Journal of Equine Veterinary Science 70 (2018) 91–95

Contents lists available at ScienceDirect

Journal of Equine Veterinary Science

journal homepage: www.j-evs.com

Original Research

Objective Evaluation of the Response to Perineural Analgesia of the Deep Branch of the Lateral Plantar Nerve and Intraarticular Analgesia of the Tarsometatarsal Joint in Horses With Suspected Proximal Metatarsal Pain Using Body-Mounted Inertial Sensors

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ARTICLE INFO

Article history:
Received 17 May 2018
Received in revised form
15 July 2018
Accepted 16 July 2018
Available online 2 August 2018

Keywords:
Horse
Proximal suspensory ligament
Deep branch of lateral plantar nerve
Distal tarsal joints
Diagnostic analgesia
Objective lameness analysis

ABSTRACT

Perineural analgesia of the deep branch of the lateral plantar nerve (DBLPN block) and intraarticular analgesia of the tarsometatarsal joint (TMT block) are commonly used to differentiate pain originating from the distal tarsal and the proximal metatarsal areas in horses. However, both analgesic techniques have recently been subjected to close scrutiny, with questions raised as to their efficacy. The purpose of this study is to undertake an objective assessment of the effect of both diagnostic analgesia techniques on hindlimb lameness using a body-mounted inertial sensor system (Lameness Locator; Equinosis LLC, Columbia, MO). Horses with chronic hindlimb lameness were instrumented with inertial sensors measuring vertical pelvic asymmetry in millimeters and underwent a routine lameness examination including diagnostic analgesia. Twenty-seven horses showing an improvement in lameness after the DBLPN block were selected for the study. These horses underwent the TMT block on the following day. The change in vertical pelvic asymmetry after the DBLPN block was compared to the change following the TMT block. Of 27 horses, 17 showed improvement after the DBLPN block but not after the TMT block (group 1). The other 10 horses showed improvement in lameness after both analgesic techniques (group 2). The DBLPN block and the TMT block desensitized different structures in more than half of the horses. However, the possibility that both analgesic techniques can desensitize the same structures due to either the diffusion of the anesthetic agent or of an inadvertent injection still remains.

1. Introduction

Chronic, low-grade, hindlimb lameness caused by pain arising from the distal tarsal and proximal metatarsal area is common in sport horses across all disciplines. Proximal suspensory desmopathy and osteoarthritis of the distal tarsal joints are known to be two of the most common problems [1–4]. Nevertheless, the precise localization of the sources of pain can be challenging [3–5]. Radiography and ultrasonography as diagnostic imaging tools are routinely used to detect pathological changes in the lower hock. However, there is a poor association between radiographic findings and pain localized in the distal tarsal joints [6–8]. Alteration in the suspensory ligament (SL) tissue and adhesion of the SL to adjacent soft tissues can be visualized sonographically, but not the adhesion of the SL to the third metatarsal bone [9]. When compared with magnetic resonance imaging, ultrasonography is likely to underestimate a cross-sectional area of the proximal aspect of the SL [10,11], which could therefore underestimate the enlargement of the ligament. Furthermore, optimal sonographic images are not always obtainable due to the anatomical architecture of the plantar aspect of the proximal metatarsal region and anechoic artifacts from the plantar vessels [4,5,12].

Animal welfare/ethical statement: The study was approved by the Ethics Committee of Freie Universität Berlin.

Conflict of interest statement: The authors declare no conflicts of interest.

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https://doi.org/10.1016/j.jevs.2018.07.004
0737-0806/

Perineural analgesia of the deep branch of the lateral plantar nerve (DBLPN block) and intraarticular analgesia of the tarsometatarsal joint (TMT joint block) are commonly used to differentiate pain in the proximal metatarsal and distal tarsal areas [2,3,12]. However, several studies suggested the potential diffusion of the anesthetic agent and inadvertent penetration into the adjacent synovial structures after the completion of the DBLPN block. In one study, blue food dye was found contained in tarsal sheath after being infiltrated around the DBLPN in 1 of 19 harvested limbs [13]. The other studies using iohexol and mepivacaine injected around the DBLPN also showed the distribution of iohexol in tarsal sheath and TMT joint under radiographic control [14,15], as well as mepivacaine contained in TMT joint after the synovial sampling [15]. The TMT block could also possibly desensitize the plantar metatarsal nerves due to the diffusion of the anesthetic agent from the plantarolateral and medial outpouchings of the joint [3]. A study showed the distribution of contrast media around proximal plantar metatarsus after being injected into the TMT joint [16]. The desensitization of the structures in question might overlap after the implementation of the techniques mentioned previously.

Subjective assessment of lameness was shown to have relatively low agreement between observers especially in low-grade lameness [17], and the assessment of the response to diagnostic analgesia might be biased [18]. Recently, several inertial sensor systems have been developed as an objective tool to aid lameness evaluation [19–21]. An inertial sensor-based method characterizing lameness as an asymmetry of the vertical movement of the head and pelvis between the right and left strides was tested to detect and quantify lameness in horses with sufficient repeatability [21,22].

The aim of this study is to objectively measure the effect of DBLPN block and TMT joint analgesia on hind limb asymmetry, using a body-mounted inertial sensor system (Lameness Locator; Equinosis LLC, Columbia, MO[a]). We hypothesized that the response of the TMT block will differ significantly from the DBLPN block in the horses with suspected proximal metatarsal pain.

2. Material and Methods

2.1. Horses

Horses included in the study were selected from cases presented to the Equine Clinic of Freie Universität Berlin for lameness examinations between July 2012 and April 2017. Inclusion criteria were (1) consistent, chronic (>2 weeks) hind limb lameness when trotted in a straight line on hard ground on two consecutive days, (2) no substantial improvement of lameness after the low six-point block, (3) significant improvement after the DBLPN block, and (3) the owner's consent for the horse to participate in this study. The hindlimb lameness before block (baseline) was assessed subjectively by the attending clinician and objectively using the inertial sensor system. The study was approved by the Ethics Committee of Freie Universität Berlin.

2.2. Lameness Assessment and Diagnostic Analgesia

On day 1, each horse underwent a standard lameness examination including trotting in a straight line, flexion tests of all four legs, and lunging on a soft surface. During the straight-line evaluation, an objective lameness assessment with body-mounted inertial sensors was used to evaluate baseline lameness. The minimum of 25 trotting strides which are required to enable adequate recording of data for the objective method was achieved by having each horse trot up and down on a 30-m long hard surface. Diagnostic analgesia was performed on the lame(*r*) hind limb. To rule out the possibility of the pain having arisen from a more distal part of the limb, a low six-point block was performed. The plantar nerves at the level of the mid-metatarsus proximal to the digital tendon sheath, the plantar metatarsal nerves at the level of the distal end of the second and fourth metatarsal bones, and the dorsal metatarsal nerves at the same level as plantar nerves were all anesthetized. Two milliliter of 2% mepivacaine (Scandicain 2%[b]; AstraZeneca GmbH, Wedel, Germany) were injected per site using a 25-gauge (5/8 inch) needle. After 10 minutes, skin sensitivity in the dorsal and plantar regions of the pastern was tested by pressing a blunt object into the limb in this area to confirm a successful block. The same clinician then reassessed lameness.

For the DBLPN block, the skin at the injection site was aseptically prepared. With the limb in an elevated and flexed position, the superficial digital flexor tendon was deflected medially and a 23-gauge (1½ inch) needle was used to deposit 5 mL of 2% mepivacaine near the DBLPN as described by Hugh et al. [13]. Lameness was reevaluated 10 minutes after the analgesia. On the following day, baseline lameness was again assessed to confirm the original lameness from day 1. After aseptical preparation of the injection site, the TMT block was performed by injecting 2–3 mL of mepivacaine using standard technique [23]. Lameness was reevaluated after 5 and 10 minutes.

2.3. Instrumentation and Data Analysis

Each horse was instrumented with three inertial sensors; one uniaxial accelerometer was attached at the poll region, a second uniaxial accelerometer at the dorsal midline of the pelvis between the tubera sacralia, and one uniaxial gyroscope at the dorsal aspect of the right forelimb pastern. The resulting data were transmitted wirelessly to a tablet computer and analyzed using the fault-detection algorithm, which measures vertical head and pelvic movement asymmetry. For this study, the measurement of vertical movement asymmetry for hindlimb lameness was the data of interest. Vertical pelvic asymmetry is reported as the mean pelvic maximum and the mean pelvic minimum as height difference between right and left hind limb strides (P_{max} and P_{min}). P_{max} indicates decreased upward pelvic movement after push off of the lame hind limb and P_{min} indicates decreased downward movement during the lame hind limb stance. Positive values of P_{max} and P_{min} indicated right hindlimb asymmetry and negative values indicated left hindlimb asymmetry due to lameness.

The estimated threshold of both pelvic values between “sound” and “lame” of a horse trotting in a straight line is ±3 mm, which is the experimentally determined 95% confidence interval of the y-intercept when the mean AAEP score [24] from three subjective individuals is 0 [25]. For the calculation, P_{max} and P_{min} from the left hindlimb were multiplied by −1 to convert them to positive values and allow the comparison to right hindlimb values.

The P_{max} and P_{min} values of each horse were evaluated independently according to the one-component model of pelvic movement. The change in P_{max} or P_{min} (ΔP_{max} or P_{min}) was calculated by subtracting P_{max} or P_{min} at baseline by P_{max} or P_{min} after analgesia (ΔP_{max} (or ΔP_{min}) = P_{max} (or P_{min}) baseline−P_{max} (or P_{min}) after block).

The change in P_{max} or P_{min} greater than 3 mm was considered to be a nonrandom change [22] and used to calculate the percent improvement of lameness as follows:

$$\frac{\Delta P_{max}\ (\text{or } P_{min})}{P_{max}\ (\text{or } P_{min})\ \text{baseline}} \times 100$$

[a] Lameness locator; Equinosis LLC, Columbia, MO.

[b] Scandicain 2%; AstraZeneca GmbH, Wedel, Germany.

Table 1
Percentage of improvement of P_{max} and P_{min} after DBLPN block and TMT block compared to baseline of the corresponding day from 27 horses.

Horse	DBLPN (Day 1)		5 min TMT (Day 2)		10 min TMT (Day 2)	
	% P_{max}	% P_{min}	% P_{max}	% P_{min}	% P_{max}	% P_{min}
1	-	60%	-	No change	-	No change
2	76%	91%	No change	No change	No change	No change
3	100%	-	No change	-	No change	-
4	52%	-	No change	-	No change	-
5	45%	100%	No change	No change	No change	No change
6	78%	No change	No change	No change	Worse	No change
7	-	66%	-	No change	-	No change
8	-	50%	-	No change	-	No change
9	100%	100%	No change	No change	No change	No change
10	-	50%	-	No change	-	No change
11	51%	34%	No change	No change	No change	No change
12	68%	No change	Worse	No change	No change	No change
13	97%	-	No change	-	No change	-
14	58%	-	No change	-	No change	-
15	82%	-	No change	-	No change	-
16	51%	-	No change	-	No change	-
17	60%	-	No change	-	No change	-
18	-	62%	-	50%	-	48%
19		100%	-	67%	-	81%
20	100%	100%	NA	NA	76%	-
21	No change	49%	No change	No change	No change	50%
22	-	49%	-	100%	-	100%
23	51%	-	No change	-	49%	-
24	65%	89%	No change	No change	51%	No change
25	100%	-	79%	-	100%	-
26	73%	No change	40%	No change	51%	No change
27	48%	-	32%	-	50 %	-

Abbreviations: NA, measurement was not available as the horse was sedated for the diagnostic analgesia procedure; no change, the change of P_{max} or P_{min} less than 95% CI for a nonrandom change (±3 mm); Worse, lameness has worsened after the analgesia.
A positive response was defined as an improvement by 50%.
-, this P_{max}/P_{min} at baseline either does not exceed the threshold of sound/lame at ±3 mm, or indicated lameness on contralateral limb that was anesthetized.

A positive response to analgesia is an improvement of P_{max} or P_{min} by at least 50% [26]. Lameness was considered abolished when P_{max} and P_{min} values after analgesia have the opposite sign (±) than the values at baseline and reported as a 100% improvement. Lameness was recorded as having shifted to the contralateral hind limb when after analgesia P_{max} and/or P_{min} from the contralateral limb rose above the threshold. A worsening of lameness is when P_{max} or P_{min} after analgesia has increased by 3 mm. The horses were divided into two groups based on the response to the TMT block. Group 1 included horses with negative response and group 2 included horses with positive response to the TMT block.

2.4. Statistical Analysis

A Shapiro–Wilk normality test was performed on all analyzed data to decide if the parametric or nonparametric statistic should be used. Baselines between day 1 and day 2 were compared in all, group 1, and group 2 horses using a paired sample *t*-test or its nonparametric equivalent (Wilcoxon signed rank test). Baselines between group 1 and group 2 were compared for both for 2 days using an independent-sample *t*-test or its nonparametric equivalent (Man-Whitney *U* test).

Effect of block on change in lameness parameters were compared in all, group 1, and group 2 horses using the Friedman test.

Change in lameness parameters after the TMT block between group 1 and group 2 horses were compared using independent sample *t*-test or Man-Whitney *U* test. Values of $P < .05$ were considered significant. The analysis was carried out by a commercial software company (SPSS Statistics 24[c], IBM, Brussels, Belgium).

3. Results

Of the 27 horses included in the study, the median age was 9 years (3–22 years). Breeds included 17 Warmbloods, three Standardbreds, three American Quarters, and four others. There were 14 mares, 11 geldings, and one stallion. Group 1 (negative to the TMT block) consisted of 17 horses, while group 2 (positive to the TMT block) consisted of 10 horses. Percent of improvement of P_{max} and P_{min} from both groups are presented in Table 1.

The P_{max} and P_{min} at baseline on day 1 were not significantly different from day 2 for all horses of group 1 and group 2. The P_{max} and P_{min} at baseline also showed no significant difference between group 1 and group 2 horses on both day 1 and day 2.

The change in P_{max} and P_{min} after the DBLPN block was significantly greater than after the low six-point block in both group 1 ($P < .001$ for P_{max}, $P = .011$ for P_{min}) and group 2 ($P = .015$ for P_{max}, $P = .003$ for P_{min}). In group 1, the change in P_{max} at 5 minutes after the TMT block was significantly less than after the DBLPN block ($P < .001$) while at 10 minutes after the TMT block, the change in both P_{max} and P_{min} was significantly less than after the DBLPN block ($P < .001$ for P_{max}, $P = .019$ for P_{min}). In group 2, the change in P_{max} and P_{min} at 5 and 10 minutes after the TMT block did not significantly differ from the change after the DBLPN block (Table 2).

The changes in P_{max} and P_{min} at 5 and 10 minutes after the TMT block from group 2 were higher than group 1. However, only at 10 minutes after the TMT block were the changes in P_{max} and P_{min} different statistically ($P < .001$ for P_{max}, $P = .004$ for P_{min}) (Table 2).

Ten of 27 horses were found to have bilateral hindlimb lameness. Four of these horses showed bilateral hindlimb lameness at

[c] SPSS Statistics 24, IBM, Brussels, Belgium.

Table 2
Mean of the change (Δ) in P_{max} and P_{min} in mm after analgesia compared to corresponding baseline in mm from group 1 and group 2 horses.

	ΔP_{max} (Range)				ΔP_{min} (Range)			
	Low 6	DBLPN	TMT 5	TMT 10	Low 6	DBLPN	TMT 5	TMT 10
Group 1	0.75[a] (−1.02 to 4.3)	5.13[b,c] (3.02–16.3)	−0.1[b] (−3.37 to 4.12)	0.22[c,d] (−3.12 to 3.2)	0.54[a] (−7.2 to 2.55)	4.56[c] (0.26–14.03)	0.685 (−2.07 to 3.98)	0.765[c,d] (−2.5 to 2.18)
Group 2	−0.435[a] (−0.9 to 1.8)	4.38[a] (3.06–10.94)	3.195 (0.42–4.17)	4.605[d] (3.14–5.94)	1.52[a] (−0.9 to 2.69)	4.18[a] (2.6–10.29)	2.76 (0.1–6.76)	3.65[d] (−0.5 to 7.58)

[a] Significant change in mean pelvic value after the low 6-point block compared with after the DBLPN block.
[b] Significant change in mean pelvic value after the DBLPN block compared with after the TMT block at 5 minutes.
[c] Significant change in mean pelvic value after the DBLPN block compared with after the TMT block at 10 minutes.
[d] Significant change in mean pelvic value at 10 minutes after the TMT block from group 1 compared with group 2.

baseline, meaning both P_{max} and P_{min} were above threshold between sound and lame (±3 mm.) but had opposite sign. The other six horses showed unilateral hindlimb lameness at baseline, but after the blocks (DPLPN or TMT) lameness switched to the contralateral limb in four horses, while in two horses, lameness on primary lame limb was improved but not eliminated while the contralateral limb became lame.

4. Discussion

Seventeen of 27 horses in this study improved after the DBLPN block but not after the TMT block. Our results suggest, that in this horse population, the source of pain arose from the proximal metatarsal area rather than distal tarsal joints and that the anesthetic agent injected after the DBLPN block apparently did not diffuse to the TMT joint.

The precision of the DBLPN block to anesthetize the DBLPN is a controversial topic. Although Hugh et al. (2007) reported a high accuracy in a cadaveric study [13], other studies suggest that the local diffusion might anesthetize other nerves like the lateral plantar nerve and other structures like the distal tarsal joint and the tarsal sheath [13–15]. Although this block is not as specific as expected, it seems to be able to localize pain in the subtarsal region. Theoretically, the effect of the DBLPN block in anaesthetizing pain from the more distal part of the limb could be ruled out by having previously performed the low six-point block. Based on our results, blocking the TMT on a separate day from the DBLPN might also help to differentiate the origin of the pain. In this context, the clinician should also take into account that a blocking pattern presenting a positive DBLPN and a negative TMT is not specific for SL pathologies and might also involve other soft tissue structures in the subtarsal region.

On the other hand, controversial results were obtained in the second group (10/27), which presented lameness improvement after both the DBLPN block and the TMT block. Several reasons could explain the aforementioned response; the distal tarsal joints could be penetrated while performing the DBLPN block [14,15]. Another possible cause could be the improvement of lameness resulted from the proximal diffusion of the anesthetic agent after the DBLPN block and the inadvertence desensitization of other structures. The study from Claunch demonstrated that the greater volume of contrast medium could diffuse significantly further in both proximal and distal direction compared with the smaller volume [14]. The volume of 5 mL mepivacaine [27,28] is more than the volume recommended by the others [4,23]. This is likely to lead to less specificity of the DBLPN block in our study. Labens and others reported that anesthesia of the DBLPN is not specific either for lesions of the origin of the SL (as other pathologies were diagnosed), or for conditions in the proximal metatarsal region because pathologies were diagnosed outside this region [11].

Diffusion of the anesthetic agent out of the distal outpouching of the TMT joint could be another possible explanation for what was observed in the second group. Proximal diffusion has been previously suggested by a study in which the distribution of contrast media was observed around the proximal plantar metatarsal area as soon as 5 minutes after injecting the TMT [16]. Finally, concurrent pathologies of the proximal SL and the distal tarsal joints including osteoarthritis are as previously reported [11].

Assuming only some of the horses in the second group had concurrent pathologies of the proximal SL and the distal tarsal joints, the frequency of horses having distal tarsal pain in our study population is questionably low. Nevertheless, the excluded horses which were eventually positive to the tibial and fibular nerve blocks were also negative to the TMT block on the following day. Therefore, it could almost be concluded that there was actually lower ratio of the horses with distal tarsal pain compared to those with proximal metatarsal pain in the population presented to our clinic at the time of the study.

This study has several limitations. First, the imaging modalities used were restricted to sonography and radiography. Results from diagnostic imaging were inconsistent with the results from diagnostic analgesia (Supplementary Data). This is not unexpected because both aforementioned imaging modalities are not as sensitive as advanced medical imaging in diagnosing proximal metatarsal and tarsal lesions [29–31]. Further studies using experimental induced pain such as synovitis of the TMT joint [32,33] would be beneficial for determining the effects of the TMT joint blocks in comparison to the DBLPN block. Second, the fact that lunging trials (on soft ground) could not be included, limiting the study only to straight line trials. It is possible that cases presenting subtle lameness, only observed during lunging, might have been excluded. Finally, the true distribution of the anesthetics could not be documented.

In conclusion, this is the first study investigating the effect of the DBLPN and the TMT blocks in clinical cases with suspected proximal metatarsal pain using an objective method. Based on the blocking pattern observed in this study population, in approximately 60% of the horses, the DBLPN block was able to desensitize different structures when compared to the TMT block. This summary is based on the fact that in this group, none of the horse responded to the intraarticular analgesia of the TMT block performed on the second day of the lameness examination. On the other 40% of the patients, this differentiation was not possible. Although there are several possible explanations for this phenomenon, it is still an open question what was the exact cause of the decrease of the lameness when using both analgesia techniques.

We believe that further investigations are needed to fully comprehend the effect of the DBLPN block and the TMT block on the analgesia of pain arising from the distal tarsal and proximal metatarsal areas. An experiment model of TMT synovitis might

bring light to the interaction of these blocks with the local structures. Furthermore, clinical studies combining the use of diagnostic analgesia, objective gait analysis, and advanced medical imaging modalities might help to better correlate the block response of the DBLPN and TMT to a particular pathology.

Acknowledgments

Special thanks to the clinicians who performed the lameness examinations and diagnostic imaging; Dr Christoph Klaus, Dr Matthias Rettig, Dr Bettina Rheiner, Dr Wiebker Schröder, and Dr Sarah Jones.

Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jevs.2018.07.004.

Financial disclosure

No funding was received for this study.

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