Complementary Imaging Modalities for the Diagnosis of Equine Lameness

Introduction

Diagnostic imaging is a fundamental component of equine lameness evaluation. Imaging assists with establishing a definitive diagnosis, guiding treatment decisions, determining prognosis, monitoring progression or resolution of lesions, and supporting management strategies for performance horses. Selection of the appropriate imaging modality requires consideration of the suspected pathology, anatomic location, availability of equipment, cost, safety considerations, and the specific information desired from the study.

Timing of Imaging

Imaging should ideally be performed at, or shortly after, the onset of lameness. Most imaging modalities can identify significant pathology immediately or within the first week following injury. Certain conditions, however, require specific timing considerations:

- Bone scintigraphy may detect stress fractures as early as 48 hours after injury, although sensitivity increases substantially by one week.
- Acute tendon injuries may continue to evolve during the first week following injury. Initial ultrasonography should therefore be followed by repeat examination approximately 7 days later, as lesion size is expected to increase over the first week.

Value of Imaging

Imaging contributes to lameness management in several important ways:

- Provides diagnostic information that directs treatment planning.
- Assists in establishing a realistic prognosis.
- Allows objective monitoring of healing or disease progression.
- Helps determine whether continued rehabilitation is justified.
- May ultimately reduce overall costs by avoiding prolonged, ineffective rest or training interruptions without a diagnosis.
- Reduces uncertainty by narrowing differential diagnoses, even when findings are negative. Absence of abnormalities on imaging remains clinically valuable information because it excludes numerous potential causes.

Imaging Performance Horses Before Clinical Lameness

By the time overt lameness develops, substantial soft tissue or osseous injury may already be present. Consequently, imaging can serve as a proactive management tool rather than solely a diagnostic tool.

Baseline imaging may:

- Identify subclinical abnormalities.
- Facilitate early detection of developing pathology.
- Provide reference images for future comparison.
- Help distinguish longstanding incidental findings from clinically significant changes.

Particular value exists in routine imaging of the equine foot. Many horses possess radiographic abnormalities, such as pronounced navicular bone synovial invaginations, that remain unchanged and clinically insignificant for years. Knowledge of an individual horse's baseline appearance can prevent overinterpretation of these findings if lameness develops later.

Selection of structures for surveillance imaging should reflect:

- Discipline-specific injury patterns.
- Breed predispositions.
- Level of athletic performance.
- Economic value of the horse.

Importance of Lameness Localization

Accurate localization remains the cornerstone of successful imaging.

The smaller the region localized through diagnostic analgesia and clinical examination, the more efficient and informative imaging becomes. This is particularly important for advanced imaging modalities such as MRI, where reduced imaging time minimizes anesthetic risks, including:

- Myopathy
- Radial neuropathy
- Femoral neuropathy

Localization also:

- Lowers diagnostic costs.
- Reduces unnecessary radiation exposure.
- Improves interpretation of identified abnormalities by confirming their relationship to the source of pain.

Available Imaging Modalities

Modern equine practice utilizes a range of complementary imaging techniques:

- Digital radiography
- Ultrasonography
- Nuclear scintigraphy (bone scan)
- Low-field MRI
- High-field MRI
- Computed tomography (CT)
- Positron emission tomography (PET) in select centers

No single modality can answer every diagnostic question. Each provides unique information and should be selected based on the suspected pathology.

Selecting an Imaging Modality

Selection should be guided by the suspected disease process and the type of information needed.

Bone Pathology

Potential abnormalities include:

- New bone production
- Bone loss or lysis
- Fluid accumulation within bone
- Fracture
- Displacement

Radiography and CT are particularly effective for assessment of bone density changes and fractures. MRI uniquely detects intraosseous fluid and active inflammation. Bone scintigraphy identifies areas of increased bone turnover but does not define structural abnormalities directly.

Additional considerations include:

- Cost
- Availability
- Examination duration
- Need for general anesthesia
- Staffing requirements
- Safety for both horse and personnel
- Clinical usefulness of obtained information

Complementary Nature of Imaging

Diagnostic imaging modalities should be viewed as complementary rather than competing techniques.

For example, a horse with stifle lameness may demonstrate:

- Subtle sclerosis on radiographs.
- A meniscal tear on ultrasound.
- Osteoarthritis and subchondral pathology on CT.

Similarly, a fetlock case may require:

- Radiographs for screening.
- Bone scintigraphy to identify active remodeling.
- MRI to define subchondral bone injury and determine whether lesions represent acute or chronic disease.

Each modality contributes different information, leading to a more complete diagnosis.

Radiography

Strengths

Radiography remains the most widely used imaging modality due to:

- Immediate availability
- Ease of use in field practice
- Familiarity among practitioners
- Ability to evaluate large regions rapidly
- Excellent assessment of osseous structures

Radiographs provide a summation image, allowing appreciation of overall relationships between structures within the limb.

Limitations

Major limitations include:

- Superimposition of structures masking subtle changes
- Requirement for 40-60% change in bone density before abnormalities become radiographically apparent
- Inability to distinguish sclerosis from bone edema
- Limited soft tissue evaluation

Radiographic findings therefore often lag behind clinical disease progression.

Ultrasonography

Strengths

Ultrasound is:

- Portable
- Widely available
- Well suited for field use

- Highly effective for soft tissue evaluation

Advantages include:

- Characterization of tendons and ligaments
- Evaluation of effusion and soft tissues within joints
- Detection of subtle peripheral bone changes
- Assessment of bone surface quality

Modern portable ultrasound units provide image quality approaching that of larger referral-based systems.

Limitations

Limitations include:

- Inability to image inaccessible structures (those deep to the hoof capsule, bone, or air)
- Cannot evaluate deep osseous pathology
- High dependence on operator skill and experience
- Reduced sensitivity for very subtle soft tissue lesions compared with MRI

Ultrasound possesses a steep learning curve but becomes an exceptionally powerful diagnostic tool when mastered.

Ultrasound Tissue Characteristics

Understanding tissue appearance is essential for interpretation.

Tendons and Ligaments

- Hyperechoic
- Highly angle dependent
- Require that ultrasound probe is perpendicular to collagen fibers for optimal imaging

Muscle

- Generally hypoechoic
- Less angle dependent

Fat

- Hyperechoic
- Not angle dependent

Fluid

- Typically anechoic
- Not angle dependent
- Can create acoustic artifacts affecting deeper structures

Fibrous Tissue

- Usually hyperechoic
- Less influenced by probe angle

Degenerative Tendon and Ligament Tissue

- Variable appearance
- May demonstrate altered fiber alignment and abnormal angle-dependent characteristics

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Nuclear Scintigraphy

Strengths

Scintigraphy provides:

- Whole-body screening
- Evaluation of the axial skeleton
- Detection of increased bone metabolism
- Assessment of areas that cannot be safely blocked

It is especially valuable when lameness localization is difficult.

Limitations

Scintigraphy:

- Is generally limited to referral institutions
- Inconsistent availability
- Increasing expense
- Identifies areas of activity but not specific lesions
- May miss some distal limb pathology
- Has lower spatial resolution than CT or MRI

A positive bone scan identifies active biological processes but requires additional imaging for definitive diagnosis.

Computed Tomography (CT)

Strengths

CT offers:

- Exceptional spatial resolution
- Superior sensitivity to bone density changes
- Cross-sectional imaging without superimposition
- Rapid image acquisition
- Three-dimensional reconstruction capabilities

CT is particularly valuable for:

- Fracture assessment
- Subchondral bone evaluation
- Complex joint pathology
- Surgical planning

Some modern systems also provide improved soft tissue imaging, particularly when contrast techniques are utilized.

Limitations

Limitations include:

- Limited availability
- Cannot detect bone marrow fluid
- Restricted soft tissue contrast compared with MRI
- Possible need for general anesthesia depending on the region being examined

Certain structures, including the pelvis, stifles, and caudal cervical region, may still require anesthesia for optimal evaluation even when standing CT is available.

Magnetic Resonance Imaging (MRI)

Strengths

MRI is the most comprehensive imaging modality currently available.

Advantages include:

- Evaluation of both bone and soft tissue
- Detection of bone marrow edema
- Functional and physiologic information
- Identification of lesions not visible with other modalities

MRI is especially valuable for:

- Distal limb lameness
- Tendon and ligament injuries
- Early osseous disease
- Complex diagnostic cases

Higher-field-strength magnets provide superior image quality and lesion detection.

Limitations

MRI:

- Is expensive and specialized
- Often requires anesthesia for high-field studies
- Provides lower spatial resolution than CT for cortical bone detail
- Cannot evaluate fiber alignment which is important for evaluating healing of tendons and ligaments, ultrasound is complimentary here

Interpretation also varies according to field strength and scanner design.

Positron Emission Tomography (PET)

PET imaging is an emerging modality in equine practice.

Advantages include:

- Greater sensitivity than scintigraphy
- Detection of pathology at earlier stages
- Evaluation of both bone and soft tissue activity
- Correlation of physiologic activity with CT or MRI findings

Current limitations include:

- Limited availability
- Distal limb applications only
- High cost
- Continued development of clinical interpretation guidelines

At present, PET remains largely confined to specialized referral centers in the US.

Digital Venography

Digital venography can provide valuable information regarding hoof vascular perfusion and is feasible in field settings.

Applications include:

- Severe hoof abscesses
- Keratoma localization
- Evaluation of vascular compromise (thrombosis)
- Assessment of laminar integrity

Procedure highlights include:

- Sedation sufficient for cooperation but not excessive instability.
- Regional anesthesia using either a low four-point or abaxial sesamoid block.
- Placement of a tourniquet at the base of the sesamoids.
- Administration of 25-30 mL contrast medium into the digital vein.
- Rapid acquisition of radiographic projections before contrast dissipation.

Normal studies demonstrate a uniform vascular network, whereas filling defects indicate vascular compromise or pathology. Cases of severe chronic abscessation may demonstrate marked vascular loss, supporting prognostic decision-making. Larger studies will be needed to further validate utility for determining prognosis.

Advanced Ultrasonographic Techniques

Off-Incidence Ultrasonography

Altering probe angle can reveal tissue organization not visible on standard imaging.

Applications include:

- Evaluation of suspensory ligament architecture
- Assessment of core lesion healing
- Identification of scar tissue organization

This technique can distinguish whether apparent defects represent true lack of tissue or poorly organized reparative tissue.

Non-Weight-Bearing Ultrasonography

Flexion and unloading of structures may:

- Improve visualization
- Increase contact area
- Reveal lesion severity

Particularly useful for:

- Suspensory ligament evaluation
- Meniscal injuries
- Tendon and ligament tears

Lesions may widen under reduced tension, helping differentiate tears from fiber disruption.

Doppler Ultrasonography

Color Doppler

Evaluates:

- Blood flow direction
- Blood flow velocity
- Larger vessels

Normal tendons should not demonstrate Doppler flow.

Power Doppler

More sensitive than color Doppler for detecting small vessels.

Clinical applications include:

- Monitoring tendon healing
- Identifying active inflammation
- Differentiating acute-on-chronic from chronic lesions

Power Doppler has become a standard assessment tool in tendinopathy monitoring in people.

Microvascular Flow Imaging

The newest vascular imaging technology allows visualization of very small, slow-flowing vessels.

Potential applications include:

- Earlier detection of tendon injury
- Monitoring healing progression
- Identification of subclinical pathology

Research has demonstrated prolonged detection of lesion-associated blood flow compared with conventional power Doppler techniques.

Clinical Research Findings

Power Doppler may have predictive value in equine athletes.

In a study of Thoroughbred racehorses without structural superficial digital flexor tendon lesions, horses demonstrating positive Power Doppler signals were 3.17 times more likely to develop tendon injury within one year than horses without detectable vascular activity. These findings suggest that vascular abnormalities may precede structural injury and may assist in identifying horses at increased risk.

Key Take-Home Points

- Imaging is essential for diagnosis, prognosis, treatment planning, and monitoring of equine lameness.
- Accurate lameness localization greatly improves imaging efficiency and diagnostic yield.
- Imaging modalities are complementary and should be selected according to the specific clinical question being asked.
- Radiography and CT excel for osseous detail; ultrasound is indispensable for soft tissue assessment; MRI provides the most comprehensive evaluation of both soft tissue and bone.
- Nuclear scintigraphy and PET provide physiologic information and help identify active lesions.
- Advanced techniques such as venography, off-incidence ultrasonography, non-weight-bearing ultrasound, and Doppler imaging enhance diagnostic capability and monitoring of equine orthopedic disease.

Equine Lameness Evaluation and Referral Decision-Making

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Introduction

This session will focus on equine lameness evaluation, interpretation of gait asymmetry, the strengths and limitations of objective gait analysis technologies, challenges associated with diagnostic anesthesia, and considerations for referral of complex lameness cases.

Understanding Lameness

Lameness is defined as an **asymmetry of gait**, rather than an automatic indicator of pain. While pain is a common cause of gait asymmetry, clinicians must remain aware of other potential causes including neurologic disease and mechanical abnormalities. Subtle neurologic deficits may mimic painful lameness, and some horses may simultaneously exhibit both neurologic and orthopedic conditions. Mechanical causes of gait asymmetry include conditions such as fibrotic myopathy and stringhalt, although other less obvious conformational or biomechanical factors may also contribute.

With increasing use of objective gait analysis systems, distinguishing clinically significant asymmetry from normal individual variation has become increasingly important. Not every measurable asymmetry necessarily represents pain or pathology.

Passive Lameness Examination

The passive examination was identified as a critical but frequently overlooked component of lameness evaluation. Clinicians should deliberately assess:

- Overall conformation
- Abnormal postures
- Foot balance
- Limb symmetry

- Joint range of motion
- Axial skeleton mobility
- Musculoskeletal palpation findings

A comprehensive passive examination can provide valuable clues about both current pathology and potential future orthopedic concerns. Familiarity with normal anatomy and normal range of motion allows clinicians to identify subtle abnormalities more effectively when they arise.

Clinical Examples

A mature horse with croup-high conformation. Could this conformation contribute to impinging dorsal spinous processes? Although not considered a sole causative factor, this conformational characteristic may predispose some horses to back-related issues despite appropriate rehabilitation and fitness.

Another example involved a horse with high-low foot conformation. The horse exhibited asymmetry in limb length and shoulder structure but remains clinically sound. Early training challenges, such as difficulty consistently picking up the canter lead on the high foot, appeared to be aided by normalizing the limb length disparity. Maintaining appropriate trimming to equalize limb length reduced these issues, although shoulder asymmetry remains unchanged.

Active Lameness Examination

Active assessment includes observation of the horse moving under a range of conditions. Ideally, horses should be evaluated:

- On both hard and soft surfaces
- On straight lines
- On circles
- Under saddle when appropriate

Timing relative to shoeing or trimming is important. Horses examined shortly after trimming, particularly barefoot horses with thin soles, may exhibit temporary soreness that complicates interpretation of findings. Conversely, horses overdue for corrective hoof care may also demonstrate altered movement patterns.

For subtle or multi-limb lameness, evaluation under a variety of conditions is essential. Identifying situations that exacerbate or improve the asymmetry often assists with localization.

Case Example:

A high-level Morgan show horse presented with a complaint that it was not elevating the left forelimb as effectively as expected during performance. Under saddle, the trainer noted reduced left forelimb action, but no obvious weight-bearing lameness was apparent. Further evaluation revealed a mild right forelimb lameness that became substantially worse on a hard-surface circle. Diagnostic anesthesia localized the problem to the right front foot, and MRI ultimately identified a deep digital flexor tendon lesion. The apparent deficiency in left forelimb action was actually compensation for right forelimb pain.

This case highlighted the importance of evaluating both the horse's observable performance issue and the traditional lameness examination findings before drawing conclusions.

Flexion Tests

Flexion testing remains a commonly used component of lameness evaluation but is highly subjective. Results depend upon the examiner, the degree of flexion applied, and the horse's individual response.

Research evaluating 100 clinically sound horses demonstrated that approximately 60% produced at least one positive flexion response. Among positive responses:

- 50% were slight
- 35% were mild
- 15% produced more distinct lameness

Repeated flexions within short periods produced cumulative effects, with subsequent evaluations appearing more positive. Flexion response patterns also changed significantly when horses were re-evaluated six months later. These findings suggest clinicians should interpret mild flexion responses cautiously, particularly when they are not supported by other clinical or imaging abnormalities.

Reliability of Subjective Lameness Evaluation

Studies evaluating inter-observer agreement among experienced veterinarians demonstrated relatively strong consistency in identifying the primary lame limb. Experienced clinicians agreed on the primary affected limb approximately 76% of the time during straight-line evaluation and approximately 73% of the time during a complete examination.

Agreement improved dramatically when lameness grades exceeded 1.5 on standard scoring systems, reaching approximately 93%. Disagreement was most common among very mild lameness cases, which is not surprising given the inherent difficulty of detecting subtle asymmetries.

Research evaluating human visual perception demonstrated that observers are generally unable to reliably detect asymmetries below approximately 25%. This finding underscores the biological limitations of visual assessment and provides context for differences among clinicians evaluating subtle lameness.

Objective Gait Analysis

Overview of Available Technologies

Several technologies have been developed to objectively measure gait asymmetry, including:

- Force plate analysis
- High-speed video and kinematic analysis
- Inertial sensor-based systems
- Smartphone application-based technologies

Force plates provide valuable kinetic information but are largely limited to research facilities and cannot assess limb motion during flight phases. High-speed video systems provide detailed kinematic information but are often impractical outside specialized settings.

The Equinosis Lameness Locator, is the most established field based system and uses sensors attached to the poll, pelvis, and right forelimb to assess head and pelvic movement patterns during trot. Additional systems, including EquiMove and EquiPro, incorporate larger numbers of sensors and may provide additional information regarding body motion and axial skeletal function. Smartphone-based applications such as Sleip are becoming increasingly popular but remain relatively new technologies requiring further validation.

Clinical Utility and Limitations

Objective gait analysis can be useful for:

- Supporting findings during pre-purchase examinations
- Communicating findings to owners

- Assisting with localization in complex cases
- Monitoring individual horses over time

However, limitations remain. Unfortunately, systems often perform best with clear, consistent lameness but may be less reliable in very subtle, multi-limb cases where clinicians would most appreciate assistance.

My personal experience with the Lameness Locator during a research project involving induced lameness and repeated sensor evaluations demonstrated that even minor distractions affecting head position could significantly influence measurements of low grade lameness. Reliable data required highly consistent horse behavior and movement patterns that are often difficult to achieve in clinical practice.

Clinical Interpretation Challenges

A central concern with increasingly sensitive technologies is determining whether detected asymmetry truly represents pain. Studies evaluating apparently sound horses in work found that nearly three-quarters demonstrated measurable asymmetry using objective systems. When these horses were treated with meloxicam, asymmetry measurements did not change significantly, raising questions about whether all detected asymmetries represent painful pathology.

We need to exercise caution against overinterpreting subtle asymmetries without clinical context. Objective gait analysis should be viewed as a valuable tool, but not as a replacement for comprehensive clinical evaluation.

Diagnostic Local Anesthesia

Diagnostic nerve blocks remain a cornerstone of lameness localization but present several challenges:

- Time requirements
- Safety considerations
- Block accuracy
- Proximal anesthetic migration
- Non-responders
- Interpretation bias

Research suggests that experienced clinicians remain relatively objective when reassessing horses after nerve blocks, whereas students and less experienced veterinarians are more likely to be influenced simply by being told that a block has been performed.

Block Migration

The presenter reviewed factors influencing proximal migration of anesthetic, including:

- Excessive anesthetic volume
- Delayed reassessment
- Inadvertent synovial infiltration
- Leakage from intra-articular injections

A notable case involved a horse with severe lameness that completely resolved following a palmar digital nerve block. Radiographs and MRI of the foot were essentially normal. Subsequent MRI evaluation of the fetlock revealed a significant proximal P1 lesion characterized by bone edema and subchondral bone pathology. The findings strongly suggested proximal migration of local anesthetic beyond the intended site.

Timing of Block Responses

A study examining palmar digital nerve blocks using mepivacaine and lidocaine demonstrated that complete lameness resolution may occur substantially later than cutaneous desensitization. Some horses required 40 to 85 minutes after apparent skin desensitization before achieving complete lameness resolution.

As a result, clinicians should consider reassessing horses at regular intervals rather than immediately progressing to higher nerve blocks when early responses are incomplete.

Non-Responders

Some horses fail to respond appropriately to diagnostic anesthesia despite substantial pathology. Chronic pain, advanced osteoarthritis, and mechanical components of disease may contribute to incomplete responses. Horses with severe pastern osteoarthritis, for example, may demonstrate minimal improvement despite repeated local anesthetic blocks.

One horse with advanced pastern osteoarthritis underwent bone scintigraphy that confirmed intense focal activity corresponding to severe pathology. Following pastern arthrodesis, the horse returned sound one year later, confirming the clinical significance of the lesion despite poor response to diagnostic anesthesia.

Indications for Referral

Referral decisions should consider:

Veterinarian Factors

- Experience with lameness and imaging modalities
- Available facilities
- Access to imaging equipment
- Technical support and staff

Horse Factors

- Safety and behavior
- Complexity of lameness
- Presence of multiple-limb involvement
- Value and intended use

Owner Factors

- Budget
- Expectations
- Communication challenges
- Willingness to pursue advanced diagnostics

Common referral scenarios include:

- Persistent lameness localized to the foot without diagnostic imaging findings
- Cases requiring MRI, CT, scintigraphy, or advanced ultrasound
- Severe acute lameness with negative radiographs
- Persistent unresolved lameness despite extensive workup
- Conditions involving anatomically difficult regions such as the neck, pelvis, stifle, or proximal suspensory region

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Referral Communication and Client Expectations

The presenter stressed the importance of setting realistic owner expectations. Referral specialists rarely identify complex lameness problems immediately upon initial examination. Success often stems from access to more time, advanced imaging, and collaborative expertise rather than superior clinical intuition.

Owners should understand that:

- Complex lameness may require multiple diagnostic modalities.
- Previous treatments can complicate interpretation.
- Chronic cases after prolonged rest are often more difficult to diagnose.
- A rapid, comprehensive workup is generally faster but more expensive.
- A stepwise diagnostic approach may reduce costs but prolong diagnosis.

Successful case management of complex cases frequently requires collaboration among owners, trainers, farriers, primary care veterinarians, surgeons or lameness specialists, radiologists, and internal medicine clinicians.

Illustrative Cases

Case 1: Grand Prix Dressage Horse

A 10-year-old Warmblood competing at Grand Prix dressage presented with poor hind-end engagement despite recent hock injections. No obvious lameness was identified, but the horse consistently buckled in a hind limb during transitions from trot to walk. Cervical radiographs ultimately revealed marked narrowing at C6-C7, and further neurologic evaluation identified mild ataxia. This case illustrated how subtle neurologic disease can masquerade as a performance problem without clear lameness.

Case 2: Reining Horse with Hindlimb Lameness

A four-year-old Quarter Horse Reining Horse developed acute right hindlimb lameness while competing. Initial evaluations focused on potential stifle pathology, but radiographs and ultrasonography were inconclusive. Bone scintigraphy revealed increased radiopharmaceutical uptake in the central tarsal bone, raising concern for stress fracture. Subsequent CT identified a

chronic incomplete fracture of the central tarsal bone with marked sclerosis. This case highlighted the value of advanced imaging when conventional diagnostics fail to explain severe lameness.

Key Take-Home Messages

1. Lameness should be defined as gait asymmetry, not automatically interpreted as pain.
2. Thorough passive and active examinations remain essential despite advances in technology.
3. Flexion tests and subjective lameness grading have recognized limitations and should be interpreted within the larger clinical picture.
4. Objective gait analysis is a valuable adjunct but cannot replace experienced clinical judgment.
5. Diagnostic anesthesia requires thoughtful interpretation because of migration, delayed onset, and occasional non-response.
6. Referral decisions should be individualized based on clinician experience, case complexity, available resources, and owner goals.
7. Effective communication and realistic expectations are essential components of successful lameness investigation and management.