Equine scintigraphy: basic principles and interpretation

Bone scintigraphy is the only imaging technique able to demonstrate organ function rather than anatomical details. It involves intravenous injection of a radiopharmaceutical that binds to the bone structures and display alteration in osteoblastic activity. It is commonly used in horses presented for lameness investigation or poor performances, although the sensitivity of the technique in identifying the lesion causing lameness in poor performing sport horses was demonstrated to be low. Conversely, scintigraphy shows high sensitivity in detecting remodelling related to stress-related bone injury and stress fractures, which often occur in racehorses. It must be remembered, however, that the presence of increased radiopharmaceutical uptake does not necessarily indicate a lesion causing pain, and lameness and scintigraphy should be always used in conjunction with in-depth lameness investigation and, when possible, diagnostic analgesia.

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Scintigraphy is a procedure that involves the use of a radioactive material labelled with a tissue-seeking pharmaceutical. Based on the pharmaceutical used, the radioactive material is carried to different organs and will display the activity of the target organ. The radioactive material decays with production of gamma radiation that is captured by a gamma camera and processed to obtained a visible image. Scintigraphy is the only imaging technique that is capable of evaluating organ function/physiology rather than anatomy. However, it has poor spatial resolution, and therefore specific anatomical details can be lost.

For bone scintigraphy, commonly known as a 'bone scan', the radioactive material used is ^{99m}technetium; this is attached to diphosphonate salts which selectively carry it to the bone. Pharmaceuticals used are mytilene diphosphonate (MDP) and hydroxymethylene diphosphonate (HDP). The diphosphonate salts bind to hydroxyapatite in the bone and display areas with increased osteoblastic activity.

The radiopharmaceutical is injected intravenously before image acquisition, usually through a catheter placed in the jugular vein. It has been demonstrated that exercising the horse before injection of the radiopharmaceutical increases the blood flow to the distal limb, improving the uptake in this region (Dyson et al, 2001) and therefore the horse is usually lunged before injection, unless clinically contraindicated. A dose of 1 MBq per 100 kg is recommended to obtain diagnostic images, and the horse should remain confined for 24 hours after injection until most of the radioactive material has been eliminated through the urine or decayed.

Image acquisition

Bone scintigraphy is a three-phase study that involves acquisition of images at different times after injection to evaluate different tissue types. Vascular or flow phase images are obtained immediately after radiopharmaceutical injection and are used to display the distribution of blood flowing through a region (Weekes and Dyson, 2003). These are useful only for assessing regional perfusion, for example in cases of aortoiliac thrombosis. Between 2 and 15 minutes after injection, soft tissue or pool phase images can be acquired while the radiopharmaceutical has not yet bound to the bone (Weekes and Dyson, 2003). Because of the small window while soft tissue images can be acquired, it is usually not possible to image more than one region. Soft phase images can highlight pathology within the soft tissue, such as deep digital flexor tendinopathy within the foot. The high muscular uptake usually precludes the acquisition of diagnostic soft tissue phase images in regions proximal to the carpus or tarsus.

'Bone phase' images are usually obtained 2–2.5 hours after injection of the radiopharmaceutical and are used for evaluation of the skeletal component although uptake in the soft tissue can sometime be seen (Weekes and Dyson, 2003). For example, stripy muscular uptake is seen in the affected musculature, usually gluteal muscles, of horses with exertional rhabdomyolysis in bone phase images. Often, especially in cases where lameness has not been localised to one region, only bone phase images are acquired.

Images can be acquired in a static (continuous acquisition for a specific length of time or number of counts) or dynamic mode (acquisition of multiple 1–2 seconds separate frames); each region (joint) should be acquired separately and two projections per region are advised if possible. Images of both limbs should always be acquired to allow comparison of the uptake.

Because images are acquired with the horse standing and sedated, motion correction techniques are used to correct for motion artefact

caused by swaying during acquisition. For this purpose, dynamic mode images need to be obtained and then reprocessed to correct for motion, A final single image is used for interpretation.

Indication for scintigraphic examination

Skeletal scintigraphy can provide additional information during lameness work up, especially if used in conjunction with in-depth clinical examination, diagnostic analgesia (when applicable) and other imaging modalities. Scintigraphy is specifically indicated in horses with clinical signs suggestive of a fracture without localising signs, horses with dangerous behaviour or intermittent lameness where diagnostic analgesia is difficult to perform (Dyson, 2014).

In sport horses, scintigraphy is more useful in lame horses where lameness has been localised to a particular region (Ross and Stacy, 2011). Despite being commonly performed, the use of scintigraphy as a screening tool for poorly performing horses, has little diagnostic value. In a retrospective study, by Quiney et al (2018), sensitivity and specificity of increased radiopharmaceutical uptake for detecting lesions contributing to lameness was evaluated in a large group (n=480) of sport horses presented for poor performance. In this group, sensitivity of increased radiopharmaceutical uptake was poor but specificity was high; this was mainly related to a high proportion of false-negative results and presence of areas of increased radiopharmaceutical uptake, which were not associated with pain. Some soft tissue injuries can show increased radiopharmaceutical uptake at the insertion site, but in the majority of the cases of primary soft tissue lesion, there is no alteration of the uptake (Dyson, 2014). Quiney et al (2018) suggest that the high prevalence of chronic suspensory ligament desmopathy in the population included may have been responsible for the high number of false-negative cases. However, when results were analysed per anatomical region, substantial agreement was identified between increased radiopharmaceutical uptake and final diagnosis for the upper forelimbs (*Figure 1*) and front feet; in the other region the agreement was less than a chance.

Scintigraphy is often used to evaluate areas that are difficult to access with other imaging modalities, such as the pelvis and the thoracolumbar spine, although imaging findings should be supported by in-depth clinical evaluation to reach the correct diagnosis.

The pattern of uptake in the sacroiliac region was different in normal horses compared with horses with suspected sacroiliac pain; the latter being more likely to have poorly defined and asymmetric uptake in the tuber sacrali and increased radiopharmaceutical uptake in the sacroiliac region (Dyson et al, 2003). To complicate interpretation, different shape and conformation of the sacrum influence the distribution of radiopharmaceutical uptake in this region (Gorgas et al, 2009). When results of bone scintigraphy were compared with a positive response to diagnostic analgesia, only 42% of the horses with sacroiliac pain showed alteration of the radiopharmaceutical uptake (Barstow and Dyson, 2015) with a high number of false-negative results. It was therefore concluded that the use of scintigraphy alone was not reliable for diagnosing sacroiliac disease (Gorgas et al, 2009; Barstow and Dyson, 2015).

Horses with back pain are more likely to have increased radiopharmaceutical uptake in the thoracolumbar spinous processes (*Figure 2*), however alteration of the uptake can also be seen in horses without back pain. The presence of pathology affecting the spinous processes in both radiology and scintigraphy is more sensitive in predicting horses with back pain compared to either modality in isolation (Zimmerman et al, 2012).

Horses without back pain usually have normal distribution of the radiopharmaceutical uptake in the thoracolumbar articular process joints, however only 61% of horses with back pain and evidence of articular process joints osteoarthritis showed alteration of the radiopharmaceutical uptake (Gillen et al, 2009). The authors suggest that radiological evidence of osteoarthritis is not necessarily associated with active bone remodelling.

In racehorses, skeletal scintigraphy is more likely to give positive results compared to mature sport horses because of the much higher prevalence of stress-related bone injury and stress fractures (*Figure 3*). In this group, scintigraphic screening is indicated in horses with sudden onset of moderate to severe lameness that quickly resolves with rest (Dyson, 2014). Because fractures are secondary to stress

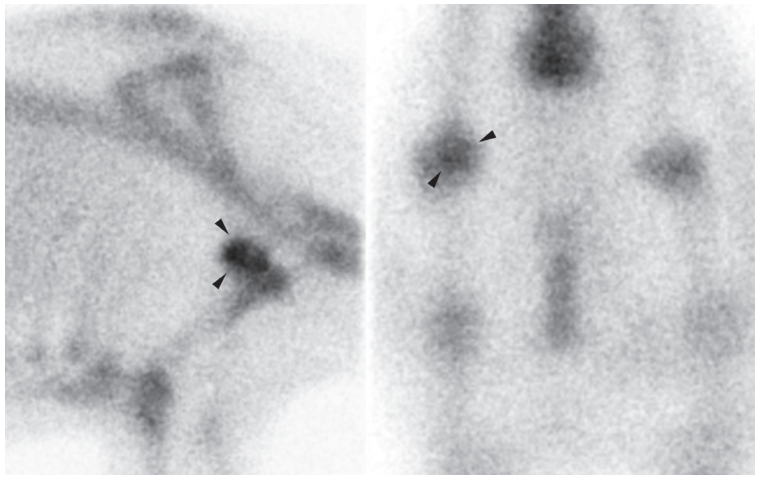

Figure 1. Six-year-old miniature gelding presented for intermittent right forelimb lameness of 6 months duration, negative to distal limb analgesia. There is diffused intense increased radiopharmaceutical uptake involving the caudal aspect of the glenoid and humeral head (arrowheads). Radiology showed fragmentation of the caudal margin of the glenoid and severe periarticular remodelling consistent with osteoarthritis likely secondary to mild joint dysplasia.

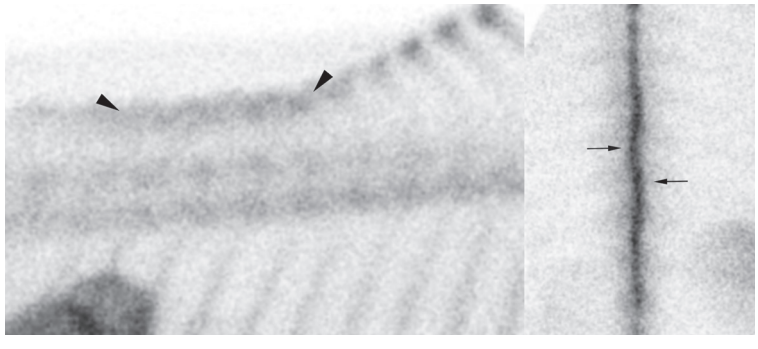

Figure 2. Four-year-old Thoroughbred stallion presented for stiffness and reluctance to move. Bone phase scintigraphy showed mild increased radiopharmaceutical uptake in the summit of the mid thoracic spinous processes (arrowheads) and misalignment (arrows) suggestive of impinging and overlapping spinous processes.

related bone injury, the scintigraphic uptake can be recognised soon after onset of lameness because of the ongoing bone remodelling. Use of scintigraphy in racehorses has drastically reduced the proportion of complete fractures (Dyson, 2014).

Image interpretation

In clinical settings, interpretation is usually based on subjective assessment of the images, although objective analysis such as profile of uptake and regions of interest may be used in specific regions or specific cases (Archer et al, 2007). For example, a profile analysis can help identifying subtle uptake abaxial to the tuber sacrali, which may be indicative of sacroiliac remodelling; on the other hand, region of interest analysis can be used to differentiate adaptive remodelling from stress fracture. Subjective interpretation may also be affected by the colour used to view images, with areas of subtle uptake becoming more obvious in coloured images compared to grey-scale images potentially resulting in overinterpretation (Erichsen et al, 2003).

Multiple studies, describing the distribution of the radiopharmaceutical uptake in specific areas of the body, are available for normal and symptomatic horses and can be used as a baseline guide for subjective interpretation. However, variation of the distribution of the uptake occurs based on the animal's age, athletic use and level of current training, making differentiation between individual variation and pathology often challenging for the inexperienced eye. For example, immature horses have greater radiopharmaceutical uptake in the cranial proximal and caudal proximal aspects of the tibia, while mature horses have greater radiopharmaceutical uptake in in the patella and caudoproximal aspect of the tibia (Dyson et al, 2007). The distribution of uptake varies greatly between sport horses and racehorses; in the fetlock region, for example, sport horses tend to have increased remodelling on the dorsal aspect of the joint while in racehorses, the remodelling is more commonly in the palmar/plantar aspect in relation to the loading pattern that the different type of activity causes (Biggi et al, 2009).

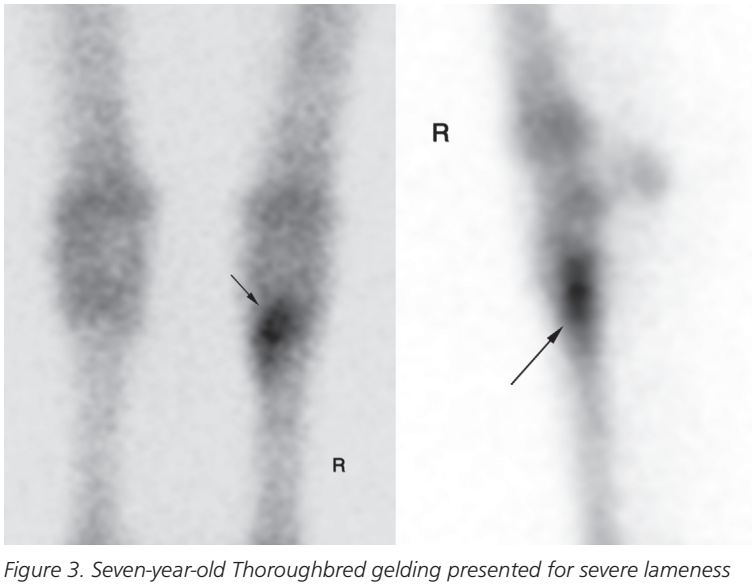

Figure 3. Seven-year-old Thoroughbred gelding presented for severe lameness following a race 1 month previously. Images show intense increased radiopharmaceutical uptake in the palmaro medial aspect of the proximal third metacarpal bone consistent with palmar cortical stress fracture or severe enthesopathy/avulsion fracture of the origin of the suspensory ligament. A lucent line surrounded by sclerosis was confirmed radiologically.

It is important to remember that increased radiopharmaceutical uptake does not equal pain causing lameness, but it only reflects increased osteoblastic activity (Dyson, 2014). Some regions are more likely to show increased radiopharmaceutical uptake associated with mild bone remodelling than others; for example, linear increased radiopharmaceutical uptake is often found in the subchondral bone of the tarsometatarsal joint or distal intertarsal joint in horses with mild radiological changes, while osteoarthritis of the metacarpophalangeal joint does not show changes in radiopharmaceutical uptake until lesions are advanced (Dyson, 2014).

On the other hand, exostosis of the accessory metacarpal/metatarsal bones show marked increased radiopharmaceutical uptake, which persists for a long time despite the lesion being clinically incidental.

Conclusion

Scintigraphy is a valuable technique to investigate areas that are difficult to access with other imaging modality or diagnostic analgesia, especially in horses that are lame. However, alteration of the radiopharmaceutical uptake reflects increased bone turnover and not necessarily pain causing lameness, and therefore the clinical significance of an area of uptake needs to be accurately verified. EQ

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