Ex Vivo Assessment of an Ultrasound-Guided Injection Technique of the Lumbosacral Disc in the Horse

Mickaël Robert*, Hadrien Manet, Guillaume Manneveau, Olivier Geffroy

Department of Equine Surgery, ONIRIS, Nantes Atlantic College of Veterinary Medicine, Food Science and Engineering, Nantes, France

*Address for correspondence
Mickaël Robert, Department of Companion Animal Clinical Studies, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, 0110 Onderstepoort, South Africa

Email: dr.mickael.robert@gmail.com

Abstract

Objectives: The aim of this study was to describe an ultrasound-guided injection technique of the lumbosacral disc in horses through the cranial vertebral notch of the sacrum and to evaluate both accuracy and potential complications of the technique on equine cadavers.

Materials and Methods: Twenty-four injections of the lumbosacral area were performed on 12 equine cadavers shortly after euthanasia under ultrasound guidance with the horse in recumbency using two different dyes (one colour for each side). The lumbosacral area was dissected in each horse and the accuracy of the technique, as well as its potential complications, was evaluated detecting the dyes and the structures that have been coloured.

Results: The lumbosacral area was correctly reached in only 11/24 injections. However, this technique allowed a lumbosacral peridiscal injection in 7/12 horses. The main difficulty was reaching the ventral opening of the L6-S1 intervertebral foramen that is partially hidden by the iliac wing on ultrasound. Puncture of the vertebral canal has been observed in 11/24 cases. The L6 spinal nerve roots emerging through the intervertebral foramen could potentially be damaged when inserting the needle.

Clinical Significance: The described ultrasound-guided technique allows peridiscal injection in the lumbosacral space in less than 60% of cases with potential sciatic nerve damage. Further investigations are warranted before using this technique in clinical practice in horses suffering from lumbosacral lesions.

Keywords: equine - lumbosacral joint - ultrasound - intervertebral disc - horses

Introduction

Low back pain is a common complaint in both sport and racehorses. It is a suspected cause of poor performance, lack of propulsion and irregular gait or discomfort in the hindlimbs.[1]

The equine lumbosacral joint (articulatio lumbosacralis) consists of five articulations: the left and right synovial intervertebral joints dorsally (between the caudal articular processes of the last lumbar (L6) and the articular processes of the first sacral (S1) vertebra), left and right synovial intertransverse joints (between the transverse processes of L6 and S1) and the intercentral joint with its large fibrocartilaginous disc.[1] [2] [3]

It is the most mobile joint in flexion and extension motions of the horse's back.[4] [5] [6] [7] [8] Lumbosacral flexion can reach 20°, whereas a 5 to 10° extension is possible, with wide variations between horses.[1] [7] [8] This dorsoventral movement is favoured by the intertransverse joints preventing lateromotion (1–2° maximum), by the small vertical articular facettes that limit axial rotation (3–5° maximum), by the diverging orientation of the last lumbar and first sacral spinous processes, by the poorly developed interspinous and absent supraspinous ligaments and by the thick lumbosacral disc.[4] [6] [7] [8] [9] The lumbosacral disc is anatomically adapted to these movements. Indeed, despite a large individual variation, the limit between the nucleus pulposus and the annulus fibrosus is poorly demarcated in horses compared with other mammals.[10] The equine nucleus pulposus is composed of a fibrocartilaginous matrix unlike the gelatinous, glycosaminoglycan-laden structure found in oxen, dogs and humans.[11] Similarly, the annulus fibrosus is designed to provide rotational stability by being formed of concentric layers of fibres angled relative to each other.[12] The lumbosacral disc undergoes low shearing but high compression and traction forces: it sustains ventral traction when the lumbosacral joint is extended and ventral compression with bulging of the disc and dorsal traction when this joint is flexed.[7] Its roles are to assure a good vertebral flexibility, to act as a shock absorber and to support the spine. These massive mechanical solicitations could predispose the lumbosacral disc to lesions.[3] [6]

After the first gross pathological lumbosacral disc lesions have been described, the ultrasonographic aspect of the lumbosacral disc has been well described using a transrectal approach.[13] [14] In our population, ~6.3% of horses presented for lameness evaluation were found to have abnormalities upon ultrasonographic examination of the lumbosacral junction.[15] Even though it is known that intervertebral discs are innervated by proprioceptive and nociceptive fibres in their outer third, the relationship between ultrasonographic lesions, histological grades and clinical signs remains uncertain.[2] [12] [14] [16] Indeed, as many as 21% of sound horses have signs of an abnormal lumbosacral area (hyperechogenic regions within the lumbosacral disc and mild or moderate irregularity of the opposing surfaces of L6 and S1 vertebral bodies) on ultrasound.[17] Ultrasonographic signs such as cavitation or fissuration of the lumbosacral disc, ventral hernia or dystrophic mineralization have been related to disc degeneration[1] which histologically seems to increase with age.[10] The only reported specific treatment for these ultrasonographically abnormal lumbosacral discs is deep paramedian corticosteroid (±sarapin or local anaesthetics) injection around the lumbosacral disc, with a variable effect.[1] [3]

In human beings, where the histological and physiological properties of the lumbosacral disc have been well reported, discal affections represent an important cause of low back pain. Disc degeneration is defined as an aberrant, cell-mediated response to progressive structural failure, leading to destruction of the disc extracellular matrix. Pain is attributed in part to ingrowth of nerves and vessels in the degenerative disc because of its loss of hydrostatic pressure and decreased proteoglycan content.[18] Among other treatment options, fluoroscopically guided or computed tomography-guided intradiscal corticosteroid injections have been reported as being safe, rapid and beneficial for patients with degenerative disc disease and chronic low back pain. The efficacy of this technique is, however, better in patients exhibiting discogenic inflammation on magnetic resonance imaging and of short-term duration.[19] [20] [21] Recent studies also report encouraging results when injecting platelet-rich plasma into degenerative lumbar discs.[22] [23]

Given the apparent pathological similarities between equine and human discal lesions, intradiscal injection could also be beneficial to horses suffering from a degenerative lumbosacral disc. As a consequence, the aims of this study are to develop an ultrasound-guided injection technique of the lumbosacral disc on equine cadavers, to evaluate its accuracy and to describe the potential complications when considering the anatomic structures that could potentially be injured.

Our hypothesis was that the injection technique we present would be able to reach the lumbosacral disc with a good accuracy and a low risk of complications.

Materials and Methods

Animals

Twelve dead horses (7 mares, 5 geldings) of different breeds (6 Selle Français, 3 Thoroughbred, 1 French Sports Pony, 1 Arabian and 1 of unknown origin) weighing 493.2 kg ± 79.1 kg and aged 9.2 ± 4.4 years old were used in this study. All had been euthanized for reasons unrelated to lumbosacral pathology and kept in the refrigerator at 4°C until the injections were performed.

Materials

For this injection technique, we used a 20-gauge 20 cm long spinal needle (Mila Spinal Needle 2008, Mila International, Florence, Kentucky, United States) for each horse. A portable ultrasound machine (LOGIQ e, General Electric Healthcare, Chicago, Illinois, United States) with a 2.0 to 5.5 MHz macroconvex probe was utilized for ultrasonographic guidance. Two different dyes were used to mark the injected sites: methylene blue and azorubine.

Injection Protocol

All injections were randomly performed within 48 hours from euthanasia by one of three operators, depending on their availability. One operator was a first year ECVS resident (A), one was a final year ECVS resident familiar with ultrasound-guided treatment in horses (B) and the last operator was an ECVS/ACVSMR diplomate experienced in ultrasound-guided treatments (C). Horses were positioned either in right lateral recumbency with a neutral position of the lumbosacral joint or in sternal recumbency with the hindlimbs in abduction ([Supplementary Appendix Table A], available in online version only). The skin was clipped from the mid lumbar to the mid sacral region for ~20 cm on either side of the dorsal midline. The skin was then soap washed and coupling gel was applied.

The first step was to identify the spinous process of L6 positioning the ultrasound probe parallel to the spine between the tuber sacrale. The spinous process of L6 is angulated craniodorsally, whereas the spinous process of S1 is angulated caudodorsally. Alternatively, the transverse process of L6 could be located starting from the thoracolumbar junction and counting the transverse processes from L1 to L6. The second step was to locate the cranial intervertebral notch (incisura vertebralis cranialis) of the sacrum, also called the ventral opening of the lumbosacral intervertebral foramen.[24] This foramen is located under the iliac wing when observed dorsally. As a consequence, the ultrasound probe had to be rotated ~45° (counterclockwise for the left intervertebral foramen and clockwise for the right one) and angled ~30° caudal to orientate the ultrasonographic beam under the ileal wing ([Fig. 1]). The foramen then became visible, enclosed between the L6-S1 articular processes and the L6 transverse process. The spinal needle was then inserted 1 cm cranial to the ultrasound probe and advanced in a craniolateral to caudomedial path aiming at the cranial intervertebral notch under ultrasonographic guidance ([Fig. 2]). The needle was then passed through this foramen. From this point, the tip of the needle was no longer visible. Advancement was pursued until the needle touched the intervertebral disc, supposed to have a rubbery consistency,[25] or bone. The stylet of the spinal needle was removed, 2mL of dye was injected (methylene blue on the left side, azorubine on the right side), the stylet was replaced and the needle removed. The contralateral side was then injected similarly. Carcasses were kept in the refrigerator until dissection was performed.

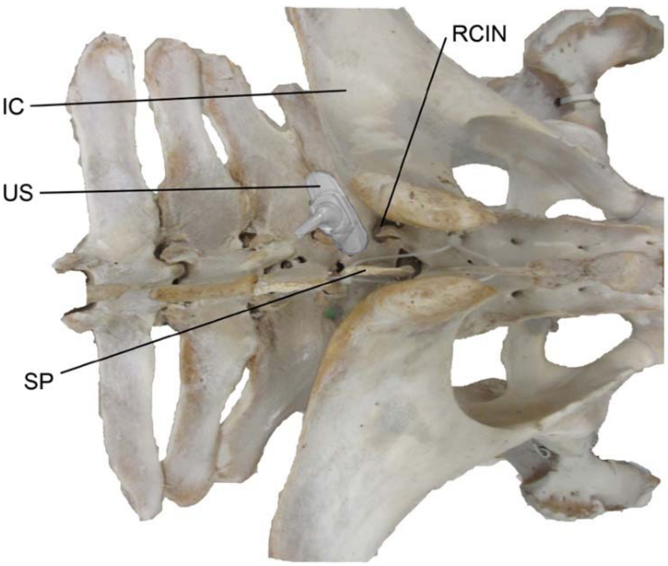

Fig. 1 Dorsal view of the lumbosacral area showing the position of the ultrasound probe to inject the lumbosacral disc from the right side. IC, iliac crest; RCIN, right cranial intervertebral notch of S1; SP, spinous process of L6; US, ultrasound probe.

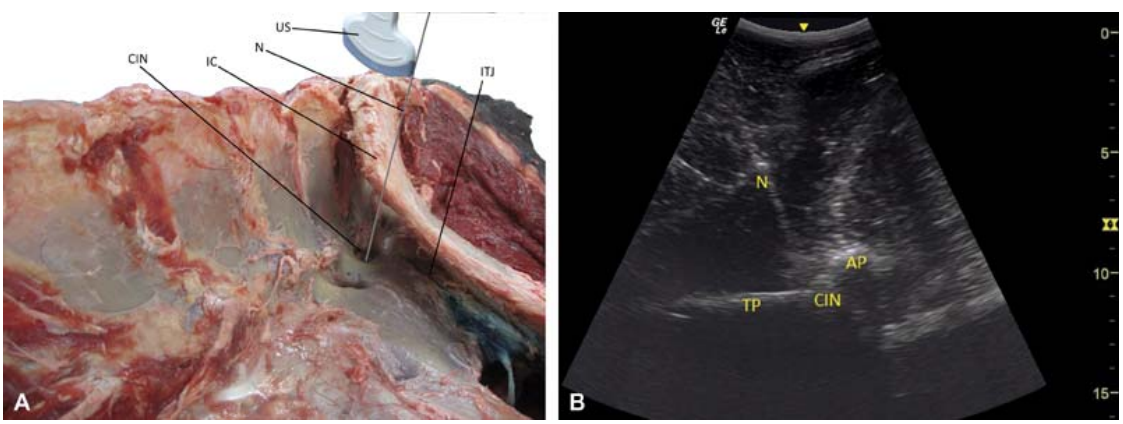

Fig. 2 Description of the ultrasound-guided injection of the lumbosacral disc from the left side. (A) Craniolateral view of an anatomical specimen illustrating the needle path. Top is dorsal; left is cranial. (B) Ultrasound picture depicting the needle path to reach the lumbosacral disc. AP, articular processes of L6-S1; CIN, cranial intervertebral notch of S1; IC, iliac crest; ITJ, L6-S1 intertransverse joint; N, spinal needle; TP, transverse process of L6; US, ultrasound probe.

Dissection Technique

All dissections were performed less than 7 days after the injections. The goal of the dissection was to assess the injected sites and the anatomic structures that had been coloured. The carcasses were suspended by the front limbs, eviscerated through the ventral midline and the hindquarters were separated by sectioning the spine at the thoracolumbar junction. The coxofemoral joints were disarticulated and then the dorsal musculature (musculus gluteus medius, m. longissimus dorsi and m. multifidus) was dissected to reach the lumbar intervertebral foramens and look for any dye deposition. Then the lumbosacral joint was approached ventrally and the ventral musculature removed (m. psoas major, m. psoas minor, m. iliacus and m. quadratus lumborum) to reach the lumbar ventral intervertebral foramens and assess dye deposition. The lumbosacral intertransverse joints were disarticulated, then the lumbosacral disc was transversally incised from its ventral aspect and the lumbosacral joint was finally disarticulated. It was possible to see the roots of the L6 nerves at this point. If dye was observed in another intervertebral foramen than L6-S1, this particular intervertebral space was dissected as well.

For each injection site, three main outcomes were evaluated: the craniocaudal position of the dye (i.e. which intervertebral foramen had been coloured), the depth of the injection (i.e. dye into the disc, at the level of the intervertebral foramen or in another location) and the presence or not of dye into the vertebral canal (meaning that the vertebral canal had been penetrated). Adjacent structures that had been coloured were noted as well.

Statistical Analysis

Descriptive statistics were used to report the three different outcomes at the injection sites. Fisher's exact test was performed to assess the influence of the operator, of the carcass position used for the injection and of the injection side on the different outcomes (BiostaTGV: http://marne.u707.jussieu.fr/biostatgv/?module=tests/fisher). The effect of the depth of injection on the risk of vertebral canal puncture was also assessed. Differences were considered significant at $p < 0.05$.

Results

Results are presented in [Supplementary Appendix Table A]

Cranio-caudal Position of the Dye

Eleven out of the 24 injections performed reached the lumbosacral space ([Fig. 3]). Eleven injections reached the L5 to L6 intervertebral space and two injections were performed in the S1 to S2 intervertebral space. Position of the horse ($p = 0.21$), injection side ($p = 1$) and the operator performing the injection ($p = 0.40$) had no significant effect on the craniocaudal position of the dye.

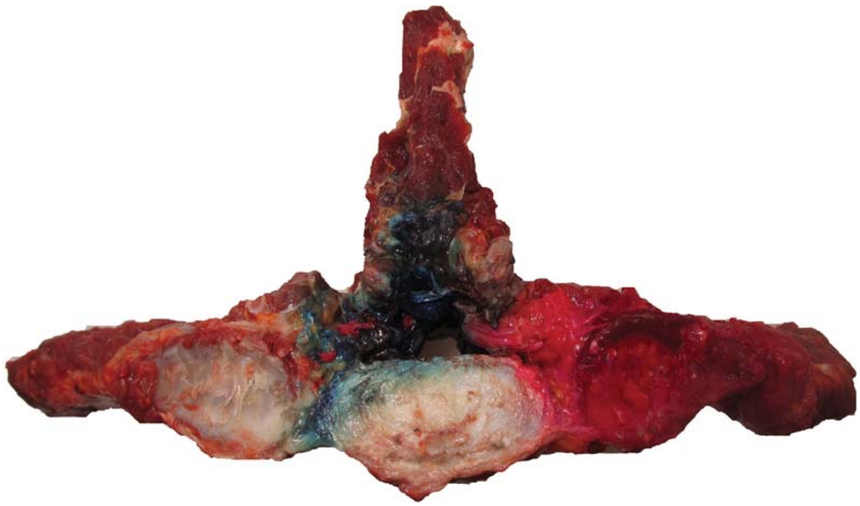

Fig. 3 Caudal view of L6 after ultrasound-guided injection of the lumbosacral disc has been performed. Note the dye deposition in the lumbosacral disc and the adjacent area: methylene blue on the left side; azorubine on the right side.

Depth of Injection

Ten of the 24 injections performed reached the L5 to L6 or L6 to S1 intervertebral disc, 9 were in the L5 to L6 or L6 to S1 intervertebral foramen and 1 coloured an intertransverse joint. Two injections were performed in the S1 to S2 intervertebral space and two in a fused L5 to L6 intervertebral space. These four injections reached the intervertebral foramen but, given the fact that no intervertebral disc was present in these joints, the depth of the injection was impossible to evaluate. Overall 19/24 injections were deemed peridiscal (colouring the intervertebral foramen or the disc itself). Concurrent coloration of the intertransverse joint was observed in three horses despite peridiscal presence of dye. Position of the horse ($p = 0.39$), injection side ($p = 0.68$) and the operator performing the injection ($p = 0.24$) had no significant effect on the depth of injection.

Overall Results Regarding the Lumbosacral Joint

Four horses (I, VI, IX and X) had dye deposition in the lumbosacral disc (on right, left or both sides). Three horses had at least one injection in the lumbosacral intervertebral foramen. Overall 7/12 horses had a lumbosacral peridiscal injections performed.

Vertebral Canal Penetration

Eleven out of 24 injections led to coloration of the vertebral canal. Overall 7 out of 12 horses had their vertebral canal penetrated. Neither the depth of the injection ($p = 0.68$) nor the operator performing the injection ($p = 0.44$) had a significant effect on the risk of vertebral canal puncture.

Discussion

The ultrasound-guided injection technique we described was able to reach the lumbosacral disc in only one-third of horses. When considering injections reaching the lumbosacral peridiscal area however, 7 out of 12 horses were positively stained. The vertebral canal was penetrated in more than half of the horses in this study.

The positions of the horse (lateral versus sternal recumbency) were not statistically different when testing for the craniocaudal location nor the depth of the injections. We expected that the sternal recumbency would have given a position more similar to that of a standing horse and facilitated the ultrasonographic guidance. Indeed, lumbosacral extension is supposed to 'open' the ventral intervertebral foramen of L6.[7] In fact this lumbosacral extension made the injection subjectively more difficult, probably because of the cranial movement of the iliac wing relative to the sacrum. By contrast, obtaining a neutral lumbosacral position seemed more easily achievable in lateral recumbency, but the position for the operator was more awkward.

The dyes we used were chosen because of their low viscosity, comparable to that of corticosteroids or platelet-rich plasma solutions that could potentially be used for discal pathologies. Two different colours were used. However, azorubine being a pink dye, it was sometimes not easily identified during the dissection process. Another drawback of using these dyes was their tendency to diffuse after injection, making precise evaluation of the injected spot sometimes difficult. Despite this, the diffusion pattern observed may approach that of potential treatment injected with this technique. An alternative technique to precisely evaluate the deposition of the injectate without disruption of the anatomy would have been to perform computed tomography of our specimens after injecting iodinated contrast material,[26] but unfortunately this modality was not available at the time of this experiment. Another option to limit diffusion would have been to inject latex, as reported previously.[27]

No effect of the operator on the outcome of the injection was observed in this study. Nevertheless, the most experienced surgeon performed only three injections, which could represent a potential limitation of these results. Ideally the three operators should have randomly performed a similar number of injections.

The fact that only 11 out of the 24 injections were able to reach the lumbosacral joint space illustrates the difficulty of identifying precisely the L6 to S1 intervertebral foramen with ultrasound. Indeed, this foramen is not ultrasonographically different from the adjacent ones and is underneath the iliac wing necessitating to angle the ultrasound probe to visualize it. Furthermore, the depth of this foramen (~12–15cm) implies that a small variation in probe angulation can lead to targeting errors. Additionally, sacralisation of L6 with a caudally oriented L6 spinous process and motion occurring between L5 and L6, as well as a missing L6 have been previously described and are not rare.[8] [28] Theses anatomical variations could further complicate the correct identification of the lumbosacral joint. Finally, the ultrasonographic image quality can also be impeded by the thick skin and the dorsal fat accumulation.[29] In humans, fluoroscopy allows a precise and three-dimensional assessment of the needle position, but unfortunately the size of the horse limits the use of this modality.

Even though the ventral intervertebral foramen was easily attainable, reaching the disc appeared more complicated. This is due to the fact that the needle is advanced blindly after it has entered the foramen. When it was successful, the rubbery consistency with firm resistance when reaching the annulus fibrosus described in human beings was sometimes, but not always, readily felt upon needle advancement in our specimens.[25] Overall, 19/24 of our injections were peridiscal (with 11/24 in the lumbosacral area) with a good diffusion of the dye around the disc in all these cases. In humans, a beneficial effect of transforaminal injections on the pain level has been shown.[30] It is thus possible that peridiscal injections could have a beneficial effect on horses with discal pathologies.

The fact that only 7/12 of our horses had a lumbosacral peridiscal injection illustrates the limited accuracy of our technique to precisely localize the lumbosacral space. Additionally, both sides were injected in our cases, whereas humans are injected in only one side of the disc owing to the good accuracy of the technique.

Eleven injections led to coloration of the vertebral canal. At the lumbosacral junction, the vertebral canal contains the spinal cord surrounded by the meninges. However, the spinal cord is located dorsally and axially to the ventral intervertebral foramen (in which the needle is inserted), protected laterally by the articular process, and is theoretically not directly accessible with the technique we used. The most plausible explanation is therefore penetration of the lateral epidural space. Indeed, in humans, this lateral epidural space communicates freely with the paravertebral space through the intervertebral foramina.[31] In humans, transforaminal injections can be used to purposely reach this lateral epidural space. Additionally, the large peridural space at the equine lumbosacral space could be another factor to explain the diffusion of the dyes from the lateral epidural space to the vertebral canal.[32] Another possible option to explain the coloration of the vertebral canal is a puncture of the dura mater that covers the spinal nerves from their emergence to the intervertebral foramen.[32] A microscopic evaluation of the spinal cord was unfortunately not performed to assess this theory. Subarachnoid injections in the lumbosacral space can be used safely in horses for anaesthetic purposes.[33] In humans, injections performed in the dura mater only cause cephalalgia. As a consequence, the potential risk of dura mater penetration when performing ultrasound-guided injections as described should not be a limiting factor. Nonetheless, because of the close proximity of the spinal cord, injection of toxic products is contraindicated, should this technique be utilized in live horses. Similarly, depot corticosteroids such as prednisolone acetate have been associated with paraplegia due to spinal cord ischemia of arterial origin in humans after transforaminal injections and should therefore not be used.[34]

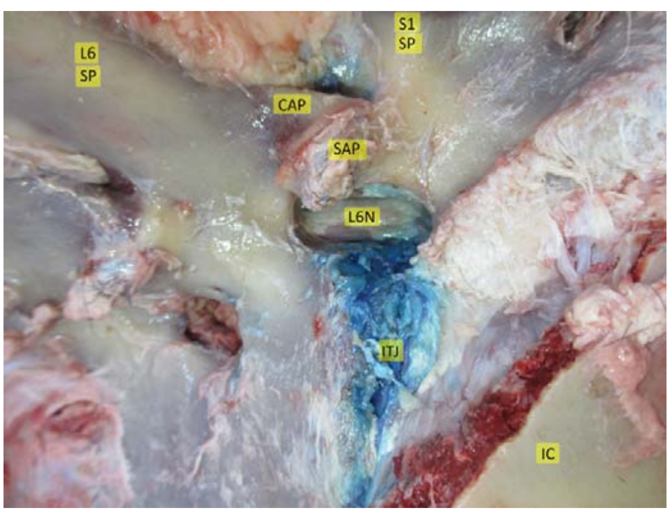

Fig. 4 Dorsal view of the left L6-S1 ventral intervertebral foramen after sectioning of the left iliac wing. Note that the L6 spinal nerve occupies a large part of this foramen. Top is dorsal; left is cranial. CAP, caudal articular process of L6; IC, iliac crest; ITJ, L6-S1 intertransverse joint; L6N, L6 spinal nerve; SAP, sacral articular process; SP: spinous process.

Another potentially injured structure is the L6 spinal nerve, which occupies a large part of the intervertebral foramen ([Fig. 4]). This nerve is implicated in the formation of the obturator nerve, the gluteal nerves and the sciatic nerve.[32] As a consequence, this nerve can potentially be harmed when the needle is inserted through the intervertebral foramen with unknown consequences on a live horse. It is possible that horses could react violently when the needle strikes the nerve because of the painful stimulus, as described in humans when the needle is in close proximity to the nerve.[25] The caudal gluteal artery, lying ventrally to the L6 spinal nerve, could also be potentially injured using this technique.[35]

Given the low accuracy of this technique, one can wonder if an alternative technique could be used to inject the lumbosacral disc. One option could be to use an axial approach, as described for lumbosacral cerebrospinal fluid collection. However, it would require a penetration of the spinal cord that runs into the vertebral canal up to the middle to caudal third of S1, with unpredictable effects.

Conclusion

The ultrasound-guided injection technique of the lumbosacral disc we described offers only a limited accuracy. Even if the lumbosacral area was reached in 7 out of 12 horses, only one-third of horses truly had an intradiscal injection. Given the risk of vertebral canal puncture and L6 nerve damage, the innocuity of this technique cannot be validated. As a consequence, this cadaveric study has to be considered as a preliminary study and the technique presented should not be recommended to treat clinical cases until further work has been done to approach the lumbosacral disc safely.

Conflict of Interest

None declared.

Author Contribution

All authors contributed to conception of study, study design, acquisition of data, and data analysis and interpretation. All authors drafted, revised and approved the submitted manuscript.

References

1 Denoix JM, Audigié F, Coudry V. Review of diagnosis and treatment of lumbosacral pain in sport and race horses. In: Proceedings of the 51st Annual Convention of the American Association of Equine Practitioners; December 3–7, 2005; Seattle, Washington; 2005: 366–373

2 Head M. Ultrasonography of the pelvis. In: Kidd JA, Lu KG, Frazer ML., eds. Atlas of Equine Ultrasonography. Oxford, UK: Wiley; 2014: 183-197

3 Dyson SJ. Lumbosacral and pelvic injuries in sports and pleasure horses. In: Ross MW, Dyson SJ., eds. Diagnosis and Management of Lameness in the Horse. 2nd ed. Philadelphia, PA: Elsevier; 2011: 571-582

4 Townsend HG, Leach DH, Fretz PB. Kinematics of the equine thoracolumbar spine. Equine Vet J 1983; 15 (02) 117-122

5 Denoix JM. Kinematics of the thoracolumbar spine in the horse during dorsoventral movements: a preliminary report. Paper presented at: Second International Conference on Equine Exercise Physiology; 1987; Davis, CA: ICEEP Publications

6 Jeffcott LB, Dalin G. Natural rigidity of the horse's backbone. Equine Vet J 1980; 12 (03) 101-108

7 Denoix JM. Spinal biomechanics and functional anatomy. Vet Clin North Am Equine Pract 1999; 15 (01) 27-60

8 Denoix JM. Approche sémiologique des régions lombo-sacrale et sacro-iliaque chez le cheval. Prat Vet Eq 1992; 24 (13) 13-21

9 Townsend HG, Leach DH. Relationship between intervertebral joint morphology and mobility in the equine thoracolumbar spine. Equine Vet J 1984; 16 (05) 461-465

10 Bergmann W, Bergknut N, Veraa S. , et al. Intervertebral disc degeneration in warmblood horses: morphology, grading, and distribution of lesions. Vet Pathol 2018; 55 (03) 442-452

11 Yovich JV, Powers BE, Stashak TS. Morphologic features of the cervical intervertebral disks and adjacent vertebral bodies of horses. Am J Vet Res 1985; 46 (11) 2372-2377

12 Jeffcott LB. The normal anatomy of the osseous structures of the back and pelvis. In: Henson FMD., ed. Equine Back Pathology. Ames, Iowa: Wiley-Blackwell; 2009: 3-15

13 Denoix JM, Audigié F. Imaging of the musculoskeletal system in horses. In: K Hinchcliff AK, Geor RJ. eds. Equine Sports Medicine and Surgery. London: Saunders; 2004: 161-187

14 Bergman EHJ, Puchalski SM, Denoix JM. How to Perform a Transrectal Ultrasound Examination of the Lumbosacral and Sacroiliac Joints. Proc Am Assoc Equine Pract: Nashville, TN; 2013

15 Alexandre A, Meyer CM, Dauchel D. , et al. Prévalence et aspects cliniques des affections du disque lombo-sacré chez le cheval athlète. 44e Journées annuelles de L'Association Vétérinaire Equine Française: Reims, France; 2016

16 Fölkel IM. Lumbar intervertebral disc disease (IVDD) in horses: a longitudinal ultrasonographic and histomorphological comparison: University of Utrecht; 2012

17 Nagy A, Dyson S, Barr A. Ultrasonographic findings in the lumbosacral joint of 43 horses with no clinical signs of back pain or hindlimb lameness. Vet Radiol Ultrasound 2010; 51 (05) 533-539

18 Adams MA, Roughley PJ. What is intervertebral disc degeneration, and what causes it?. Spine 2006; 31 (18) 2151-2161

19 Buttermann GR. The effect of spinal steroid injections for degenerative disc disease. Spine J 2004; 4 (05) 495-505

20 Fayad F, Lefevre-Colau MM, Rannou F. , et al. Relation of inflammatory Modic changes to intradiscal steroid injection outcome in chronic low back pain. Eur Spine J 2007; 16 (07) 925-931

21 Buttermann GR. Intradiscal injection therapy for degenerative chronic discogenic low back pain with end plate Modic changes. Spine J 2012; 12 (02) 176; discussion 177

22 Tuakli-Wosornu YA, Terry A, Boachie-Adjei K. , et al. Lumbar Intradiskal Platelet-Rich Plasma (PRP) Injections: a prospective, double-blind, randomized controlled study. PM R 2016; 8 (01) 1-10, quiz 10

23 Levi D, Horn S, Tyszko S, Levin J, Hecht-Leavitt C, Walko E. Intradiscal platelet-rich plasma injection for chronic discogenic low back pain: preliminary results from a prospective trial. Pain Med 2016; 17 (06) 1010-1022

24 König HEL. H. G. Veterinary Anatomy of Domestic Mammals. 6th ed. Stuttgart, Germany: Schattauer; 2014

25 Peh W. Provocative discography: current status. Biomed Imaging Interv J 2005; 1 (01) e2

26 Stack JD, Bergamino C, Sanders R. , et al. Comparison of two ultrasound-guided injection techniques targeting the sacroiliac joint region in equine cadavers. Vet Comp Orthop Traumatol 2016; 29 (05) 386-393

27 Cousty M, Rossier Y, David F. Ultrasound-guided periarticular injections of the sacroiliac region in horses: a cadaveric study. Equine Vet J 2008; 40 (02) 160-166

28 Stubbs NC, Hodges PW, Jeffcott LB, Cowin G, Hodgson DR, McGowan CM. Functional anatomy of the caudal thoracolumbar and lumbosacral spine in the horse. Equine Vet J Suppl 2006; (36) 393-399

29 Whitcomb MB. Ultrasonography of the lumbosacral spine and pelvis. In: Henson FMD., ed. Equine Back Pathology. Ames, Iowa: Wiley-Blackwell; 2009: 112-214

30 Ghahreman A, Ferch R, Bogduk N. The efficacy of transforaminal injection of steroids for the treatment of lumbar radicular pain. Pain Med 2010; 11 (08) 1149-1168

31 Costanza AB, Abdi S. Epidural steroid injections. In: Smith HS., ed. Current Therapy in Pain. Philadelphia, PA: Elsevier; 2009: 582-587

32 Barone RSP. Anatomie comparée des mammifères domestiques Tome.7–Neurologie. In: Barone R., ed. Paris, France: Vigot; 2010: 838

33 Natalini CC. Spinal anesthetics and analgesics in the horse. Vet Clin North Am Equine Pract 2010; 26 (03) 551-564

34 Wybier M, Gaudart S, Petrover D, Houdart E, Laredo JD. Paraplegia complicating selective steroid injections of the lumbar spine. Report of five cases and review of the literature. Eur Radiol 2010; 20 (01) 181-189

35 Espinosa P, Benoit P, Salazar I, de la Fuente J, Heiles P. Transrectal ultrasonography of equine lumbosacral nerves: pilot study in 28 healthy Warmblood horses. Vet Radiol Ultrasound 2017; 58 (02) 228-236