilage lesions still is undefined. Considering the plethora of imaging protocols, joint-specific orientations, and potential artefacts, the design and interpretation of MR imaging examination is difficult.

Shortcomings of MR imaging include the lack of consensus among radiologists with respect to which protocols best image articular joints. Musculoskeletal MR specialists are also looking forward to specific improvements that the 3-tesla will bring to orthopaedic imaging, including better visualisation of articular cartilage. The visualisation of cartilage and its lesions seems to be even more difficult in the dog probably because articular cartilage in dogs is very thin. The distinction between cartilage and synovial fluid is not obvious, at least not in young dogs because the amount of contrast between the joint fluid and articular cartilage is not enough. Also the intra-articular administration of Gadolinium-containing agents is not helpful. The intravenous injection of such contrast agents can be useful in the detection of inflammatory processes.

MRI can be of use in the diagnosis of bicipital pathology and other shoulder lameness. It is also a useful technique to reveal subchondral lesions like inflammatory changes in cases of OCD (fig 5). In humans it is also used to check stability of osteochondral fragments, which influences

Figure 5. An MRI picture of a dogs shoulder with OCD: Notice the severe subchondral inflammatory changes within the caudal humeral head (white arrows). It is not possible to see a distinction between articular cartilage and synovial fluid in this picture.

the therapeutic regime. In the detection of a fragmented coronoid process in the elbow joint, the technique could be helpful in detecting non-mineralised cartilaginous fragments not to be seen on CT. As with man, in the dog MRI has promising capabilities for imaging stifle pathology.

The disadvantages are the same as with CT, the high cost of the equipment and its high maintenance cost. Also the full understanding of the physics behind this imaging technique is not obvious.

Ultrasound

Ultrasound (US) is a potential valuable imaging technique of the musculoskeletal system in small animals. Linear transducers with frequencies higher than 7.5 MHz are used because of their flat application surface and high resolution power. With this technique imaging of joints, especially of the soft tissues (e.g. ligaments, capsule) and of the articular cartilage, can be obtained. Accurate examination of joints requires substantial ultrasonographic experience and a standardised examination procedure. In most of the joints even small amounts of fluid accumulation (hypo- to anechoic) can be easily demonstrated in the area of the joint pouches. The subchondral bone is visible as a hyperechoic line with a strong acoustic shadow. Arthritic new bone formation can be picked up as irregularities on the bony surface and can be detected at an early stage. The surface of normal joint cartilage appears as an anechoic layer and is examined for its integrity. Cartilage defects for example in the lateral femoral condyle or in the humeral head associated with OCD have irregular borders with pronounced contractions. The presence of a second hyperechoic line at the bottom of the subchondral defect seen on US is a pathognomic sign for the presence of a flap. Synovial proliferation can be evaluated as well. In the stifle joint it is possible to evaluate an old rupture of the cranial cruciate ligament (hyperechoic structures at the ends of the ligament), a meniscal tear or degeneration (seen as distinctly unhomogeneous and with a mixed pattern of hyperechoic and hypoechoic areas).

US is only of limited use in the diagnosis of a fragmented coronoid process. Pathologic changes of the soft tissues (e.g. tumour) can usually be diagnosed. Joint effusion in the shoulder joint can be diagnosed easily, and appears as a hypo- to anechoic area around the bony components. Bicipital pathology can be easily evaluated (fig 6). Also Achilles tendon lesions can be evaluated sonographically. Instabilities of the hip joint can be evaluated by dynamic examination. By seeing movement (real-time-system) between the femoral head and the acetabulum it is possible to evaluate laxity of the hip joint. A recent application of ultrasound is the monitoring of fracture healing.

Ultrasound biomicroscopy (UBM) is a new technology that uses very high frequency ultrasound (20~55 MHz or even higher, compared to 3~15 MHz in conventional clinical ultrasound systems). The spatial resolution of a two-dimensional image is up to ~50 μm with penetration depth of ~20 mm. UBM of articular cartilage reflects histological structure and can accurately detect early changes such as fibrillation. UBM has the potential to be a valuable tool for the *in vivo* identification of early lesions of osteoarthritis.

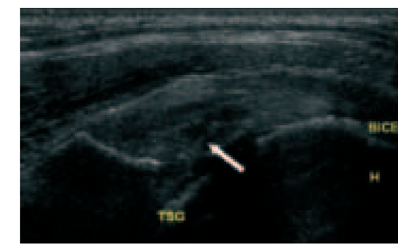

Figure 6. Longitudinal ultrasound view of a partial rupture of a biceps tendon: Notice the unhomogeneous and hypoechoic areas within the tendon (white arrow)
H = Humerus
TSG = Tuberculum Supra Glenoidale (supraglenoid tuberosity)

Conclusion

Radiography and CT are still superior techniques to evaluate bony changes. To visualise soft tissues, MRI and ultrasound are better. An ideal imaging technique would evaluate changes in articular cartilage, where the primary pathology of most disease takes place. Plain radiographs are the simplest and most readily available means of joint evaluation. However, radiography, along with nuclear medicine scans, arthrography, and computed tomography (CT) scans, are limited in their use because they are unable to detect early cartilage abnormalities. Magnetic resonance imaging (MRI) has the advantages of multiplanar imaging, soft tissue contrast, and non-invasiveness. And, like radiography, MRI can also underestimate the extent of cartilage abnormality. To detect early lesions and follow their evolution in time with imaging, a higher resolution is necessary. More work needs to be done in high resolution and volumetric MR imaging of articular cartilage but Ultrasound biomicroscopy (UBM) has promising potentials.

As a conclusion we could state that, although a variety of imaging techniques are available nowadays, we should always consider if the results of the intended imaging examination (or examinations) will influence the treatment of the patient and, if so, what is the most direct (i.e. cost effective) way to obtain these results. As in man, the question of over utilisation of high technology imaging techniques can be raised in animals as well.

Technique	Benefit	Specific use	Limitations
Scintigraphy	• High sensitivity for early disease and for surveying the entire skeleton.	• Localising the cause of obscure lameness. • Investigation of the metabolic function of the skeleton.	• Poor spatial resolution and meaningful interpretation of findings.
Radiography	• Good for bony structures. • Excellent spatial resolution. • Some indirect information on soft tissues.	• Evaluation of the subchondral bone plate, trabecular subchondral bone, articular margins, and peri-capsular attachments.	• Generally poor for soft tissue changes. • Superimposition of structures.
Stress radiography	• Indirect method for diagnosis of ligamentous problems.	• Very sensitive for detection of ruptured cranial cruciate ligament	• Radiation safety!
Arthrography	• Simple to use. • Mostly in the shoulder joint. • Rough imaging of intra-articular structures.	• Cartilage fissuring, joint mice, synovial proliferation, severe bicipital lesions. • Distinction between clinical and non-clinical OCD lesions.	• Not as accurate as newer techniques like arthroscopy and ultrasound.
Computerised Tomography (CT)	• Excellent for bony structures and ability to examine complex joint structures. • Absence of superimposition. • Better soft tissue differentiation than radiography.	• Detection of subtle new bone formation and bone lysis. • Fragmented coronoid process, tarsocrural OCD, the dorsal acetabular rim, extent of primary bone tumours.	• Needs general anaesthesia and cost of maintaining the equipment. • Getting use to reading axial images
Magnetic Resonance Imaging (MRI)	• Can evaluate the various components and surrounding structures of the joint.	• Bone marrow alterations, bicipital pathology, subchondral lesions in OCD. • Extent of primary bone tumours.	• Needs general anaesthesia and cost of maintaining the equipment. • Artefacts. • In dogs evaluation of cartilage is difficult.
Ultrasound	• Non-invasive technique. • Good for soft tissue structures like ligaments and joint capsules. • Can also pick up new bone formation in the early stages.	• Synovial evaluation, as well as tendon visualisation and real-time evaluation of hip instability. • Articular cartilage can be visualised. • Fracture healing can be monitored.	• Operator dependant. • Requires substantial ultrasonographic experience. • Not all areas are accessible.

Table 1. A quick guide to diagnostic imaging

Further reading

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