Is anaesthesia of the deep branch of the lateral plantar nerve specific for the diagnosis of proximal metatarsal pain in the horse?

G. Hinnigan¹; P. Milner²; A. Talbot¹; E. Singer²

¹Dalehead Veterinary Group, Settle, North Yorkshire, UK; ²Department of Musculoskeletal Biology, Institute of Ageing and Chronic Disease, Faculty of Health and Life Sciences, University of Liverpool, Leahurst Campus, Neston, Wirral, UK

Summary

Objectives: To investigate the specificity of anaesthesia of the deep branch of the lateral plantar nerve (DB-LPN).

Methods: Twenty horses had DB-LPN anaesthesia performed by a single injection technique as part of a lameness investigation. The mechanical nociceptive threshold (NT) was measured using a handheld force meter at six points on the lateral aspect of the limb: before diagnostic anaesthesia (T0), and at 15 (T15) and 30 (T30) minutes post anaesthesia. Paired t-tests were performed and significance was set at p <0.05. In addition, ten cadaveric limbs were injected with 2.5 ml new methylene blue solution using a single injection technique to evaluate the extent of dye diffusion within the proximal metatarsal region.

Results: Compared with T0, there was a significant decrease in NT for all points combined at T15 (p = 0.008) and also at T30 (p = 0.007). There was a significant decrease in NT at T15 on the lateral third metatarsal bone (p = 0.012). At T30 there was a significant decrease in NT at the lateral sesamoid (p = 0.007), lateral third metatarsal bone (p = 0.031), and mid metatarsus (p = 0.033). Four out of 20 horses had a NT greater than 10 N at the lateral heel bulb at T30. In the cadaveric limbs, the total diffusion distance for all limbs (mean ± SD) was 70.4 ± 20.5 mm. Dye surrounded the DB-LPN in all limbs and the lateral plantar nerve (LPN) in nine out of 10 limbs.

Clinical significance: Concurrent anaesthesia of the LPN is likely to occur when DB-LPN anaesthesia is performed using a single injection technique.

Introduction

Diagnostic anaesthetic techniques are well established and are routinely used to localize the source of lameness in the horse (1). The specificity of several perineural and intra-synovial diagnostic anaesthetic techniques of the distal limb have been investigated (2–6). False positive results from diagnostic anaesthesia of the distal limb have been attributed to diffusion of local anaesthetic solution from the intended injection site or incorrect needle placement (2, 5, 7). Accurate diagnosis of conditions of the proximal metatarsal region, particularly proximal suspensory desmitis, is heavily reliant upon diagnostic anaesthetic techniques. In cases of proximal suspensory desmitis, there are often no localizing clinical signs, and radiographic and ultrasonographic findings can be equivocal with considerable overlap between normal and abnormal horses (8, 9). Advanced imaging such as nuclear scintigraphy and magnetic resonance imaging can provide further diagnostic information; however, these techniques are not available or employed in all cases (9-11).

Several different techniques for anaesthesia of the proximal metatarsal region have been described (12–14). Inadvertent injection of local anaesthetic solution into the tarsal sheath or the tarsometatarsal joint can occur, which may lead to false negative or false positive results. Single injection techniques for anaesthesia of the deep branch of the lateral plantar nerve (DB-LPN) have been described. Lateral placement of the needle reduces the risk of inadvertent penetration of the tarsometatarsal joint and the tarsal sheath, when compared with other methods of proximal metatarsal anaesthesia (13, 14). Hughes and colleagues concluded that a 25 mm needle inserted axial and 15 mm distal to the head of the fourth metatarsal bone was an accurate technique in an in vitro model. In 18 of 19 limbs (95%), a small volume of solution (0.2 ml) would have resulted in anaesthesia of only the DB-LPN in this model. Due to the close anatomical relationship between the DB-LPN and the lat-
eral plantar nerve (LPN) in the proximal metatarsal region (Figure 1), the in vivo result of local anaesthetic placed in the region of the DB-LPN may differ from that noted in vitro. Contrast material is known to diffuse over a variable distance following perineural injection. This has been shown in proximal metatarsal bones injection techniques, perineural injection of the palmar nerves at the level of the proximal sesamoid bones, perineural injection in the proximal metacarpal region, and perineural injection of the DB-LPN (12, 15-17). Therefore, in vivo, the volume used for local anaesthesia of the DB-LPN (2-4 ml) may result in anaesthesia of both the DB-LPN and the LPN. Inadvertent anaesthesia of the LPN could lead to pathological conditions of the distal lateral limb corresponding to sub-tarsal anaesthesia, thus providing a misleading result as to the origin of the lameness.

The abolition of skin sensation is routinely used in equine practice to ascertain whether perineural diagnostic anaesthesia has been performed correctly, and has resulted in desensitization of the expected area of the distal limb (1). Subjective testing of skin sensation is routinely performed with a blunt, pointed object pressed into the skin, with a view to stimulating withdrawal or avoidance behaviour if sensation is still present. Mechanical and electrical nociceptive thresholds (NT), which allow objective assessment of skin sensation are rarely used to evaluate diagnostic anaesthetic results in the horse (18). The analgesic effects of extracorporeal shock wave therapy and systemic alpha-2 agonist administration have been investigated using NT in the horse (19, 20). In the study presented here, semi-quantitative mechanical NT measurement was used to quantify the effect of diagnostic anaesthesia of the DB-LPN on skin sensation in the distal lateral aspect of the pelvic limb. An increase in the mechanical NT would indicate a reduction in skin sensitivity.

The purpose of the study was two-fold. The first aim was to evaluate the effect of anaesthesia of the DB-LPN on the NT at specific anatomic sites of the distal limb of the horse in vivo. Our hypothesis was that anaesthesia of the DB-LPN would lead to an increase in NT on the distal lateral aspect of the limb, distal to the site of local anaesthetic placement, due to concurrent anaesthesia of the LPN. The second aim was to measure the distribution of a clinically relevant volume of dye in an in vitro model of the DB-LPN block. Our hypothesis was that dye would disperse beyond the DB-LPN, in particular to include the LPN.

Materials and methods

Nociceptive threshold assessment

Twenty client-owned horses referred for investigation of pelvic limb lameness had DB-LPN anaesthesia performed as part of a diagnostic investigation. All clients consented to their horses taking part in the study. There were eight mares and 12 geldings with a mean age of 7.9 years (range 5-15) of various breeds (10 Warmblood, 5 Thoroughbred cross, 2 Connemara, 1 Thoroughbred, 1 Appaloosa, 1 Cob cross). Following clipping and aseptic preparation of an area of approximately 10 cm² in the region of the proximal plantar metatarsus, anaesthesia of the DB-LPN was performed. The nerve block was performed using a 25 mm, 23 or 22 gauge needle inserted 15 mm distal to the head of the fourth metatarsal bone with the pelvic limb flexed and the digital flexor tendons displaced medially. The needle was inserted perpendicular to the skin and into the hub (14). Two and a half ml of 2% w/v mepivacaine hydrochloride were injected, as per the standard protocol in the hospital, which is slightly less than the referenced volume of 3 ml (1). No medications with sedative or analgesic effects were administered to any of the horses included in the study.

Figure 1 Line drawing illustrating the course of the plantar nerves in the tarsal region of the horse. The dorsal nerves of this region are not illustrated. The deep branch of the lateral plantar nerve separates from the lateral plantar nerve in the distal tarsal region proximal to the level of the tarsometatarsal joint. a = tibial nerve; b = medial plantar nerve; c = lateral plantar nerve; d = deep branch of the lateral plantar nerve; e = communicating branch.

Figure 2 Schematic of the anatomical points for nociceptive threshold testing on the lateral aspect of the left pelvic limb.

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The mechanical NT was measured at six points (P1-P6) on the lateral aspect of the pelvic limb (Figure 2). These points were: 1 cm proximal to the coronary band at the heel bulb (P1); 1 cm proximal to the coronary band on the dorsal lateral aspect of the pastern (P2); the lateral proximal sesamoid bone (P3); the third metatarsal bone at the level of the metatarsophalangeal joint (P4); the skin over the deep digital flexor tendon in the mid metatarsal region (P5); and the site of needle puncture of perineural anaesthesia (P6). Each individual NT measurement was always performed in the same order (P1 to P6) at three time points: before diagnostic anaesthesia (T0), and at 15 (T15) and at 30 minutes (T30) following diagnostic anaesthesia. The horses were all walked and trotted in a straight line and in circles, as part of their lameness investigation between T15 and T30. The diagnostic anaesthesia and the data collection for each horse were performed in the same diagnostic suite within the hospital and by the same operator (GJH). The NT was measured semi-quantitatively in Newtons (N) with a handheld force meterb (Figure 3) attached to a blunted 2 mm diameter metallic probe. Pressure was applied to the limb over approximately two to three seconds with the ipsilateral eye covered. Movement of the horse, lifting of the limb or greater than 10 N of force applied (the maximum force measurable with the force meter) indicated the test end point.

Diffusion study

Ten cadaveric pelvic limbs were removed at the mid-tibia level from horses euthanatized for reasons other than proximal metatarsal pain. The limbs were held in flexion to mimic the in vivo situation for placement of the DB-LPN block. The injection was performed in an identical fashion to the NT assessment, using 2.5 ml of 0.5% w/v methylene blue solution rather than local anaesthetic. The limb was straightened and kept upright for ten minutes, after which the limbs were dissected, preserving the neurovascular bundle of the LPN, DB-LPN and medial plantar nerve (MPN). The proximal and distal extent of dye distribution relative to the fixed reference point of the head of fourth metatarsal bone was measured. Dye staining of the LPN, DB-LPN, MPN or tarsal sheath was recorded.

Statistical analysis

Descriptive statistics were performed for both parts of the study. For the NT measurements, normality was determined with a normal Q-Q plot. The NT data were analysed using a commercially available statistical software programc. Paired sample t-tests were performed comparing TO, T15 and T30 for all anatomical points combined. Each individual anatomical point (P1 – P6) was then compared between T0 and T15 and then T0 and T30. Statistical significance was set at p < 0.05.

Results

Nociceptive threshold measurement

The NT (mean ± SE) for all points on the limb at T0 (3.45 ± 0.20 N) and T15 (2.67 ± 0.23 N) was significantly different (p = 0.008). The mean NT for all points on the limb at T30 (2.68 ± 0.25 N) was significantly different to T0 (p = 0.007), but not T15 (p = 0.914). When the individual points were tested, a significant decrease in NT was noted between T0 to T15 at P4 (p = 0.012), with no difference at any other point on the limb at this time point. At T30 there had been a significant decrease in NT at P3 (p = 0.007), P4 (p = 0.031), and P5 (p = 0.033) with no significant change at P1, P2 and P6 (Figure 4).

Out of a total of 360 individual NT measurements, the test end point was indicated by movement of the horse in 97.5% (351/360) of tests, with nine test points failing to elicit a withdrawal response. In these nine tests, a force of greater than 10N was applied without eliciting a reaction from the horse. Four out of 20 horses had a NT greater than 10N at the lateral heel bulb (P1) at T30. Two of these four individual horses had a NT greater than 10N at T15 at P1. One horse had a NT greater than 10N at the dorsal lateral coronary band (P2) at T30. One horse had a NT greater than 10N at P6 at T15 and T30. None of the pre-local anaesthetic NT measurements (T0) failed to elicit a withdrawal response.

Diffusion study

The diffusion distance for all limbs (mean ± SD) was 32.0 ± 21.1 mm proximal to and 38.4 ± 16.5 mm distal to the head of the fourth metatarsal bone, with a total distance of 70.4 ± 20.5 mm. The maximum diffusion distance identified was 62 mm proximal to the head of the

b RVFM Products, Rapid Electronics Ltd, Colchester, Essex, UK
c PASW statistics 17.0 for Windows: SPSS Inc., Chicago, Illinois, USA
fourth metatarsal bone and 73 mm distal to the head of the fourth metatarsal bone. In all limbs, there was dye surrounding the DB-LPN. In nine out of 10 limbs the LPN was also surrounded by dye (▶ Figure 5). Although no dye was found staining the lateral deep digital flexor tendon or synovial fluid of the tarsal sheath, the lateral wall of tarsal sheath structure was stained in three of 10 limbs. No dye was found adjacent to the MPN and no injections into the tarsometatarsal joint were identified.

**Discussion**

The aim of the study was to investigate the specificity of anaesthesia of the DB-LPN for diagnosis of proximal metatarsal pain. An alteration in skin sensation of the distal limb, assessed by NT measurement, would indicate that conditions of the distal limb may be affected by DB-LPN anaesthesia. When considering individual animals, four horses in this study had an NT greater than 10 N at the lateral heel bulb (P1) 30 minutes following anaesthesia of the DB-LPN, which was greater than three times the mean NT for all anatomical points. Based on the baseline response to application of the probe (3.45 ± 0.20 N at T0), 10 N was considered a substantial force to apply without eliciting a withdrawal response from the horse. This lack of a response indicates that skin sensation was lost or substantially reduced at this anatomic location as a result of local anaesthetic placed for the DB-LPN anaesthesia.

Innervation of the pelvic limb lateral heel bulb is derived predominantly from the LPN, indicating that this nerve had been anaesthetised in the individual horses that were non-responsive to the application of the probe. Only two of these horses had an NT greater than 10 N at the lateral heel bulb at 15 minutes which would indicate that over time, further diffusion of local anaesthetic in the proximal plantar aspect of the metatarsus led to anaesthesia of the LPN in these horses. One horse had an NT greater than 10 N at the dorsal coronary band (P2) at T30, a point on the limb that also receives innervation from the LPN. These findings support the theory that the LPN is anaesthetized in a proportion of cases following attempted anaesthesia of the DB-LPN. The only other point on the limb at which the test end point was greater than 10 N was P6 in one horse. Although skin sensation at this point was unlikely to be affected by anaesthesia of the LPN, lack of sensation could be attributed to diffusion of local anaesthetic to the skin at the site of the needle puncture.

The potential for anaesthesia of the LPN to occur with the DB-LPN block was supported by the findings of our diffusion study in which nine of 10 limbs demonstrated dye surrounding the LPN, as well as the DB-LPN. Despite the limitations of assuming that cadaveric dissection studies are equivalent to the in vivo situation, these results support the potential desensitization of nerves proximal and distal to the specific injection site for the DB-LPN block. The molecular properties of methyl-
ene blue solution are different to those of the lower molecular weight mepivacaine hydrochloride solution. It has been suggested that the lower molecular weight may lead to greater diffusion of mepivacaine hydrochloride when compared to methylene blue (15). Greater diffusion of solutions may be anticipated in vivo when compared with an in vitro dissection study, due to active circulation and movement of the horse following the injection, although no attempt to quantify this was made here. Contrast medium has been shown to diffuse a greater distance as time progresses following perineural injection of the DB-LPN in an in vivo model (16). This finding supports our conclusion that further diffusion of anaesthetic was responsible for differences at T15 and T30 of the horses that had an NT greater than 10N at P1. Similar to previous studies, we have assumed that staining of the nerve with dye would be equivalent to a successful ‘block’ of the nerve when using local anaesthetic (14–16). The total mean distance of diffusion was 70.4 ± 20.5 mm, which was comparable to studies assessing diffusion following perineural injections of the palmar nerves at the base of the fetlock and of the nerves of the proximal metacarpal and metatarsal regions (15–17). In the current study, the dye diffused proximally and distally between fascial planes and often extended dorsal to the plantar ligament. There were no inadvertent injections into the tarsometatarsal joint or the tarsal sheath; however, there was staining of the lateral tarsal sheath wall in three of 10 limbs. Therefore, we suggest that the tarsal sheath, the DDFT and possibly other structures of the tarsal region may be desensitized inadvertently in clinical cases, following a single injection technique to block the DB-LPN. This is in agreement with other work regarding the diffusion of local anaesthetic and contrast material following perineural injection of the DB-LPN. These studies showed the possible diffusion and inadvertent anaesthesia of synovial structures in the proximal metatarsal region (17, 21). A reduction in the volume of local anaesthetic used increases the specificity of the technique (21). The single injection technique has been shown to accurately place a small volume (0.25 ml) of solution in contact with the DB-LPN (14). Although in clinical cases 0.25 ml may not be considered a sufficient volume, reducing the injection volume to 1 ml may lead to greater specificity whilst still anaesthetizing the DB-LPN.

There was no anatomical point on the limb at which an increase in the mean NT of all horses was measured at either T15 or T30. The mean NT for all points on the limb combined actually showed a significant reduction from T0 to T15 and from T0 to T30. The overall reduction in NT from T0 to T15 and T0 to T30 represented a generalized increase in responsiveness of the horses to the stimulus applied following diagnostic anaesthesia. When the anatomical test points were considered separately, there was no significant change in NT at P1, P2, or P6 at either T15 or T30 (Figure 4); however, the NT had reduced significantly at P3, P4 and P5, indicating that overall, the horses were more sensitive to stimulus at T30. This reduction in NT following a painful procedure such as a perineural injection may be an expected result. Mechanical NT has been shown to be significantly lowered in the region around a skin incision (22). Hyperalgesia (an increased response to a normally painful stimulus) and allodynia (pain caused by a normally non painful stimulus) are thought to be responsible for a reduction in NT around a surgical wound. However, the mechanisms that result in hyperalgesia and allodynia require a significant degree of tissue inflammation and central sensitization (23). Although 2% mepivacaine solution is known to be an irritant, the low volumes administered in diagnostic anaesthesia rarely cause signs of inflammation or pain at the site of injection in clinical cases. Therefore, a single perineural injection was not considered to be sufficient to induce a physiological response of hyperalgesia or allodynia. The reduction in the NT was more likely to represent a learned response by the horses to repeated measurements. The anticipation of the noxious stimulus may have led to a ‘hypersensitivity’ to that stimulus. Anticipation of the stimulus was apparent whilst performing the study, as some horses quickly reacted to a very low force (less than one N). Repetition of the stimulus was unavoidable, as the testing had to take place within the time constraints of performing the lameness examination and to adhere to the study protocol. Given this learned response to repetitive stimulation, the lack of response to a stimulus of greater than 10N in individual horses is particularly notable.

The mean NT for all points on the limb prior to performing the perineural anaesthesia was 3.48 ± 0.20 N, which is consistent with reported values for mechanical NT in the horse of between 2 and 6 N, dependent on the diameter of the probe used to exert the force, and hence the pressure applied (18, 19). The NT measurement was performed semi-quantitatively with a handheld force meter in this study. There was a larger variation in the mean NT when compared to other studies that assessed mechanical NT on the distal limb of the horse at only one anatomical point on the limb (19, 21). Threshold testing of one anatomical point enabled a bandage to be placed on the limb and the mechanical stimulus to be applied remotely. Therefore, mechanical NT could not only be measured more accurately but the horse was also less able to anticipate the stimulus being applied. Given the multiple anatomical test points used in this study, semi-quantitative measurement was considered acceptable and superior to subjective assessment of abolition of skin sensation. It is possible that semi-quantitative NT measurement was not a sensitive enough method to detect subtle alterations in cutaneous sensation; however, it did demonstrate a total loss of response to the stimulus in a number of horses.

There may be several reasons to explain why most horses failed to show an increase in NT in the distal lateral limb following single injection technique DB-LPN anaesthesia. Cutaneous innervation to the distal lateral pelvic limb is derived from branches of the tibial and peroneal nerves. There is some disagreement as to the exact cutaneous zones which each nerve supplies (24, 25). There is certainly greater importance of the dorsal nerve supply to skin sensation in the distal pelvic limb as compared to the thoracic limb. The dorsal nerve supply to the distal pelvic limb is derived from the peroneal nerve and its distal branches, and is likely to provide some de-
degree of innervation to many of the points investigated in the NT study. Unfortunately, there are no autonomous cutaneous innervation zones for the LPN, DB-LPN or the plantar metatarsal nerves. If such zones were available, accurate assessment of the specificity of DB-LPN anaesthesia would be possible using NT measurement. Given the complex cutaneous innervation of the distal lateral limb it may be that semi-quantitative NT measurement, especially given the anticipation of the stimulus as discussed above, was not a sensitive enough method to detect subtle alterations in cutaneous sensation. Since all of these nerves are distal branches of the tibial nerve, and are all located in the anatomically narrow portion of the proximal metatarsal region, we must question the ability for placement of local anaesthetic on the DB-LPN without affecting the surrounding nerves.

The failure of all horses to show an increase in mean NT in the distal lateral limb may be attributable to the communication from the MPN to the LPN in the mid metatarsal region (Figure 1). Even if the LPN is anaesthetized in the proximal metatarsal region, the communicating fibres from the un-anaesthetized MPN are likely to provide sensory innervation to the lateral distal limb. The communication between the medial and lateral plantar nerves is more slender in the pelvic as compared to the thoracic limb lateral palmar nerve communication; however, any sensory fibre crossover could be sufficient for sensation to the skin in the region to remain (26). A different explanation for the degree of variation in NT could be that in those individuals with an increased NT in the distal lateral limb, the MPN had also been anaesthetized in the proximal metatarsal region. Following a dissection study, Hughes and colleagues suggested that a DB-LPN block could result in anaesthesia of both medial and lateral plantar nerves due to their proximity in the proximal metatarsal region. Diffusion to affect the MPN was not supported by the results of the dye diffusion study presented here, which was performed at the identical injection site to Hughes and colleagues, but with a higher volume of dye which more accurately represents the volume used in the clinical situation. The NT was not measured on the medial aspect of the limb to minimize the total number of measurement points and due to operator safety in accurately measuring NT on the medial aspect of the pelvic limb. The NT measurements were not performed on the contralateral limb due to time constraints and concerns for operator safety, although these additional points could have acted as further internal control points.

The NT study provides clinical evidence that in a proportion of horses, desensitization of structures distal to the fetlock on the lateral aspect of the limb may occur following placement of local anaesthetic for of the DB-LPN block. The dye diffusion study supports the poor specificity of the DB-LPN block by providing evidence that local anaesthesia of the LPN is likely to occur due to diffusion of local anaesthetic placed. Since structures in addition to those in the proximal metatarsal region may be anaesthetized with the DB-LPN block, false positive results to diagnostic anaesthesia of the DB-LPN will occur, potentially leading to an inaccurate diagnosis of the source of lameness. Specific diagnostic anaesthetic techniques of the distal metatarsal region and below must be performed whenever a positive response to anaesthesia of the DB-LPN is obtained, to prevent misdiagnosis of pain originating from the proximal metatarsal region.

**Conflict of interest**

There are no conflicts of interest to declare.

**References**