EQUINE VETERINARY JOURNAL

EQUINE VETERINARY JOURNAL
Equine vet. J. (2010) **42** (6) 512-518
doi: 10.1111/j.2042-3306.2010.00076.x

Distribution of radiodense contrast medium after perineural injection of the palmar and palmar metacarpal nerves (low 4-point nerve block): An *in vivo* and *ex vivo* study in horses

A. NAGY*, G. BODÒ†, S. J. DYSON‡, F. COMPOSTELLA and **A. R. S. BARR**

Equine Diagnostic Centre, University of Bristol, UK; †Large Animal Hospital, Szent Istvàn University, Faculty of Veterinary Science, Budapest, Hungary; and ‡Centre for Equine Studies, Animal Health Trust, Suffolk, UK.

Keywords: horse; diagnostic analgesia; lameness; radiography

Summary

Reasons for performing study: **Evidence-based information is limited on distribution of local anaesthetic solution following perineural analgesia of the palmar (Pa) and palmar metacarpal (PaM) nerves in the distal aspect of the metacarpal (Mc) region ('low 4-point nerve block').**

Objectives: **To demonstrate the potential distribution of local anaesthetic solution after a low 4-point nerve block using a radiographic contrast model.**

Methods: **A radiodense contrast medium was injected subcutaneously over the medial or the lateral Pa nerve at the junction of the proximal three-quarters and distal quarter of the Mc region (Pa injection) and over the ipsilateral PaM nerve immediately distal to the distal aspect of the second or fourth Mc bones (PaM injection) in both forelimbs of 10 mature horses free from lameness. Radiographs were obtained 0, 10 and 20 min after injection and analysed subjectively and objectively. Methylene blue and a radiodense contrast medium were injected in 20 cadaver limbs using the same techniques. Radiographs were obtained and the limbs dissected.**

Results: **After 31/40 (77.5%) Pa injections, the pattern of the contrast medium suggested distribution in the neurovascular bundle. There was significant proximal diffusion with time, but the main contrast medium patch never progressed proximal to the mid-Mc region. The radiological appearance of 2 limbs suggested that contrast medium was present in the digital flexor tendon sheath (DFTS). After PaM injections, the contrast medium was distributed diffusely around the injection site in the majority of the limbs. In cadaver limbs, after Pa injections, the contrast medium and the dye were distributed in the neurovascular bundle in 8/20 (40%) limbs and in the DFTS in 6/20 (30%) of limbs. After PaM injections, the contrast and dye were distributed diffusely around the injection site in 9/20 (45%) limbs and showed diffuse and tubular distribution in 11/20 (55%) limbs.**

Conclusions and potential relevance: **Proximal diffusion of local anaesthetic solution after a low 4-point nerve block is unlikely to be responsible for decreasing lameness caused by pain in the proximal Mc region. The DFTS may be penetrated inadvertently when performing a low 4-point nerve block.**

Introduction

The specificity of diagnostic analgesia has been investigated in several studies (Dyson and Kidd 1993; Schumacher *et al.* 2000, 2001a,b, 2004; Gough *et al.* 2002; Harper *et al.* 2007); however, there is limited information on potential distribution after perineural blocks (Schumacher *et al.* 2004; Nagy *et al.* 2009). In a recent study, a radiographic contrast model was used to demonstrate potential distribution of local anaesthetic solution after a palmar nerve block performed at the base of the proximal sesamoid bones (Nagy *et al.* 2009). In that study, after the majority of injections, the contrast medium was determined radiographically to be located within the neurovascular bundle, and there was significant proximal diffusion of the contrast medium with time, with the most diffusion occurring during the first 10 min after injection.

Perineural analgesia of the palmar nerves at the junction of the proximal three-quarters and distal quarter of the metacarpal region and the palmar metacarpal nerves at the level of the distal aspect of the second and fourth metacarpal bones (low 4-point nerve block) is performed commonly in equine practice and should desensitise the fetlock region and the distal aspect of the limb (Bassage and Ross 2003). Anecdotal information suggests that partial improvement in the degree of lameness can be seen after a low 4-point nerve block in horses lame because of pain in the proximal metacarpal region, and that this improvement is probably due to proximal diffusion of the local anaesthetic solution (Dyson and Genovese 2003). To the authors' knowledge, there is no evidence-based information about potential distribution of local anaesthetic solution after a low 4-point nerve block.

The aims of this study were to demonstrate the potential distribution of local anaesthetic solution after a low 4-point nerve block using radiographic contrast medium in place of local anaesthetic solution and to assess the influence of weightbearing or nonweightbearing positions of the limb during injection on distribution of the solution. It was hypothesised that: 1) after injecting a contrast medium over the palmar nerve, the contrast medium would be distributed in the neurovascular bundle in most horses and that the extent of proximal diffusion would increase with time; and 2) after injecting a contrast medium over the palmar metacarpal nerves, the contrast medium would be distributed

*Corresponding author. Present address: A. Nagy, Centre for Equine Studies, Animal Health Trust, Suffolk, UK. Email: annamaria.nagy@aht.org.uk
[Paper received for publication 21.09.09; Accepted: 20.10.09]

diffusely around the injection site, indicating that it was not distributed in a neurovascular bundle.

Materials and methods

Live horses

Ten mature horses free from lameness with no palpable effusion of the digital flexor tendon sheath (DFTS) were used in the study. The junction of the proximal three-quarters and distal quarter of the metacarpal region was determined by measuring the metacarpal region (between the levels of the carpometacarpal joint and the fetlock joint), using a ruler and a radiodense marker was placed at this level on the dorsal aspect of the limb. Two ml of radiodense contrast medium (iohexol: Omnipaque 300 mg iodine/ml)[1] were injected subcutaneously over the medial or the lateral palmar nerve between the deep digital flexor tendon and the suspensory ligament at the junction of the proximal three-quarters and distal quarter of the metacarpal region (palmar injection) and another 2 ml over the medial or the lateral palmar metacarpal nerve immediately distal to the distal aspect of the second or fourth metacarpal bones (palmar metacarpal injection), using a 25 gauge 16 mm needle directed distally. On Day 1, the lateral palmar and palmar metacarpal injection sites in both forelimbs were injected. One randomly selected limb was injected while weightbearing, and the other was injected while nonweightbearing. On Day 2, the medial aspect of each limb was injected with the contrast medium at the same sites with the limb either weightbearing or nonweightbearing. If on Day 1 the limb was injected while weightbearing, then on Day 2, the limb was injected with the limb nonweightbearing and *vice versa*. All injections were performed by the same clinician (A.N.). The contrast medium was injected with no resistance, and if blood appeared in the needle hub indicating penetration of a blood vessel, the needle was redirected in a slightly palmar direction. The fetlock region was radiographed immediately after injection of the contrast medium and 10 and 20 min later[2]. Radiographic views included lateromedial and a dorsal 45° lateral-palmaromedial oblique view, if the lateral sites were injected, or a dorsal 45° medial-palmarolateral oblique radiographic view, if the medial sites were injected. The needles were left in place for the radiographs obtained immediately after injection and were then removed. All horses stood still until the last radiograph was obtained. If the radiographs indicated that some contrast medium diffused proximally beyond the area examined, radiographs of more proximal regions of the limb were also obtained, sometimes more than 20 min after injection, to determine the proximal extent of diffusion. The study was approved by the Ethical Committee of Szent Istvan University*.

Radiographs were analysed subjectively and objectively. The pattern of the patch of contrast medium was described as either elongated (Fig 1), distributed diffusely around the injection site (Figs 1, 2 and 3) or distributed diffusely, but showing a tubular pattern (Fig 2). The presence of a radiopaque line extending proximally or distally from the patch of contrast medium was recorded (Figs 1, 4). The proximal and distal extents of distribution were measured in lateromedial radiographs, as the distance between the level of the distal aspect of the sagittal ridge of the third metacarpal bone and the most proximal or distal end of the patch of contrast medium (Fig 1). Repeatability of measurements was assessed 10 times in 10 radiographs.

Normality of data was assessed using a Kolmogorov-Smirnov test. The extents of proximal and distal diffusion between subsequent radiographs were compared using a paired t test or a Wilcoxon signed rank test. Statistical significance was set at $P<0.05$. The effect of weightbearing or nonweightbearing position of the limb during injection on the distribution of the contrast medium was assessed using a Chi-squared test.

Fig 1: Lateromedial radiographic view of a left forelimb of a live horse obtained immediately after subcutaneous injections of 2 ml contrast medium over the lateral palmar nerve at the junction of the proximal three-quarters and distal quarter of the metacarpal region and over the lateral palmar metacarpal nerve immediately distal to the distal aspect of the fourth metacarpal bone. The injections had been performed with the limb weightbearing. A radiodense marker was placed dorsally at the junction of the proximal three-quarters and distal quarter of the metacarpal region. The tip of the needle at the palmar injection site is indicated with the black arrow. The contrast medium located palmarly has an elongated pattern. The extents of proximal and distal diffusion after the palmar injection were measured as the distance between the level of the distal aspect of the metacarpal condyle and the most proximal (A) or distal end of the contrast patch, (B). There is a fine radiopaque line extending proximally from the palmar contrast patch (white arrow). The contrast medium was diffusely distributed around the palmar metacarpal injection site (black arrowheads). The tip of the needle is indicated by the black arrow.

Cadaver study

A mixture of 1 ml 0.1% methylene blue and 1 ml radiodense contrast medium[1] was injected in 20 cadaver limbs using the same techniques as were used for the live horses. In 10 limbs, the injections were performed with the limb horizontal on a table, mimicking a nonweightbearing position. In another 10 limbs, the injections were performed with the limb held upright on the ground by an assistant, who applied vertical pressure to the limb to extend the fetlock to mimic a weightbearing position. In 5 limbs of each group, injections were performed on the medial aspect of the fetlock, and in the other 5 limbs, injections were performed on the lateral aspect of the fetlock. The fetlock region was radiographed immediately after injection[2], using a lateromedial view, a dorsal 45° lateral-palmaromedial oblique view, if the lateral sites were injected, and a dorsal 45° medial-palmarolateral oblique radiographic view, if the medial sites were injected. The limbs were dissected to examine the distribution of dye after the radiographs had been acquired.

Fig 2: Lateromedial radiographic view of a left forelimb of a live horse obtained 10 min after subcutaneous injection of 2 ml contrast medium over the lateral palmar nerve at the junction of the proximal three-quarters and distal quarter of the metacarpal region and over the lateral palmar metacarpal nerve immediately distal to the distal end of the fourth metacarpal bone. The injections had been performed with the limb in a nonweightbearing position. A radiodense marker was placed dorsally at the junction of the proximal three-quarters and distal quarter of the metacarpal region. The palmar patch of contrast medium has an elongated pattern (arrows). Some contrast medium is diffusely distributed around the palmar metacarpal injection site (black arrowheads), but some of the contrast medium is distributed in an elongated pattern (white arrowheads), resembling distribution of the palmar patch.

Fig 3: Lateromedial radiographic views of a right forelimb of a live horse obtained 0 (a) and 25 (b) min after subcutaneous injection of 2 ml contrast medium over the medial palmar nerve at the junction of the proximal three-quarters and distal quarter of the metacarpal region and over the medial palmar metacarpal nerve immediately distal to the distal end of the second metacarpal bone. The injections had been performed with the limb in a weightbearing position. A radiodense marker was placed dorsally at the junction of the proximal three-quarters and distal quarter of the metacarpal region. There is a thick radiopaque line extending proximally from the palmar contrast patch (arrows) and there is hardly any contrast medium left around the tip of the needle. The line could be followed up to the proximal aspect of the radius and was still present on the radiograph obtained 25 min after injection (b), suggesting distribution in a lymphatic rather than a blood vessel. The contrast medium is distributed diffusely around the palmar metacarpal injection site and there is a fine radiopaque line extending proximally from the contrast patch (b, arrowheads), suggesting distribution of contrast medium in a lymphatic vessel.

To determine how distribution of contrast medium injected into the DFTS would appear radiographically, we injected a mixture of 2 ml radiodense contrast medium, along with 2 ml povidone iodine (Betadine)[3] into the lateral aspect of the proximal pouch of the DFTS proximal to the proximal sesamoid bones using a 20 gauge, 25 mm needle in another cadaver limb. Lateromedial, dorsopalmar, dorsal 45° lateral-palmaromedial oblique and dorsal 45° medial-palmarolateral oblique radiographic views were obtained, and the limb was dissected to examine the distribution of the dye.

Results

Live horses

In total, 80 sites in 20 limbs of 10 horses were injected with the contrast medium. Half of the injections were performed with the limb weightbearing, and the other half with the limb nonweightbearing. The 240 radiographic views were analysed subjectively and measurements were made on the 120 lateromedial views. Repeatability of subjective and objective image analyses was confirmed.

Palmar injections: In the lateromedial radiographic views obtained immediately after injections, the contrast medium was seen to be distributed in an elongated pattern around the palmar injection site in 31/40 (77.5%) limbs (Fig 1), suggesting that the contrast medium was present within the neurovascular bundle. Sixteen of the 31 limbs had been injected while they were nonweightbearing, and 15 while they were weightbearing. In 3 limbs, all of which had been injected with the limb in a weightbearing position, the contrast medium was distributed diffusely around the palmar injection site, indicating that the contrast medium had not entered the neurovascular bundle.

In 2 limbs, one of which had been injected while weightbearing and the other while nonweightbearing, the proximal aspect of the contrast patch had an elongated pattern and seemed to be contained within the neurovascular bundle, but the contrast also had spread markedly distally in a pattern that indicated that some of the contrast medium was contained within the DFTS (Fig 4). In 2 limbs, most of the contrast medium was diffusely distributed, suggesting that it was outside of the neurovascular bundle, but some of the contrast medium was distributed in an elongated pattern, indicating that it was contained within the neurovascular bundle.

In one limb, all the contrast medium appeared as a 1–2 mm wide line that extended proximally (Fig 3). This appearance was consistent in all radiographs of that limb, including those obtained

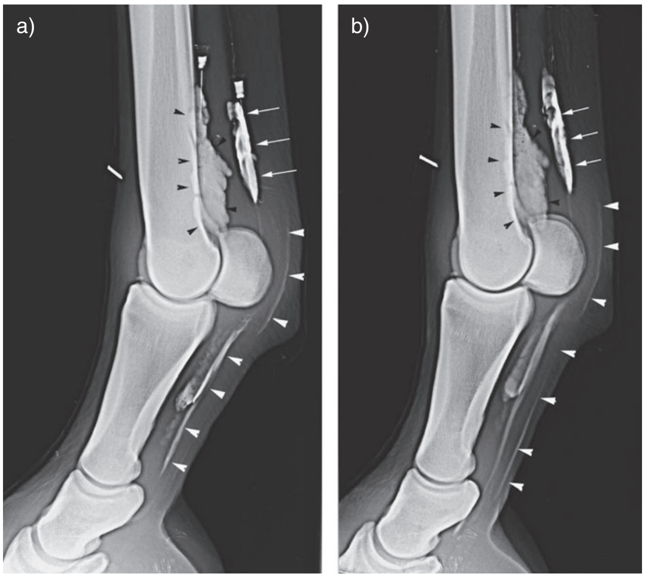

Fig 4: Lateromedial radiographic views of a left forelimb of a live horse obtained 0 (a) and 10 (b) min after subcutaneous injection of 2 ml contrast medium over the medial palmar nerve at the junction of proximal three-quarters and distal quarter of the metacarpal region and over the medial palmar metacarpal nerve immediately distal to the distal end of the second metacarpal bone. The injections had been performed with the limb in a nonweightbearing position. A radiodense marker was placed dorsally at the junction of the proximal three-quarters and distal quarter of the metacarpal region. At the palmar injection site, the proximal aspect of the contrast patch has an elongated pattern and seems to be in the neurovascular bundle (arrows), but the contrast has also spread markedly distally, in a pattern that probably represents injection or diffusion of the contrast medium into the digital flexor tendon sheath (white arrowheads). Note that in the radiograph obtained 10 min after injection (b), the dorsal wall in the distal aspect of the digital flexor tendon sheath is better defined by the contrast medium. Also note that the proximal end of the palmar patch of contrast medium is more proximal on the second than on the first radiograph, indicating proximal diffusion with time. The contrast medium is diffusely distributed around the palmar metacarpal injection site (black arrowheads).

20 min after injection, suggesting that the contrast medium was distributed in a lymphatic vessel. In one limb, a small amount of contrast medium around the injection site and a faint line extending proximally from the contrast patch were seen in the radiographs obtained immediately after injection. In the subsequent radiographs only the small patch of contrast medium around the injection site was seen, but the faint line was no longer present, suggesting that the majority of the contrast medium had been injected into a blood vessel, despite no blood having appeared in the needle hub. Whether or not the horse was weightbearing or nonweightbearing during injections did not have an effect on either the pattern or the distribution of the contrast medium.

A fine (<1 mm wide) radiopaque line extending proximally from the palmar patch of contrast medium was present in 14/40 (35%) limbs (Figs 1, 4). In one limb, this line could be identified only in the oblique radiographic view. In 3 limbs, a wider radiopaque line extended proximally from the palmar patch of contrast medium and was present in all radiographs. A fine radiopaque line extending distally from the palmar patch of contrast medium was identified in all radiographs of 4 limbs. In one limb, a wide radiopaque line extended distally from the palmar patch of contrast medium.

The tip of the needle for palmar injections could be identified in radiographs of 30 limbs, therefore allowing the extent of distribution from the tip of the needle to be measured in those 30 limbs. The mean ± s.d. extent of proximal diffusion observed in the radiographs obtained immediately after injection was 25.8 mm (± 23.9), and mean distal diffusion was 36.9 mm (± 15.4). The mean distance the contrast medium had diffused proximally after palmar injection, measured from the level of the most distal aspect of the sagittal ridge of the third metacarpal bone was 108.6 mm (± 22.3) immediately after injection, 110.9 mm (± 21.2) at 10 min and 112.5 mm (± 20.6) at 20 min. Proximal diffusion with time was significant between 0 and 10 min ($P = 0.002$) and between 10 and 20 min ($P = 0.01$). The mean distal diffusion measured from the level of the most distal aspect of the sagittal ridge of the third metacarpal bone was 50.5 mm (± 18.8) immediately after injection, 47.2 mm (± 20.2) at 10 min and 46.8 mm (± 24.8) at 20 min. In the radiographs obtained immediately after injection, the mean proximal diffusion was 116.7 mm in limbs that had been injected while weightbearing and 110.1 mm in limbs that had been injected while nonweightbearing. These data were not analysed statistically because the number of observations was too small for the statistical tests required.

Palmar metacarpal injections: After the palmar metacarpal injections, the contrast medium was diffusely distributed around the injection site in all radiographs of 27/40 (67.5%) limbs (Figs 1, 3, 4). Some of the contrast medium was distributed in a more elongated and sometimes tubular pattern in all radiographs of 13/40 (32.5%) limbs (Fig 2). A fine radiopaque line extending proximally from the patch of contrast medium was observed in radiographs of 13/40 (32.5%) limbs (Fig 4). This fine radiopaque line could be clearly identified only in the oblique radiographic views of 8 of the 13 limbs. A fine radiopaque line that extended distally was seen in radiographs of 4 limbs and in one limb, a wide radiopaque line extending distally from the palmar metacarpal patch of contrast medium was identified.

Cadaver study

Palmar injections: After the palmar injection, the contrast medium was seen radiologically to be distributed in an elongated pattern in 8/20 (40%) limbs, and dissection confirmed presence of methylene blue within the neurovascular bundle. In 3 limbs, the contrast medium and dye were seen radiologically to be distributed diffusely around the injection site, outside the neurovascular bundle. In 3 limbs, some of the contrast medium was seen in radiographs to be distributed diffusely not only around the injection site, but also in an elongated pattern, indicating that some, but not all, had entered the neurovascular bundle. Dissection revealed methylene blue around the injection site and within the neurovascular bundle. In 6/20 (30%) limbs, the radiological appearance of the limb suggested that the contrast medium had been injected into the DFTS, and this was confirmed when dye was found within the sheath during dissection. Four of these 6 limbs had been injected while they were in a nonweightbearing position.

Palmar metacarpal injections: After the palmar metacarpal injection, the contrast medium was seen radiologically to be distributed diffusely and solely around the injection site in 9/20 (45%) limbs. In at least one radiographic view of 11/20 (55%) limbs, some contrast medium, in addition to that distributed around the injection site, also appeared to surround a tubular structure, similar to how contrast medium surrounds neurovascular structures in a neurovascular bundle (Nagy *et al.* 2009). In the limb where contrast medium and povidone iodine were injected intentionally into the DFTS, both the radiological appearance of the distribution of the contrast medium and identification of dye within the DFTS during dissection of limb confirmed that the contrast medium and dye had been injected into the DFTS. Not only were the dye and contrast medium found within the DFTS, they were also found within the ipsilateral neurovascular bundle.

Discussion

After the majority of palmar injections in live horses, the contrast medium was distributed within the neurovascular bundle and diffused proximally a significant distance over time. The position of the limb (weightbearing or nonweightbearing) had no influence on whether or not contrast medium entered the neurovascular bundle. The contrast medium injected over the palmar metacarpal nerve of live horses was distributed diffusely around the injection site in the majority of limbs, but at some sites of injection, some of the contrast medium was distributed in a tubular pattern.

Palmar injections

The contrast medium was distributed in an elongated pattern after injection over the palmar nerve in 77.5% of limbs of live horses, indicating that the contrast medium had been injected into the neurovascular bundle. This incidence of injection into the neurovascular bundle after palmar injections was lower than described after injection of the site of the palmar nerve at the level of the base of the proximal sesamoid bone (89%) (Nagy *et al.* 2009). Injection of contrast medium into the neurovascular bundle at the base of a proximal sesamoid bone may be more accurate because the neurovascular bundle can be more readily palpated at the level of the proximal sesamoid bones. More proximally, in the authors' experience, the neurovascular bundle is difficult to palpate because more connective tissue lies between it and the skin, and because proximal to the proximal sesamoid bones, the neurovascular bundle courses slightly axially, which increases the depth of injection. Injection of the majority of the contrast medium into a blood vessel was observed in radiographs after one injection and injection into a lymphatic vessel was observed in radiographs after another. Injection of the majority of the contrast medium into a blood vessel or lymphatic vessel was not observed in the study examining the distribution of contrast medium injected over the palmar nerves at the base of a proximal sesamoid bone (Nagy *et al.* 2009).

In 7 limbs, most of the contrast medium was not within the neurovascular bundle. In 3 of these horses, the contrast medium was distributed diffusely around the injection site; in 2, the contrast medium was distributed both diffusely and in an elongated pattern, and in 2 limbs the contrast medium appeared to have entered the DFTS. These observations of contrast medium in locations other than within the neurovascular bundle may explain unexpected responses to a low 4-point nerve block, such as delayed desensitisation (because the local anaesthetic solution has to diffuse through the fascia surrounding the neurovascular bundle) or a false negative response.

A pattern suggesting distribution of the contrast medium into the DFTS (Hago and Vaughan 1986) was observed in one limb of 2 live horses, after palmar injections. Neither limb had palpable effusion in the DFTS before or after injection. In both horses, some contrast medium was seen in the radiographs around the injection site outside the DFTS and in one horse, contrast medium was also found within the neurovascular bundle.

It is possible that the needle had penetrated the DFTS and the contrast medium leaked from the needle hole, resulting in distribution of some of the contrast medium outside the DFTS. In one of the limbs, in the radiograph obtained immediately after injections, there was a large amount of contrast medium distributed in an elongated pattern around the palmar injection site, and only a small amount of contrast medium was in the DFTS. In both horses, the DFTS of the injected limbs appeared to contain more contrast medium in the radiographs obtained 10 min after injection than in the radiographs obtained immediately after injections. If the contrast had been injected into the DFTS and leaking from the penetration hole caused the patch of contrast medium outside the DFTS, one would expect to see less contrast medium in the DFTS in subsequent radiographs.

It is therefore possible that contrast medium diffused from the patch outside the DFTS into the DFTS through a puncture hole caused during positioning of the needle, or via an unknown mechanism of diffusion through the DFTS wall. In neither of the horses was there any indication when performing the palmar injection that the needle had penetrated the DFTS. No synovial fluid appeared in the hub of the needle, and a small subcutaneous bleb was visible at the injection site as the contrast medium was injected. One of the horses was injected while the limb was weightbearing, and the other one was injected with the limb nonweightbearing. When the limb is nonweightbearing, in the authors' experience, it is more difficult to determine the proximal extent of the DFTS, making inadvertent penetration of the DFTS more likely to occur.

A larger number of horses would be needed to determine if the position of the limb (i.e. weightbearing or nonweightbearing) influenced the risk of penetration of the DFTS. Contrast medium and dye were observed in a greater proportion of the DFTS of limbs of the cadavers than in the DFTS of the limbs of the live horses, and more of the cadaver limbs were injected while in a position that mimicked nonweightbearing than in a position that mimicked a weightbearing position. Although all cadaver limbs were injected within a few hours after the horse had been subjected to euthanasia, it is possible that the subcutaneous tissues and fasciae were adhered to each other, leading to greater number of penetrations of the DFTS. In the cadaver limb in which contrast medium and povidone iodine were deliberately injected into the DFTS, we observed distribution of the contrast medium and the dye within the DFTS and also in the neurovascular bundle on the ipsilateral side to which the injection had been performed. Inadvertent anaesthesia of the lateral palmar nerve after intrathecal anaesthesia of the DFTS has been documented and has been considered to be a result of backflow of local anaesthetic solution from the puncture hole in the DFTS. Anaesthesia of the lateral palmar nerve has been related to the site of injection of the DFTS and the size of the needle (Schneider *et al.* 2003; Harper *et al.* 2007).

In this single cadaver specimen, we injected the lateral aspect of the proximal pouch of the DFTS proximal to the proximal sesamoid bones using a 20 gauge 25 mm needle. Dissection revealed that at this level, there is no connective tissue between the fascia of the neurovascular bundle and the DFTS wall, which explains why inadvertent penetration of the DFTS may occur easily if the palmar nerve block is performed at the junction of the proximal three-quarters and distal quarter of the metacarpal region and also why backflow of local anaesthetic solution after intrathecal injection of the DFTS at the lateral aspect of the proximal pouch may anaesthetise the palmar nerve.

Penetration of the DFTS seen in our study raises concerns about potential iatrogenic synovial sepsis. In this study, the injection sites of the live horses were not clipped prior to injection, and although the sites were thoroughly cleaned, the limbs were not prepared for aseptic injection. Neither of the 2 horses whose DFTS was penetrated developed effusion of the DFTS or lameness after the study. To our knowledge, sepsis of the DFTS after a low 4-point nerve block has not been reported. Some other nerve blocks (e.g. subcarpal and subtarsal nerve blocks) also have the potential for inadvertent penetration of a synovial cavity (Dyson and Romero 1993; Bassage and Ross 2003). For these blocks, aseptic preparation is advised (Bassage and Ross 2003), but is not performed routinely by many clinicians (authors' observations). To our knowledge, infection of a synovial cavity resulting from a perineural block has not been reported, but one author (S.J.D.) is aware that this has occurred (R. Smith, personal communication). Based on the results of the current study, we recommend extra care (thorough cleaning and clipping if the hair does not permit adequate cleaning) when preparing for blocking the palmar nerves when performing a low 4-point nerve block. To minimise the risk of iatrogenic infection of the DFTS, the palmar injection should be performed proximal to the proximal extent of the DFTS. This, depending on the degree of DFTS effusion, may run the risk of desensitising more proximal structures.

The most proximal extent of the contrast medium, measured from the tip of the needle in the radiograph obtained immediately after performing the palmar injection, was 80.9 mm. The most proximal extent of a palmar patch of contrast medium was measured 156 mm proximal from the most distal aspect of the sagittal ridge of the third metacarpal bone. These results suggest that structures in the mid-metacarpal region (superficial and deep digital flexor tendons and the accessory ligament of the deep digital flexor tendon) could be desensitised after a low 4-point nerve block, but it is unlikely that diffusion of local anaesthetic solution can be responsible for desensitising structures in the proximal metacarpal region. However, the proximal-distal location of the injection site for anaesthetising the palmar nerve obviously has an effect on the extent of proximal diffusion. In the current study, significant proximal diffusion occurred with time, as was previously reported after injecting a radiodense contrast medium over the palmar nerves at the base of the proximal sesamoid bones (Nagy *et al.* 2009). These observations show that the longer the time between a perineural block and the assessment of its effect, the more likely it is that proximal structures are desensitised.

A fine radiopaque line extending proximally from the palmar patch of contrast medium was seen in 35% of limbs (14/40) and in 3 other limbs, a wide, but short line extending proximally was observed. A fine radiopaque line extending distally from the palmar contrast patch was identified in 10% limbs and, in one limb, a wide radiopaque line extended distally. These fine and wider lines were present in all radiographs of limbs of live horses and suggest distribution of contrast medium into lymphatic vessels of variable size.

Palmar metacarpal injections

Diffuse distribution of the contrast medium around the injection site after palmar metacarpal injections was observed in 67.5% (27/40) of limbs of the live horses, and diffuse distribution of methylene blue around the injection site after palmar metacarpal injections was observed in 45% (9/20) of the cadaver limbs. In the rest of the limbs of the live horses (32.5%, 13/40), some of the contrast medium was distributed in an elongated and sometimes tubular pattern, suggesting diffusion around and along the palmar metacarpal nerves. Dissection revealed that, unlike around the palmar nerve and vascular structures in the distal metacarpal region, fascia does not surround the palmar metacarpal neurovascular structures. A solely elongated pattern and marked proximal diffusion were not observed after a palmar metacarpal injection. Depending on the location of the distal extremity of the second and fourth metacarpal bones, the proximal margin of the patch of contrast medium was sometimes seen between the distal one-third and one half of the metacarpal region. It is therefore unlikely that after a palmar metacarpal injection immediately distal to the distal aspect of the second and fourth metacarpal bones, diffusion would result in improvement of pain in the proximal metacarpal region. The explanation for a low 4-point block improving lameness associated with proximal suspensory desmitis (Dyson and Genovese 2003) may be due to painful lesions in the suspensory ligament extending further distally than can be appreciated ultrasonographically, or the presence of a concurrent site of pain in the fetlock region.

Although in some horses the distal aspect of the second or fourth metacarpal bone was at the level of the proximal extent of the palmar pouch of the metacarpophalangeal joint, distribution of contrast medium into the metacarpophalangeal joint after palmar metacarpal injections was not seen in any radiograph of any horse. Dissection revealed thick connective tissue separating the palmar metacarpal nerves and the metacarpophalangeal joint capsule, which may explain why inadvertent penetration of the joint is less likely to occur than inadvertent penetration of the DFTS.

The position of the limb did not have an effect on the distribution of the contrast medium. In the authors' experience, some horses tolerate a low 4-point nerve block better if the limb is on the ground, and others are easier to inject if the limb is picked up. The results of this study suggest that with either injection technique similar results can be expected.

Limitations

In a previous study (Nagy *et al.* 2009), it was demonstrated that the limb (left vs. right), the side of injection (medial vs. lateral) or walking did not have an effect on the distribution or extent of diffusion after perineural injection at the level of the base of the proximal sesamoid bones and therefore the influences of these factors were not assessed in the current study. Accuracy of injection of the palmar nerves in the metacarpal region in the current study was less than the accuracy of injection of the palmar nerves at the level of the base of the proximal sesamoid bones (Nagy *et al.* 2009), and it is possible that had the horses been walked in the current study, the contrast medium might have been more widely distributed. There was also no significant difference between subjective or objective measurements of distribution of the contrast medium obtained after medial and lateral injections in the previous study, and therefore, only unilateral injections were performed in the current study.

Conclusions

After injection over the palmar nerve at the level of the junction of the proximal three-quarters and distal quarter of 40 metacarpi of live horses, only 77.5% of injections resulted in distribution of contrast medium into the neurovascular bundle. Inadvertent injection of local anaesthetic solution outside the neurovascular bundle could explain either a delayed effect of nerve blocks or failure to achieve adequate desensitisation of the fetlock region. It is unlikely that proximal diffusion of local anaesthetic solution after a low 4-point nerve block would be responsible for improving pain originating in the proximal metacarpal region. However, improvement in lameness may be seen if the pain extends distally to the mid-metacarpal region. There is a possibility of inadvertent and unrecognised penetration of the DFTS when performing a low 4-point nerve block.

Acknowledgements

We are grateful to Peter Toth, Arpad Nagy and the technicians of the Large Animal Hospital of Szent Istvan University for their help with the study in live horses.

*The radiographic study was performed in the Large Animal Hospital of Szent Istvan University, Budapest, Hungary after approval of the Ethical Committee of Szent Istvan University, Budapest, Hungary. The studies using cadaver limbs were performed at the University of Bristol.

Manufacturers' addresses

[1]GE Healthcare, Oslo, Norway.
[2]Philips Computed Radiography, Philips Medical System International B.V., Eindhoven, The Netherlands.
[3]Medlock Medical, Oldham, Lancashire, UK.

References

Bassage, L.H. and Ross, M.W. (2003) Diagnostic analgesia. In: *Diagnosis and Management of Lameness in the Horse*, 1st edn., Eds: M.W. Ross and S.J. Dyson, Elsevier Science, St Louis. pp 93-124.

Dyson, S.J. and Genovese, R.L. (2003) The suspensory apparatus. In: *Diagnosis and Management of Lameness in the Horse*, 1st edn., Eds: M.W. Ross and S.J. Dyson, Elsevier Science, St Louis. pp 654-672.

Dyson, S.J. and Kidd, L. (1993) A comparison of responses to analgesia of the navicular bursa and intra-articular analgesia of the distal interphalangeal joint in 59 horses. *Equine vet. J.* **25**, 93-98.

Dyson, S.J. and Romero, J.M. (1993) An investigation of injection techniques for local analgesia of the equine distal tarsus and proximal metatarsus. *Equine vet. J.* **25**, 30-35.

Gough, M.R., Mayhew, I.J. and Munroe, G.A. (2002) Diffusion of mepivacaine between adjacent synovial structures in the horse. Part 1: forelimb foot and carpus. *Equine vet. J.* **34**, 80-84.

Hago, B.E.D. and Vaughan, L.C. (1986) Radiographic anatomy of tendon sheaths and bursae in the horse. *Equine vet. J.* **18**, 102-106.

Harper, J., Schumacher, J., DeGraves, F., Schramme, M. and Schumacher, J. (2007) Effects of analgesia of the digital flexor tendon sheath on pain originating in the sole, distal interphalangeal joint or navicular bursa of horses. *Equine vet. J.* **39**, 535-539.

Nagy, A., Bodo, G., Dyson, S., Szabo, F. and Barr, A. (2009) Diffusion of contrast medium after perineural injection of the palmar nerves: an *in vivo* and *in vitro* study. *Equine vet. J.* **41**, 379-383.

Schneider, R., Gavin, P. and Tucker, R. (2003) What magnetic resonance imaging is teaching us about navicular disease. *Proc. Am. Ass. equine Practnrs.* **49**, 210-219.

Schumacher, J., Livesey, L., De Graves, F.J., Schumacher, J., Schramme, M.C., Hathcock, J., Taintor, J. and Gomez, J. (2004) Effect of anaesthesia of the palmar digital nerves on proximal interphalangeal joint pain in the horse. *Equine vet. J.* **36**, 409-414.

Schumacher, J., Schumacher, J., De Graves, F., Steiger, R., Schramme, M., Smith, R. and Coker, M. (2001a) A comparison of the effects of two volumes of local analgesic solution in the distal interphalangeal joint of horses with lameness caused by solar toe or solar heel pain. *Equine vet. J.* **33**, 265-268.

Schumacher, J., Schumacher, J., De Graves, F. Schramme, M., Smith, R., Coker, M. and Steiger, R. (2001b) A comparison of the effects of local analgesic solution in the navicular bursa of horses with lameness caused by solar toe or solar heel pain. *Equine vet. J.* **33**, 386-389.

Schumacher, J., Steiger, J., Schumacher, J. de Graves, F., Schramme, M., Smith, R. and Coker, M. (2000) Effects of analgesia of the distal interphalangeal joint or palmar digital nerves on lameness caused by solar pain in horses. *Vet. Surg.* **29**, 54-58.

Author contributions The initiation, conception and planning of this study were by A.N., G.B., S.J.D. and A.R.S.B., the execution by A.N., G.B. and F.C. The pathology was by A.N. and F.C. with statistics by A.N. and the paper was written by A.N., S.J.D. and A.B.