Sensitivity and Specificity of Nuclear Scintigraphy for the Diagnosis of Equine Suspensory Ligament Injuries

James A. Orsini, DVM[1]
Tracy Norman, VMD[2]
Michael W. Ross, DVM[1]
Raymond C. Boston, PhD[1]

[1]*Department of Clinical Studies*
New Bolton Center
School of Veterinary Medicine
University of Pennsylvania
Kennett Square, Pennsylvania
[2]*Department of Large Animal Surgery and Medicine*
Texas A&M University
School of Veterinary Medicine
College Station, Texas

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ABSTRACT

The objective of this study was to examine the relative sensitivity and specificity of nuclear scintigraphy compared with other commonly used diagnostic modalities for the diagnosis of avulsion fracture at the origin of the suspensory ligament (ASLO) in horses. Sixty horses presented with lameness localized to the suspensory origin; 34 horses had a diagnosis of ASLO and 26 horses (control group) had a diagnosis of high suspensory disease without avulsion fracture. The medical records of all 60 horses were examined and the sensitivity and specificity of each imaging modality, alone and in combination, were compared and the diagnostic power of each modality was calculated. Sensitivity was highest for scintigraphy (0.95) and lowest for ultrasonography (0.52); the sensitivity of radiography was relatively low (0.62). Specificity was highest for radiography and ultrasonography (0.95 and 0.96, respectively), and moderately high for scintigraphy (0.84). Scintigraphy was significantly more accurate than ultrasonography ($P = 0.0025$) and marginally more accurate than radiography ($P = 0.075$). The sensitivities of radiography and ultrasonography were substantially increased (1.00 and 0.94, respectively) when either modality was used in combination with scintigraphy. Scintigraphy is a highly sensitive and specific tool for the diagnosis of ASLO in horses. It was superior in diagnostic power to ultrasonography and radiography, and increased the sensitivity of those modalities for identifying this lesion.

INTRODUCTION

For more than 20 years, avulsion fracture at the suspensory ligament origin (ASLO) on the third metacarpal/metatarsal bone has

been recognized as a cause of lameness in horses.[1–4] It is believed that this injury occurs when tensile forces on the suspensory ligament exceed the integrity of its bony attachment, as may happen when the fetlock joint dorsiflexes while the carpus is stationary in a slightly flexed position.[2–6] Racing speeds apparently predispose to this condition,[1–4] but the injury also occurs in nonracing breeds.[4–8] ASLO may represent a variation of high suspensory disease (HSD). It shares many of the presenting signs of HSD, including swelling and pain on palpation in the region of the suspensory origin; lameness that ranges from mild to severe, but in most cases is mild to moderate; chronic persistence of clinical signs (even though the lameness may improve with rest); and exacerbation of the lameness when the affected limb is on the outside of a trotted circle.[4,7–10]

Complete avulsion fractures at the suspensory origin are often evident radiographically on dorsopalmar/plantar and/or lateromedial views of the proximal third metacarpus (MCIII) or metatarsus (MTIII).[1–4,8,9] However, nondisplaced, incomplete avulsion fractures may be radiographically inapparent.[2 4,9,10] Similar histories and presenting clinical findings make differentiating between the 2 conditions and reaching a definitive diagnosis of ASLO difficult. Nevertheless, the distinction is important because early identification of ASLO and immediate suspension of training can minimize further damage, shorten the recovery time, and even improve the prognosis. Thoroughbreds, in particular, can make a full recovery and return to their previous level of athletic performance.[5] In the case report in which ASLO was first documented, the convalescent period was much shorter when the diagnosis was made immediately after the injury occurred than when the horse was kept in training for weeks before the diagnosis was made.[1]

Ultrasonography is very useful for evaluating the soft tissue structures in the proximal palmar metacarpus and plantar metatarsus. However, evaluation of bony structures is limited with this imaging modality by the high reflectivity of bone to sound. Therefore, with respect to ASLO, ultrasonography is most likely to detect only complete, displaced fractures at the suspensory origin.[9]

Nuclear scintigraphy has previously been evaluated in the diagnosis of ASLO in horses. In a retrospective study by Edwards et al,[8] the specificity of scintigraphy for identifying ASLO was low (41%). However, the parameters for a positive scintigraphic diagnosis of ASLO in that study were broad (increased radionuclide uptake on the proximal palmar/plantar surface of MCIII or MTIII compared with the contralateral limb). The usefulness of scintigraphy for detection of stress fractures in human medicine suggests the potential for much higher specificity, given the ability to recognize particular patterns of abnormal uptake.[11,12] In a study of horses with lameness localized to the proximal metacarpus/tarsus and positive scintigraphic findings in that region, the focal nature, shape, and position of the area of increased radiopharmaceutical uptake (IRU) was considered important. Specifically, in the appropriate clinical setting, a focal triangular or circular area of IRU in the proximal palmar metacarpus/tarsus was considered evidence of a stress fracture.[13]

The objectives of the study reported were to determine the sensitivity and specificity of radiography, ultrasonography, and nuclear scintigraphy in the diagnosis of ASLO in horses, our hypothesis being that scintigraphy is both a sensitive and specific tool for identifying these lesions.

MATERIALS AND METHODS

Case Selection

The medical records of horses admitted to the University of Pennsylvania's George D. Widener Hospital for Large Animals between January 1993 and January 2005 were reviewed. During this period, 34 horses fit the study criteria for inclusion in the

ASLO group (ie, lameness localized to the suspensory origin and an established finding of an avulsion fracture by at least one of the following imaging modalities: radiography, ultrasonography, and scintigraphy).

An additional 26 horses with a recorded diagnosis of HSD were selected at random from the same time period; these horses served as the control group. A confirmed diagnosis of HSD was based on clinical findings and ultrasonographic evidence of suspensory desmitis, and the absence of ASLO and localization of the lameness to the high suspensory area using diagnostic nerve blocks.

Clinical Findings

The age, breed, gender, and limb(s) affected were noted for each horse. Degree of lameness, scored on a scale from 0 (normal gait) to 5 (nonweight-bearing), was also noted. In each case, the lameness had been localized to the proximal palmar/plantar MCIII or MTIII region. Evaluation included physical examination, observation of the horse at the walk and the trot, limb flexion, and diagnostic regional anesthesia.

Radiography

Radiographic evaluation involved conventional radiography or xeroradiography; in some cases, both were performed. Radiographic findings in the proximal region of MCIII or MTIII considered evidence of ASLO included the following: bone fragment at the palmar/plantar cortex on the lateromedial view; saucer- or V-shaped radiolucent line on the lateromedial view (apex of the V located proximally); or crescent-shaped radiolucent line on the dorsopalmar/plantar view (convex side of the crescent located proximally).[1,3,4,8,9]

Ultrasonography

Ultrasonography was performed in a routine manner using a 7.5 mHz transducer with fluid offset. Sonographic examinations were recorded on videotape, and sonograms were printed using a videographic printer (Sony UP-890). Sonographic diagnosis of ASLO was based on finding periosteal irregularity or discontinuity on the palmar/plantar cortex of proximal MCIII or MTIII.[4,8,9]

Nuclear Scintigraphy

Soft tissue and bone phase scintigraphy were performed in a conventional manner, using a large field-of-view gamma camera (Omega 500, Technicare Corp., Cleveland, Ohio) with a parallel hole, high-resolution collimator, and a dedicated nuclear medicine computer (Technicare 560, Technicare Corp., Cleveland, Ohio). Pool or soft-tissue phase images were obtained 5 to 10 minutes following injection of the radiopharmaceutical. Delayed or bone phase images were obtained within a window of 2 to 3 hours following injection. Scintigraphic images were printed on photographic film.

The intensity of IRU (Technetium-99 hydroxymethylene diphosphonate, Mallinckrodt Medical, Hazelwood, Missouri) in the proximal MCIII or MTIII was subjectively graded as mild, moderate, or intense, and the shape and location of the area was noted. The location was determined by triangulation, using the lateral and dorsal palmar/plantar views. Scintigraphic diagnosis of ASLO was based on finding a focal triangular or circular area of IRU in the proximal palmar/plantar region of MCIII or MTIII.[13]

Statistical Analysis

The data were compiled in a spreadsheet and then imported into Stata 6 (Stata Release 6 [1999], StataCorp, College Station, Texas) for analysis. Each diagnostic modality was evaluated for sensitivity, specificity, and diagnostic power. For the purposes of analysis, equivocal or unremarkable results were considered to be negative, and strongly suggestive or definitive evidence was considered to be positive.

Receiver operating characteristic (ROC)[14] was used to statistically quantify differences in relative diagnostic precision among modalities. Logistic regression was used to quantify the association between disease (ie, ASLO) incidence and the prediction of disease by the diagnostic modalities. All statistical tests involved 2-sided alpha risk at 5% or $P < 0.05$ considerations.

RESULTS

The 34 horses in the ASLO group comprised 15 Thoroughbreds, 7 Standardbreds, 7 Warmbloods, 3 Arabians, 1 Morgan, and 1 Quarter Horse. Twenty-two of the horses were males and 12 were females. The median age was 7 years (range, 2 to 14 years; mean, 7.1 years). Distribution of affected limb(s) was as follows: left forelimb-10 horses; right forelimb-12 horses; both forelimbs-1 horse; left hindlimb-3 horses; and right hindlimb-8 horses. In the majority of cases, the lameness was mild (13 horses with a lameness grade of <1; 11 horses with grade 2 lameness); in 3 horses the lameness was moderate (grade 3), and in 2 horses the lameness was severe (1 with grade 4 and 1 with grade 5 lameness). Lameness grade was not recorded for 5 horses.

The 26 horses in the control group comprised 9 Standardbreds, 7 Warmbloods, 6 Thoroughbreds, 1 Arabian, 1 Morgan, 1 Quarter Horse, and 1 Appaloosa. Seventeen horses were males and 9 were females. The median age was 8 years (range, 1 to 15 years; mean, 7.0 years). Distribution of affected limb(s) was as follows: left forelimb-6 horses; right forelimb-8 horses; both forelimbs-2 horses; left hindlimb-6 horses; and right hindlimb-4 horses. As in the ASLO group, in most cases the lameness was mild (13 horses with a lameness grade of <1; 4 horses with grade 2 lameness); in 6 horses the lameness was moderate (grade 3), and in 1 horse the lameness was severe (grade 4). Lameness grade was not recorded for 2 horses.

In both groups, the most commonly reported finding on physical examination was pain elicited by palpation over the suspensory origin (13 horses in the ASLO group, 9 in the control group). The next most commonly reported sign in both groups was edema or effusion in the region of the suspensory origin (6 horses in the ASLO group, 4 in the control group).

Of the 60 horses, 30 underwent all 3 diagnostic modalities. Of the remainder, 14 had both ultrasonography and radiography, 4 had ultrasonography and scintigraphy, 3 had radiography and scintigraphy, 6 had ultrasonography only, and 3 had radiography only. In none of the horses was scintigraphy alone used to diagnose ASLO or HSD.

Sensitivity and specificity results for each of the diagnostic modalities are given in Table 1. Using logistical regression, under a 95% confidence interval, correct diagnosis of ASLO was made in 76%, 72%, and 89.5% of cases for radiography, ultrasonography, and scintigraphy, respectively. Scintigraphy was significantly more accurate than ultrasonography (P = 0.0025) and marginally more accurate than radiography (P = 0.075).

Table 2 shows the sensitivity and specificity results for various combinations of diagnostic modalities. When all combinations were compared, only the combination of radiography and ultrasonography significantly improved the diagnostic power over that of either modality alone (P = 0.002).

Table 1. Successful Diagnoses for Individual Diagnostic Modalities.

Modality	Case Success (ASLO group), n/m	Noncase Success (control group), n/m	Sensitivity	Specificity
Radiography	18/29	20/21	0.62	0.95
Ultrasonography	15/29	23/24	0.52	0.96
Scintigraphy	18/19	16/19	0.95	0.8

ASLO = avulsion fracture at the suspensory origin; n/m = successful diagnosis (n) out of the total number of cases in that group in which the particular modality was used (m).
Control group was horses with high suspensory disease but no evidence of avulsion fracture.

Table 2. Successful Diagnoses for Combinations of Diagnostic Modalities.

Modality*	Case Success (ASLO group), n/m	Noncase Success (control group), n/m	Sensitivity	Specificity
Radiography + scintigraphy	10/18	13/16	0.56	0.81
Ultrasonography + scintigraphy	5/16	14/18	0.31	0.78
Radiography + ultrasonography	7/24	17/19	0.29	0.89
All modalities (+)	4/15	11/15	0.27	0.73
Radiography or scintigraphy	18/18	13/16	1.00	0.81
Ultrasonography or scintigraphy	15/16	14/18	0.94	0.78
Radiography or ultrasonography	20/24	17/19	0.83	0.89
All modalities (or)	15/15	11/15	1.00	0.73

*"x + y" = positive diagnosis when both modalities used were positive (only one must be negative to yield a negative diagnosis); "x or y" = positive diagnosis when 1 of the 2 modalities used was positive (both must be negative to yield a negative diagnosis)
ASLO = avulsion fracture at the suspensory origin; n/m = successful diagnosis (n) out of the total number of cases in that group in which the particular modalities were used (m).
Control group was horses with high suspensory disease.

DISCUSSION

Previous reports have suggested that, although nuclear scintigraphy is valuable for identifying the site(s) of lameness in horses, it lacks the specificity to definitively diagnose specific disorders.[8,15] However, we found scintigraphy to be a diagnostic tool with both high sensitivity and specificity in the identification of ASLO in horses. Of the 3 imaging modalities evaluated, scintigraphy had the highest diagnostic power, correctly identifying ASLO in almost 90% of cases. Radiography and ultrasonography each had higher specificity than scintigraphy; however, their sensitivity was relatively low. When either modality was combined with scintigraphy, their diagnostic sensitivity was markedly increased.

Edwards et al[8] compared the accuracy of scintigraphy plus radiography with that of radiography alone for the diagnosis of ASLO. While scintigraphy was positive in all horses with ASLO (sensitivity, 100%), the specificity was only 41%. One possible explanation for the low specificity in that study is that their criterion for positive scintigraphic diagnosis was very liberal, consisting merely of increased radionuclide uptake on the proximal palmar/plantar surface of MCIII or MTIII, compared with the contralateral limb. Based on the aforementioned findings of Walsh et al,[13] our criterion for a positive scintigraphic diagnosis of ASLO was more specific, which could have accounted for the higher specificity we found in our study.

In a recent study of scintigraphic patterns of injury in amateur weight lifters, the authors concluded that recognition of specific patterns of IRU can improve both the sensitivity and specificity of scintigraphic assessment.[11] It is probable that, as specific scintigraphic patterns in horses are recognized and correlated with particular disease conditions, the specificity and thus clinical utility of this already very sensitive tool will increase further. In human medicine, the classic scintigraphic pattern of a stress fracture is a focal area of hyperemia on the flow (pool phase) study, followed by an intense fusiform area of cortical uptake in the bone phase.[12] A previous study in horses established the legitimacy of classifying similar areas of IRU as stress fractures.[13]

Scintigraphy has a significantly higher sensitivity in detecting ASLO than either radiography or ultrasonography because it detects changes in bone metabolism.[12,15] Because of its exquisite sensitivity, one of the most common uses of scintigraphy in human medicine is the diagnosis of occult stress fractures undetectable by radiography.[12] Increasingly widespread use of scintigraphy in equine medicine over the past decade has confirmed its clinical value for identifying similar lesions in horses.[15,16] Nevertheless, because stress fractures, avulsion fractures, and stress reactions cannot always be differentiated on the basis of scintigraphy alone,[13] further diagnosis of ASLO probably should incorporate radiographic and/or sonographic findings to qualify the changes found on scintigraphic examination.

One practical point to note is that the inflammatory response induced by perineural or intra-articular injection of local anesthetic agents may produce potentially misleading pool-phase results for up to 17 days following injection.[17,18] Therefore, if pool-phase scintigraphy is likely to be used in the evaluation of lameness, diagnostic regional anesthesia should be postponed until after scintigraphy has been performed.

Radiography has been held to be the definitive tool in diagnosing ASLO because of the characteristic pattern seen when the avulsed fragment is displaced, and the specificity this affords.[1] However, because ASLO typically involves only partial thickness cortical disruption, and the palmar/plantar cortex of proximal MCIII or MTIII cannot be imaged without superimposition of other bone cortices, these lesions are often radiographically occult. The same problems are encountered with stress fractures in this and other locations. The sensitivity of radiography for identification of stress fractures in humans may be as low as 15%.[12] In our study, radiography had a much higher sensitivity (62%) for identification of avulsion fractures. The nature of the lesion and the use of xeroradiography and now digital radiography at this institution are likely to be at least partially responsible for this enhancement of sensitivity. Nonetheless, ASLO can be inapparent, even with high-quality digital radiography. In our study, radiography failed to identify the lesion in 11 of 29 cases of ASLO.

We found ultrasonography to be a relatively insensitive tool for detecting ASLO when compared with radiography and scintigraphy. The sensitivity of ultrasonography in this application was the lowest of the 3 modalities, even though its specificity was high. Nevertheless, ultrasonography is important in the assessment of these cases because of the detailed information it yields about damage done to the soft tissues, particularly the suspensory ligament.[9,10] As it is not possible to differentiate between HSD and ASLO on the basis of clinical findings, and assuming that the basic mechanism of injury is the same for both conditions (ie, excessive tension on the suspensory ligament),[1–6] evaluating the suspensory origin for evidence of desmitis or ligament disruption should probably be performed in each case.

In summary, we found nuclear scintigraphy to be superior in diagnostic power to ultrasonography and radiography for the diagnosis of ASLO. Addition of scintigraphy substantially increased the sensitivity of the other imaging modalities in diagnosing these lesions. Recognizing the particular pattern of increased radiopharmaceutical uptake is important in maximizing the specificity of this very sensitive diagnostic tool. Even so, scintigraphy should probably be used in combination with another imaging modality, and with supportive historical and clinical findings, to arrive at a final diagnosis of ASLO. This study is the first side-by-side comparison of the sensitivity and specificity of radiography, ultrasonography, and nuclear scintigraphy in the diagnosis and differentiation of ASLO and HSD.

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REFERENCES

1. Bramlage LR, Gabel AA, Hackett RP: Avulsion fractures of the origin of the suspensory ligament in the horse. *J Am Vet Med Assoc* 1980;176:1004-1010.
2. Dyson SJ: Proximal suspensory desmitis in the forelimb and hindlimb. *Proc Am Assoc Equine Pract* 2000;46:137.
3. Dyson SJ: Proximal suspensory desmitis: clinical, ultrasonographic and radiographic features. *Equine Vet J* 1991;23:25.
4. Dyson SJ, Genovese RL: The suspensory apparatus. In: Ross MW, Dyson SJ, eds. *Lameness in the Horse*. 1st ed. W.B. Saunders: Philadelphia, Pa; 2003:654-672.
5. Dyson SJ, Genovese, RL: The suspensory apparatus. In: Ross MW, Dyson SJ, eds. *Lameness in the Horse*. 1st ed. W.B. Saunders: Philadelphia, Pa; 2003:362-376.
6. Rooney JR: Pathogenesis of three lesions causing lameness of the foreleg in horses. *J Equine Vet Sci* 1986;6:330-332.
7. Marks D, Mackay-Smith MP, Leslie JA, et al. Lameness resulting from high suspensory disease (HSD) in the horse. *Proceedings of the 27th Annual Convention of the American Association of Equine Practitioners* 1982;493-498.
8. Edwards RB 3rd, Ducharme NG, Fubini SL, Yeager AE, Kallfelz FA: Scintigraphy for diagnosis of avulsions of the origin of the suspensory ligament in horses: 51 cases (1980-1993). *J Am Vet Med Assoc* 1995;207:608-611.
9. Dyson SJ, Arthur RM, Palmer SE, Richardson D: Suspensory ligament desmitis. *Vet Clin North Am Equine Pract* 1995;11:177-215.
10. Young RL, O'Brien TR, Craychee TJ: Examination procedures for the diagnosis of suspensory desmitis in the horse. *Proceedings of the 35th Annual Convention of the American Association of Equine Practitioners* 1990;233-241.
11. Van der Wall H, McLaughlin A, Bruce W, Frater CJ, Kannangara S, Murray IP: Scintigraphic patterns of injury in amateur weight lifters. *Clin Nucl Med* 1999;24:915-920.
12. Hendler A, Hershkop M: When to use bone scintigraphy. *Bone Scintigraphy* 1998;104:54-69.
13. Walsh BA, Ross MW, Reef V, et al: Positive scintigraphic findings in the equine proximal metacarpus and metatarsus: A comparison with clinical, radiographic and ultrasonographic findings. *J Ultrasound Med* 1996;15:59-60.
14. Cleeves M: Receiver operating characteristic (ROC) analysis. *Stata Technical Bulletin* 1999;STB-52:19-33.
15. Martinelli MJ, Chambers MD: Equine nuclear bone scintigraphy: physiological principles and clinical application. *Equine Vet Educ* 1995;7:281-287.
16. Ehrlich PJ, Dohoo IR, O'Callaghan MW: Results of bone scintigraphy in racing Standardbred horses: 64 cases (1992-1994). *J Am Vet Med Assoc* 1999;215:982-991.
17. Trout DR, Hornof WJ, Liskey CC, et al: The effects of regional perineural anaesthesia on soft tissue and bone phase scintigraphy in the horse. *Vet Radiol* 1991;32:140-144.
18. Trout DR, Hornof WJ, Fisher PE: The effects of intraarticular anaesthesia on soft tissue and bone phase scintigraphy in the horse. *Vet Radiol* 1991;32:251-255.