Risk of intra-articular injection with longitudinal ultrasound-guided injection of the collateral ligaments of the distal interphalangeal joint in the horse.

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Abstract

Study design: Anatomical study

Desmopathy of the collateral ligaments of the distal interphalangeal (DIP) joint is a common cause of foot lameness and carries a poor prognosis with conservative management. Intralesional injections may improve healing, although accuracy of radiographically-guided injections is significantly less than when guided by magnetic resonance imaging (MRI), which requires special needles. Ultrasound-guided injection of the distal collateral ligament has not been evaluated objectively.

Seven equine cadaver limbs (14 collateral ligaments) were injected with methylene blue dye and radiographic contrast medium using ultrasound to guide the needle longitudinally into the collateral ligaments until contacting bone. The insertion site of the needle proximal to the coronary band was measured on the limb and the needles left in place for radiography and computed tomography (CT) to evaluate the needle angulation, location of the contrast medium, and whether the contrast entered the DIP joint. The limbs were frozen and sectioned with a band saw to identify the location of the dye.

Fifty percentage of injections were in or around the collateral ligaments. However, the percentage of 'successful' injections, defined as in the collateral ligament but not in the joint, was only 36%. All legs had dye and contrast in the joint after both ligaments had been injected. There were no significant differences between the needle angle and entry site for 'successful' and 'unsuccessful' injections.

This study shows that ultrasound guidance alone is not a reliable method for injecting the distal portions of the DIP joint collateral ligaments.

Introduction

The medial and lateral collateral ligaments of the DIP joint arise from the middle phalanx and insert on fossae close to the articular margin of the distal phalanx [1]. The ultrasound technique and anatomy for evaluating these ligaments have been described in a detailed fashion [2], however because they extend into the hoof capsule, only the proximal one third of the ligament is visible on-incidence above the coronary band. When there is injury to these structures in the proximal third, there is often swelling in the region of the ligament at the coronary band, and abnormalities can be identified ultrasonographically [3]. However, most collateral ligament injuries affect the more distal portions of the ligament and so will not show abnormalities visible ultrasonographically. When pathology exists at their distal enthesis onto the distal phalanx, bony changes, including cystic lesions at the site of ligament insertion can be seen radiographically [1,4]. The imaging modality of choice, therefore, to identify desmopathy of the collateral ligaments of the DIP joint is MRI. The increased use of standing MRI for the diagnosis of foot lameness without radiographic abnormalities has increased the frequency of this diagnosis significantly because of its greater ability to identify soft tissue pathology inside the hoof capsule in those cases even when there are no palpable abnormalities and collateral ligament desmopathy represents the second most common soft tissue injury in the forefoot. [5-7]. The MRI diagnosis of collateral ligament desmopathy is, however, still challenging because the angulation of the ligament in standing horses makes it susceptible to a magic angle artefact [8-10]. Appreciation of this artefact has improved our diagnostic accuracy of this condition, especially with the use of additional sequences such as T2-weighted fast spin echo sequences with a particularly long echo time (TE) to distinguish injury from artefact [11]. In human medicine use of fat-suppressed T2-weighted images has also been described recently to reduce the magic angle effect in peroneal tendons [12].

Furthermore, careful patient positioning (standing the horse squarely on all four limbs, with the foot straight within a standing magnet) can assist in reduction of artefact presence, being mindful of the orientation of the static magnetic field for the specific magnet being utilised, to reduce ligament fibre orientation at or close of 55 degrees to this [9].

The mainstay of treatment has been prolonged periods of rest and careful exercise rehabilitation for up to one year. However, this approach has still been problematic with a prognosis for a return to full work of only 27-34% in a case series of 182 horses [13]. The presence of osseous abnormalities did not appear to adversely affect the prognosis in this study. Adjunctive shoeing methods using shoes with a wider branch on the affected side to reduce sinking of the foot into soft surfaces with work, thereby protecting the affected side at the expense of the loading of the other, contra-axial, collateral ligament represents a biomechanically sound approach [14] but may not produce a consistent effect [15] and has yet to be shown to be clinically effective.

Consequently, there has been an interest in treating these injuries more aggressively by intraligamentous injections of a variety of biological agents, such as stem cells and platelet-rich plasma, with the aim of supporting healing and improving return to function. Access to these ligaments is, however, limited because the majority of the ligament is distal to the coronary band and the ligament is intimately associated with the distal interphalangeal joint on its axial surface. A radiographically-guided technique has been described using radiographic contrast medium [16] but this was found to be significantly less accurate than an MRI-guided technique which used a combination of contrast medium and methylene blue (30% versus 80%) [17]. Use of the more reliable MRI-guided technique has recently been reported for the injection of platelet-rich plasma or mesenchymal stem cells with an apparently improved success rate of 10/13 (77%) horses returning to their intended level compared to published data for rest and corrective shoeing alone [7,18].

However, the MRI technique requires special non-ferromagnetic needles and an MRI scan which makes the procedure expensive. In some hospitals, standing MRI is not available, and high field MRI requires general anaesthesia, which increases the costs and risks to the horse. Ultrasound offers a way to visualise the collateral ligament in the standing horse, is cost-effective and a simple procedure applicable to field use. Recently an ultrasound-guided technique was described [19] but this utilised a needle inserted proximal to the coronary band orthogonal to the collateral ligament and therefore would be limited to those injuries that are present in the proximal third of the ligament. Most collateral ligament injuries have more extensive involvement of the more distal portions of the ligament [6] and so a longitudinal ultrasound-guided injection technique would be more appropriate but this use has not been evaluated objectively. The aim of this study was therefore to outline a method of accurately inserting a needle into the medial and lateral collateral ligaments of the DIP joint under ultrasound guidance in cadaver limbs and to determine its reliability to deposit an injected solution in or adjacent to the collateral ligament at its distal location without entering the DIP joint.

Materials and methods

Study design: Anatomical study

Seven fresh normal equine cadaveric distal forelimbs (14 collateral ligaments) were disarticulated at the level of the carpus. These limbs were selected by a veterinary student but confirmed as normal by an experienced clinician as having no visible or palpable abnormalities of the collateral ligaments. Limbs were excluded if found to be abnormal during subsequent ultrasonography radiography, computed tomography and when sectioned at the end of the study. The number of ligaments evaluated was based on a power study (with 80% power) to show significantly improved accuracy (above 65%) compared to the radiographic-guided technique. [14]. The study was approved by the Social Science Research Ethical Review Board of the institution.

The limbs were mounted vertically in a stand at approximately normal fetlock angles by loading the top of the limb with a 10kg weight. No survey radiographs were taken. The hair on the dorsal half of the pastern was clipped and prepared as for aseptic injection by scrubbing with chlorhexidine and surgical spirit. A 10-15MHz linear transducer and ultrasound machine (Logic E9; GE Medical Systems Limited, Chalfont St Giles, Bucks, UK) was used for the study. Ultrasound gel was applied to the area just above the coronary band and the linear ultrasound transducer applied transversely at the level of the coronary band by an experienced ultrasonographer to identify the collateral ligaments of the DIP joint.

A 20G, 1.5 inch long needle was inserted through the skin 1.5-2cm proximal to the coronary band over the medial collateral ligament with the transducer in the transverse orientation at the level of the coronary band to ensure that the needle was accurately located overlying the middle of the ligament (Figure 1). The needle was repositioned under ultrasound guidance until it was located over the middle of the ligament. The transducer was then rotated 90° so that the striated fibre pattern of the collateral ligament could be seen. This allowed in-plane targeting of the needle into the collateral ligament (Figure 1) in its abaxial surface. Once the needle had been introduced into the ligament, the needle was advanced, using ultrasound control to maintain its more superficial position within the collateral ligament where it was visible proximal to the coronary band, until it impacted onto the distal phalanx. The more distal aspects of the collateral ligament could not be identified ultrasonographically due to the presence of the proximal hoof. The distance between the needle entry site through the skin and the coronary band was measured on the limb with a ruler.

Radiographic contrast media (Iohexol; Omnipaque 300™, 300mgI/ml, GE Healthcare, Cork, Ireland) was mixed with methylene blue dye in a 9:1 ratio and 1ml was injected using a 2ml syringe. It was noted whether there was any resistance to injection. If resistance was encountered and the solution could not be injected forcibly, the needle was withdrawn a few millimetres only and injection attempted again. The solution was successfully injected into the distal aspect of all collateral ligaments of the DIP joint in this way.

After injection, the syringe was removed but the needle left *in situ*. Radiographs were taken using lateromedial, dorsopalmar and dorsoproximal-palmarodistal oblique (DPrPaDiO) views to evaluate the position of the needle and the location of the contrast (Figure 2). Contrast was categorised as being either in the ligament (at the site of insertion of the collateral ligament), in the DIP joint, or outside of these two areas.

The limb was then returned to the stand and the procedure repeated for the lateral collateral ligament as described above. A second set of radiographs were obtained. Location of the contrast of the second injection was identifiable when compared to the first set of radiographs - contrast was categorised as in the ligament in the same way as for the first set of radiographs (as no contrast was there previously) or in the DIP joint (where the extent of the contrast was greater than on the previous set of radiographs).

Finally the limb, with both needles still in place, underwent CT. Images were obtained using a 16-multidetector CT scanner (GE Lightspeed Pro 16, GE Medical) using the following parameters; kVp 120, mA 200, slice thickness 1.25mm, field of view (FOV) adjusted to the size of the limb but 25cm or less, and matrix size 512 x 512. The CT images were evaluated for the location of the contrast with respect to the collateral ligament (this being identifiable using a soft tissue window width and window level) and its presence within the distal interphalangeal joint used for this categorisation based on these images.

All interventional procedures were performed by an orthopaedic specialist, experienced in ultrasonography and the radiographic and CT imaging performed by a veterinary student under supervision by a diagnostic imaging resident. Evaluation of the images for the measurement of the needle position and the location of the contrast was performed by the veterinary student and the diagnostic imaging resident and the final decision based on a consensus between these two evaluators, with the final decision being made by the diagnostic imaging resident who was experienced in reading radiographs and CTs.

Measurements from the radiographs (figure 2)

The following measurements were made from digital radiographs by one observer (veterinary student) for each limb and each needle placement using the angle measurement tool of the viewing software:

(1) From the lateromedial radiographs (Figure 2A) - the dorsal to palmar angulation from the horizontal plane, with less than 90° being angulation towards the toe.

(2) From the dorsopalmar radiographs (Figure 2B) – the axial to abaxial angulation from the vertical axis of the phalanges, with positive being an abaxial angulation.

(3) From the dorsoproximal-palmarodistal oblique radiographs (Figure 2C) - the axial to abaxial angulation from the digital axis of the phalanges, with positive being an abaxial angulation.

Dissection method

The limbs were frozen at -20°C until ready for dissection. The feet were sliced with a band saw whilst frozen into four sections using three cuts; the first of which was at the coronary and the other two 1 inch (2.5cm) apart, parallel to the coronary band from proximal to distal. This resulted in six cut surfaces to examine (1+2 the two cut surfaces at the coronary band and 3+4 the two surfaces at the second, more distal, cut; no collateral ligament was evident at the third cut surfaces). These were evaluated by one observer (veterinary student) and used to identify any collateral ligament pathology (discolouration or enlargement) which may have influenced the injection and to determine the location of the injected methylene blue in or around the collateral ligament. The cut sections were photographed and reviewed by an experienced clinician.

Statistical analysis

The angles that the needles were placed in the legs were measured from the radiographs and the median (with minimum and maximum) calculated for the successful (in or adjacent to the ligament) and unsuccessful (within the DIP joint) attempts for all 14 collateral ligaments. Accuracy was presented as a percentage with a 95% confidence interval (CI) and, although the collateral ligaments were paired within a limb, they were analyzed as independent observations. Due to the small sample size, demonstrating normal distribution was not deemed reliable and so a non-parametric test was used (Mann-Whitney U) by the senior author to determine any significant differences with a significance set at $p<0.05$.

Results

The collateral ligaments could be identified in all limbs and the needles were accurately located within all the proximal portion of the collateral ligaments on ultrasound examination. Eight injections showed no resistance to injection while 6 proved difficult to inject.

Based on radiographic appraisal, there was contrast media in the DIP joint on 64.3% (9/14; 95% CI: 35%, 87%) of injections and, after attempted injection of both the lateral and medial collateral ligaments, contrast media was present in the DIP joint of all the legs. Six out of eight (75%; 95% CI: 40%, 94%) easy injections were in the joint while only three out of six resistance injections (50%; 95% CI: 19%, 81%) were in the joint. The contrast media was within the distal portion of the collateral ligament and/or periligamentous in 7/14 (50%; 95% CI: 27%, 73%) of injections (Figure 3). However, the percentage of injections that resulted in the contrast media being seen in the area of the ligament in question and not in the distal interphalangeal joint was only 35.7% (5/14; 95% CI: 16%, 61%) (Figure 4).

The radiographic findings were confirmed on CT evaluation where there was contrast in the distal interphalangeal joint of all limbs (Figures 3 and 4). Contrast media was identified in one or both of the ligaments of 10/14 ligaments (71%; 95% CI: 45%, 89%) and in the joints of all limbs in the gross sections (Figure 5).

Radiographic measurements (Table 1)

The median distance of needle entry above the coronary band was 1.90cm (1.50-2.20cm) and for those injections not into the joint and deemed to be successful (in the ligament but not in the joint), the median distance was 1.70cm (1.50-2.00cm), significantly less than when the injection resulted in deposition into the joint (2.00cm; 1.80-2.20cm; p=0.045).

The dorsopalmar angulation from the lateromedial radiograph was 76.1° (74.7-95.9°; n=4) from the horizontal (angled towards the toe) for the successful injections and 81.10° (65.7-86.9°; n=8) for the unsuccessful. The abaxial angle of the needle from the DPrPaDiO radiograph (angle away from the midline) was 3.0° (0.1-10.7°; n=5) for the successful injections and -1.3° (-7.0-11.9°; n=8) for the unsuccessful. The abaxial angle from the dorsopalmar radiograph (angle away from the midline) was 7.6° (1.4-10.8°; n=5) for the successful attempts and 1.7° (-2.3-10.1; n=8) for the unsuccessful attempts. The missing data related to technical problems (the needle lost in one limb and one of the radiographic views deemed too oblique to provide an accurate measurement). None of the radiographically determined angles were significantly different between those where the joint had been entered and those where it had not.

Discussion

This study has shown an ultrasonographically-guided method for positioning a needle longitudinally into the distal portions of the collateral ligaments of the DIP joint. However, even under this ultrasound guidance, this technique carries a high risk of DIP joint injection (approximately two thirds of injections).

Thoroughbred-type horse legs were used to reduce the variability of any anatomical differences between breeds. The cadaveric legs were set in a position that simulates standing and were loaded so that the collateral ligaments were in a similar position as they would be in a live horse although not with the load experienced in a standing horse, which is a limitation of the study. While the limbs had no evidence of collateral ligament pathology when sectioned and therefore would be anticipated to be difficult to inject, this also mimics the clinical situation where lesions are frequently chronic and filled with fibrocartilage metaplasia [6] which would also make the ligament difficult to inject.

It is logical to target injections where the lesions are most commonly found to achieve maximum efficacy and to avoid iatrogenic trauma by penetrating the remainder of the ligament [16]. As long as the selected needle is sturdy enough to maintain a straight trajectory on insertion into the collateral ligament, iatrogenic trauma is anticipated to be minimal with a small gauge needle introduced in line with the ligament fibres. For more generalised lesions involving the length of the ligament, greater dispersion of the injected therapeutic agent throughout the length of the ligament would be expected to provide a better therapeutic effect. This study took contrast media or dye in any portion of the ligament as a successful injection, although the aim was to inject at the distal portion of the ligament where the most severe injuries are located[6]. While it is possible that as long as therapeutic agent was injected into the ligament its actions would benefit a lesion at a distant site by diffusion as it spreads through the tissue, more accurate placement with respect to the lesion would still be the most desirable outcome of an injection of a therapeutic agent.

Half of the attempts reported here resulted in contrast media being seen in the collateral ligament that was injected, with just over a third classified as optimal by being in the ligament but not in the DIP joint. However, the gross sections demonstrated a higher percentage (71%) of the ligaments having some dye evident in the ligament which may suggest that the use of contrast may have underestimated the accuracy of injection or else the methylene blue may have diffused into the ligament after injection from the joint. Furthermore, the absence of contrast/dye in the ligament may not be the same as suggesting only a third of injections would have a therapeutic effect, as although this study excluded visualisation of contrast media or dye outside the ligament as successful, local diffusion could be logically hypothesised to have therapeutic effects on the adjacent ligament. Similarly, joint penetration was counted as unsuccessful although infusion of the joint with pharmacological or biological agents could still have some beneficial therapeutic effects on any secondary joint inflammation and diffuse into the target area of the ligament damage.

Since contrast was seen in the DIP joint in almost two thirds of injection attempts and in all of the legs after both lateral and medial injections, this could result in both a decrease or lack of therapeutic effect and also inflammation of the DIP joint caused by iatrogenic sepsis or reaction to the injected solution. This is a significant concern in a clinical case as sepsis in the DIP joint carries a worse prognosis than infection in other joints [20]. Therefore, if this procedure is undertaken, it should be performed in an aseptic manner. Additionally, injected agents should not be irritating to the joint. Interestingly a recent study on reaction rates associated with injection of allogenic bone marrow-derived stem cells revealed a significantly higher reaction incidence for synovial injections and DIP collateral ligament injections than all other soft tissue injections, consistent with the high frequency of DIP joint injections when attempts were being made to inject the collateral ligaments [21].

If clinicians routinely add antibiotics to their intra-articular injections, this study would also suggest that it is warranted for DIP joint collateral ligament injections. Inclusion of contrast with the injectable agent could be considered to visualise correct placement of the therapeutic agent, as performed routinely to evaluate accuracy of injection into the navicular bursa, but the effect of contrast (or antibiotic) on the ligament and any combined biological medication has not been determined and therefore some caution is warranted [22].

The low success rate is not surprising given that only the proximal portion of the ligament can be visualised ultrasonographically while the more distal parts are hidden within the hoof capsule, making it impossible to determine the position of the end of the needle. In addition, the collateral ligaments are thin and are intimately associated with the joint capsule of the DIP joint and the angle of needle insertion results in the tip of the needle being close to the axial margin of the ligament distally. Unfortunately, the ease of injection did not correspond to whether the tip of the needle was within the joint as both high and low resistance injections resulted in contrast in the joint in some cases.

The difference between the median dorsopalmar angle for successful injection of the ligaments and not the joint and unsuccessful injection was insignificant, but the values suggest that needle placement pointing subtly towards the toe at around eighty degrees from the horizontal is needed for a successful outcome as this follows the anatomical features of the ligament and the landmarks seen on radiography. The abaxial angle was larger (i.e. angled more abaxially) on the successful attempts than the unsuccessful attempts on both the dorsopalmar and DPrPaDiO radiographs although this was also not statistically significant. However, an abaxial location would be expected to minimise the location of the needle tip on the axial margin of the collateral ligaments where it can more easily enter the joint and may explain why there was an increased risk of entering the joint with a more proximal needle entry site as this leaves less room of angling the needle abaxially. Withdrawing the needle or not inserting the needle to bone contact may reduce the risk of entering the joint. Additionally, aspirating prior to injection could indicate that the needle has entered the joint, although this was not performed in this study. Because of the close proximity of the DIP joint to the distal insertion of the collateral ligaments, angling the bevel of the needle away from the joint may be another strategy to reduce the risk of joint injection. These techniques were not assessed in this study.

A recent study describing an ultrasound-guided method to inject the collateral ligaments was similarly based on cadaver limbs, using similar equipment and dissection techniques [19]. However, the ligaments were injected at a perpendicular angle to the fibres, as opposed to parallel in this study, which is only appropriate for proximally located lesions. The technique described here allows for the injection of the whole length of the ligament, which would be more appropriate for the majority of collateral ligament injuries[4,6,13]. The perpendicular technique was more likely to show dye in the collateral ligaments (97.4%) than this study, but also more likely to enter the joint (81.6%). However, it did not have a clinician experienced in ultrasound-guided techniques performing the injections and did not mimic weight bearing. Differences in conformation may contribute to differences in individual locations of the ligaments which supports the use of ultrasonography to identify the site of the collateral ligament prior to injecting it. The inability of both studies to visualise the distal portion of the ligament may not be relevant compared to MRI or radiography as there is no difference between the latter two in successfully injecting the distal portion of the ligaments [17]. The success rate could be improved by combining ultrasonography with radiography, which has been shown to be successful in reaching the distal portion of the ligament [16].

The limitations of both studies are mainly due to the use of a limited number of cadaver limbs and the use of CT after both collateral ligaments had been injected; therefore live studies are needed for further investigation of these techniques.

In conclusion, in-plane (supported by out-of-plane) ultrasonographic targeting of the collateral ligaments of the DIP joint facilitates accurate placement of the needle into the collateral ligament but carries a high risk of intra-articular injection. Therefore MRI, which has been shown to be more successful [17], should still be considered as the gold standard for this therapeutic approach to the medication of collateral ligament injuries.

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Conflict of Interest Disclosure:

The authors have no conflicts of interest

Authors contributions

Category 1

(a) Conception and Design: Smith RKW and Parson J

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Category 2

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Figure legends

Figure 1

Ultrasound transducer position (A and B) with corresponding ultrasound appearance (C and D). Transverse orientation (A and C) to identify location of collateral ligament (*). Longitudinal orientation (B and D) used to guide the needle distally. Solid arrows indicate the needle.

Figure 2

Lateromedial (A), dorsopalmar (B) and dorsoproximal-palmarodistal oblique (C) radiographs used to measure the orientation of the needle with respect to the solar surface (A) and digital axes (B and C) indicated by the white dotted lines. Radiographic exposure settings of 70kVp, 0.15 seconds and a film-focal distance of 1m.

Figure 3

Transverse computed tomographic image (A), dorsoproximal-palmarodistal oblique (B) and dorsopalmar (C) radiographs showing accurate injection of the collateral ligaments (positive contrast). Solid arrows indicate the needle. CT technical settings of 120kVp, 200mA, slice thickness 1.25mm, WW 3000 WL 800 and bone reconstruction. Radiographic exposure settings of 70kVp, 0.15 seconds and a film-focal distance of 1m. Images have been cropped to the region of interest only.

Figure 4

Transverse (A) and 3D reconstruction (B) computed tomographic images, and lateromedial (C) and dorsoproximal-palmarodistal oblique (D) radiographs showing positive contrast media (dashed arrows) present in the distal interphalangeal joint after needle placement (solid arrows). * indicates the presence of contrast in the region of the collateral ligament after the first injection (seen in figure 3B). CT technical settings of 120kVp, 200mA, slice thickness 1.25mm, WW 3000 WL 800 and bone reconstruction. Radiographic exposure settings of 70kVp, 0.15 seconds and a film-focal distance of 1m. Images have been cropped to the region of interest only.

Figure 5

Gross cross-sections of a foot after injection of methylene blue dye in the region of the collateral ligaments (solid arrows) but also with dye present in the distal interphalangeal joint (dashed arrows).

Table 1

Analysis of the contrast/dye made from radiographs, CT and dissection for all ligaments. Values in bold refer to those injections considered ‘successful’ (in the ligament but not in the joint. NV = no value due to technical issues.