The effect of a compression bandage on the distribution of radiodense contrast medium after palmar digital nerve blocks

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Summary

Background: Studies have shown proximal diffusion of injected drugs in perineural blocks; such diffusion may affect specificity of the nerve block.

Objectives: To investigate the effect of a compression bandage applied to the pastern region on proximal diffusion of contrast medium injected over the palmar digital nerves.

Study design: Experimental study, randomised cross-over design.

Methods: Radiodense contrast medium was injected over the lateral and medial palmar digital nerves of the left front limb of nine mature horses. Each horse was injected on two separate occasions, once with a 5 cm wide compression bandage applied proximal to the injection site and once without. The order of the two treatments was randomised with a wash-out period between treatments of at least 7 days. Radiographs were obtained at 5, 10, 20 and 30 min and distribution of the contrast column assessed.

Results: Proximal distribution of the contrast medium was significantly reduced (P<0.01) with compression bandage. Furthermore, the compression bandage inhibited lymphatic drainage of the injected contrast medium.

Main limitations: Clinical effect of the differences in diffusion length was not assessed.

Conclusions: The compression bandage reduced proximal diffusion and lymphatic drainage of contrast material causing it to stay localised around the injection site. Use of compression bandages could thus result in increased specificity of the nerve block and potentially prolong its effect.

Keywords: horse; local analgesia; diffusion; radiography; nerve blocks

Introduction

Multiple studies have shown that diffusion occurs in palmar digital nerve blocks [1], mid-pastern ring blocks [2], abaxial sesamoid nerve blocks [3], low 4-point blocks [4,5] and in subcarpal [6] and subtarsal blocks [7,8]. This diffusion has been shown with injection of contrast medium [3,4], contrast medium and dye [1–5], local analgesics [8] and local analgesics and contrast medium [3–5].

This diffusion causes the injected material to spread over a larger area than anticipated, which may reduce the specificity of the nerve block. In addition, radiographic studies have shown that contrast material is removed by lymphatic drainage from the injection site after perineural injection of radiodense contrast medium [1–6,8]. It is not clear how this affects specificity of the block and duration of effects of the injected drugs; it has been suggested to potentially cause insufficient analgesia, when small volumes of local analgesics are used [1].

Originally, palmar digital nerve blocks were described to desensitise the palmar third of the foot [9–11]. Research has, however, shown that a palmar digital nerve block causes a more widespread desensitisation involving the sole, the distal and proximal interphalangeal joints and even the fetlock region [12–15]. It is recommended to perform the injection just proximal to the ungular cartilages, to use a volume of 1.5 mL of local analgesics, and to orient the needle in a distal direction [1]. Performing the injection 2 cm proximal to the ungular cartilages has been shown to increase diffusion [1], as has the use of a larger volume (2.5 mL) of contrast medium [1]. One study showed that palmar digital nerve blocks performed at different levels in the pastern region caused varying desensitisation of the proximal interphalangeal joint [14], and it is plausible that proximal diffusion of local analgesics may have a similar effect.

The aim of this study was to investigate whether application of a simple compression bandage applied in the pastern before performing the palmar digital nerve block could prevent proximal diffusion of radiodense contrast medium.

Materials and methods

Animals and procedures

The investigation was performed as a cross-over study involving nine mature mares (standardbred trotters [n = 6], Danish warmblood [n = 2] and mixed breed [n = 1], 6–22 years old, 450–622 kg) from the teaching herd at the Large Animal Teaching Hospital, University of Copenhagen. Horses underwent a clinical examination of the pastern area of the left front limb.

Horses were sedated with 0.01 mg/kg detomidine and 0.01 mg/kg butorphanol (and if needed with 0.2 mg/kg xylazine)1. The horses were not exercised or moved after the perineural injections had been performed, and they stood still for the duration of the radiographic study. Injection sites were clipped and cleaned by a 4-min scrub with 4% chlorhexidine (Nex Clorex C2) followed by a 70% isopropyl alcohol wipe. An amount of 1.5 mL of the radiodense contrast medium iomeprol (Iomeron 350 mg iodine/mL) was injected subcutaneously over the lateral and medial palmar digital nerve on the left forelimb on two separate occasions with at least 7 days between injections. On one occasion, injection was performed after a compression bandage had been applied to the pastern (Fig 1), on the other without the application of the bandage. The compression bandage (E-power wrap 5 cm) was 8 cm wide, self-adhesive, elastic bandage. It was applied in four circumferential turns with moderate tightness 1 cm proximal to the ungular cartilages on the weight bearing limb. The distal border of the palmar part of the bandage was marked with a vertical paper staple. All bandages were applied by the same person. The bandage stayed on during the 30-min radiographic procedure.

The order of the treatments was randomised. Injection was performed as described previously [1]. A 25G, 16 mm needle was inserted in distal

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1Drs. Gylling and Frandsen share the first authorship.
direction at the level of the proximal aspect of the ungular cartilage. The needle was inserted to the hub and placed parallel to the neurovascular bundle. All injections were performed by the same clinician with the limb held off the ground. After injection, the injection sites were wiped with alcohol to remove any residues on the skin, and skin staples were applied horizontally at the lateral and medial injection sites.

Lateromedial (LM), dorsopalmar (D Pa), dorsolateral-palmaromedial oblique (DL-PaMO) and dorsomedial-palmarolateral oblique (DM-PaLO) radiographic projections were obtained 5, 10, 20 and 30 min after the injections using a Gierth HF 400 X-ray generator, Fuji FDR console digital X-ray and a Fuji DR D-evo 24 cm cassettes. A metal ball with a diameter of 1.3 cm was applied to the lateral aspect of the hoof and used to standardize size measurements in the radiographs.

Assessment of radiographs

Measurements of the contrast patches were performed on DL-PaMO and DM-PaLO projections, as the contrast patches were completely projected off the bones, so no superimposition occurred. The following parameters were recorded:

- The pattern of the contrast patch. This was subjectively evaluated and described as diffuse or elongated [3] (Supplementary Item 1), and for elongated patterns it was noted if they were inverted V or Y-shaped based on previous definitions [1] (Supplementary Item 2).
- Lymphatic drainage. This was recorded as present or not and was evident as one or more vertical radiodense lines running proximally from the contrast patch [3,4,6] (Fig 2).
- Proximal and distal borders of the contrast patch. All size measurements were corrected by using the metal ball as previously described [16,17] to prevent effects of image distortion on size measurements. The integrated function of measurement correction in the Neologica Remoteeye Dicomviewer was used for size measurements. Horizontal lines were drawn through both the staple marking the lateral (Fig 3, line a) and the staple marking the medial injection site. From the most proximal and the most distal points of the contrast patch, vertical lines were drawn perpendicularly to line a in proximal and distal direction (Fig 3, lines b and c, respectively), and length of lines b and c was recorded in mm as proximal and distal diffusion length, respectively. Injections were performed with a 16 mm needle inserted to hub, which caused the contrast medium to be deposited 16 mm distal to the marked injection sites; all measurements were therefore corrected by adding 16 mm to proximal diffusion distances and subtracting 16 mm from the distal distances. Measurements were performed separately by two individuals based on predefined guidelines, and the average of the two measurements was used in the statistical analyses.
Data analyses

Mixed model regression analysis was conducted using the LME4 package in R version 3.4.0 and RStudio Desktop and Microsoft Excel 365. Normality of data was assessed using a QQ-plot and found to be acceptable. Diffusion with and without compression bandage was regressed on time and treatment with horse and horse x treatment as random effects; the Chi square-test was used to reduce the model. The final model used time: treatment as the only fixed effect. Initial results showed that diffusion of medial and lateral injections did not differ (P=0.7), and an average of the two was therefore used in the subsequent analyses. Differences between treatments and significant differences between slopes of regression lines and 0 were assessed using lmerTest package in R. Yates corrected Chi square-test was used to assess differences in diffusion patterns and presence of lymphatic drainage with and without compressions bandage. The statistical significance was set at P≤0.05.

Results

In eight horses, the pastern area was found to be normal with no signs of inflammation or other changes. One horse had a 1 × 1 cm circular indolent fibrotic nodule located palmaromedially in the pastern region. At the medial injection site, diffusion of contrast material was observed proximal to the distal border of the compression bandage, while at the lateral injection site no diffusion proximal to the distal border of the compression bandage was observed. The data from this horse were not included in the statistical analyses. Diffusion proximal to the distal border of the compression bandage was not observed in any of the other limbs.

Rates of proximal diffusion differed statistically significantly between treatments (P<0.01, Fig 4). In the final regression model, rate of diffusion with compression bandage was 0.039 mm/min, this was not significantly different from 0 (i.e. slope of the regression line was not different from 0, P = 0.3). Rate of diffusion without compression bandage was 0.206 mm/min, the slope of this regression line differed statistically significantly from 0 (P<0.01). The distal diffusion did not differ (P = 0.3) between treatments (Table 1).

Compression bandage did not affect the pattern of the contrast patch; appearance of elongated distribution pattern (P = 0.7), and inverted V- or Y-shape (P = 0.1) occurred both with and without compression bandage. Contrast medium was not apparent in the deep digital flexor tendon sheath in any of the radiographs. Lymphatic drainage was observed more often without the compression bandage (15 of 16 limbs) compared with compression bandage (2 of 16 limbs, P<0.001, Supplementary Item 3).

Discussion

In accordance with a previous study [1], we show here that proximal and distal diffusion of contrast medium occurs when contrast medium is injected subcutaneously over the lateral and medial palmar digital nerves. Our results show that this diffusion can be reduced with a simple compression bandage applied before injection. The difference in proximal diffusion length between bandaged and nonbandaged limbs was modest,

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**TABLE 1: The mean, minimum and maximum distance of diffusion (measured in mm) with and without compression bandage at 5, 10, 20 and 30 min after subcutaneous injection of contrast medium over the lateral and medial palmar digital nerves**

<table>
<thead>
<tr>
<th>Time after injection</th>
<th>Proximal diffusion</th>
<th>Distal diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without bandage</td>
<td>With bandage</td>
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<tr>
<td>5 min</td>
<td>Mean 22.7</td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>Range 7.0 to 36.6</td>
<td>14.6 to 25.3</td>
</tr>
<tr>
<td>10 min</td>
<td>Mean 24.0</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>Range 7.7 to 38.3</td>
<td>16.0 to 25.8</td>
</tr>
<tr>
<td>20 min</td>
<td>Mean 26.0</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>Range 9.7 to 40.3</td>
<td>16.8 to 25.2</td>
</tr>
<tr>
<td>30 min</td>
<td>Mean 27.6</td>
<td>22.0</td>
</tr>
<tr>
<td></td>
<td>Range 11.2 to 43.9</td>
<td>16.6 to 26.4</td>
</tr>
</tbody>
</table>

Compression bandage affects diffusion after palmar digital nerve blocks

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and clinical relevance of the technique needs to be investigated. Schumacher et al. [14] showed that performing the palmar digital nerve block 2 cm proximal to the proximal margin of the angular cartilages caused the proximal interphalangeal joint to be desensitized, while the block performed 1 cm distal to this location did not. This suggests that even minor variations in diffusion length may be potentially relevant. Our statistical model suggested that compression bandage prevented proximal diffusion of radiodense contrast material completely (the rate of diffusion of 0.039 mm/min was not statistically significantly different from 0). The fact that contrast medium did not diffuse proximal to the distal end of the bandage may prove to be more clinically relevant than the diffusion distances, as these findings suggest that the compression bandage may be placed at any anatomical location where the clinician wants the proximal diffusion to stop. The compression bandage also prevented the distribution of the contrast medium to the lymphatic vessels demonstrated both by us after perineural injection without use of the bandage and in several previous studies [1–6,8]. The bandage may thus cause injected substances to remain localised at the injection site for a longer duration. Whether contrast medium can be used as an analogue for local anaesthetics is currently not clear. Contrast medium and mepivacaine differ with regard to viscosity, molecular weight and osmolality, and others have suggested that this could cause dissimilar tissue diffusion [1,2]. Future studies investigating specificity (area of desensitisation) and duration of palmar digital nerve blocks after application of a compression bandage are thus warranted.

Spread of contrast medium along lymphatic vessels was observed in the nonbandaged limbs, and over the 30-min observation period, the contrast patch became more indistinct – possibly due to contrast medium being drained from the area. These findings have been described in previous studies [2,3], but ours is the first to report prevention of lymphatic spread with a compression bandage. Clinical effects, if any, of distribution of injected drugs along lymphatic vessels are not known. Authors of previous studies have put forward the suggestion that lymphatic drainage potentially could lead to a reduction of drug concentration at the site of injection [1,3]. With small injection volumes such as those used for palmar digital nerve blocks, it is plausible that lymphatic drainage could lead to insufficient analgesia. By limiting this drainage, the pressure bandage may help retain adequate drug concentrations at the site of injection. The compression bandage had no effect on occurrence of elongated distribution pattern or the inverted V and Y patterns. These patterns have been suggested to indicate distribution of injected material along the neurovascular bundle and along the palmar branch of the palmar digital nerve and the palmar digital nerve itself, respectively [1]. These findings indicate that the compression bandage did not prevent correct injection over the palmar digital nerves. The clinician performing the palmar digital injection did, however, subjectively feel that the neurovascular bundle was easier to palpate without compression bandage.

In conclusion, this study shows that a compression bandage reduced proximal diffusion and lymphatic drainage of contrast medium injected subcutaneously over the palmar digital nerves. This simple procedure may thus be a way to increase specificity of the palmar digital nerve block, but the clinical effects of the bandage need to be evaluated as does its ability to limit proximal diffusion when horses are moving after the perineural injection.

Authors' declaration of interests

The authors have no competing interest to declare.

Ethical animal research

The experimental protocol was approved by the local ethical committee and by the Danish Animal Experiments Inspectorate (permit 2016-15-0201-01152).

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Authorship

S. Østergaard and S. Jacobsen conceived the idea for the study. S. S. Frandsen, S. M. K. Gylling and S. Jacobsen designed the study with input from M.T. Christophersen, M. H. Thomsen, and S. Østergaard. S. S. Frandsen, S. M. K. Gylling and S. Østergaard performed the study. S. Frandsen, S. M. K. Gylling and S. Jacobsen analysed and interpreted the data and prepared the manuscript. T. Krüger performed the statistical analysis. All authors contributed to and approved the final version of the manuscript.

Manufacturers' addresses

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*Scanvet, Fredensborg, Denmark.
**Nex Medical Antiseptics, Casorezzo, Italy.
**Braico Imaging SpA, Milano, Italy.
**Evet, Haderslev, Denmark.
**Geert X-Ray international GmbH, Riesa, Germany.
*Fujifilm Nordic, Ballerup, Denmark.
*Neologica, Caro Monterotite, Italy.
**IStudio, Caro Monterotite, Italy.
**Microsoft Denmark, Kongers Lyngby, Denmark.

References


Supporting Information
Additional Supporting Information may be found in the online version of this article at the publisher’s website:

Supplementary Item 1: Dorsopalmar radiograph after subcutaneous injection of 1.5 mL of the radiodense contrast material iomeprol over the lateral and medial palmar digital nerves. Distribution of contrast material has an elongated pattern medially and a diffuse pattern laterally.

Supplementary Item 2: Dorsopalmar radiograph obtained 20 min after subcutaneous injection of 1.5 mL of the radiodense contrast material iomeprol over the lateral and medial palmar digital nerves without application of compression bandage. The medial and lateral contrast patches show inverted V- and Y-shape, respectively (as described by Nagy and Malton [1]).

Supplementary Item 3: Dorsomedial-palmarolateral oblique radiograph obtained 20 min after subcutaneous injection of 1.5 mL of the radiodense contrast material iomeprol subcutaneously over the lateral and medial palmar digital nerves with application of compression bandage. Note the radiopaque line above the proximal edge of the area where the compression bandage is placed. No radiopaque lines appear under the area of the compression bandage.