

Equine Clinic, General Surgery and Radiology, Department of Veterinary Medicine
Freie Universität Berlin

Use of body-mounted inertial sensors to objectively evaluate forelimb lameness in the horse and the response to diagnostic analgesia of the distal limb

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submitted by
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For my parents, my teacher, my family

แต่ คุณมารดา ปราณจิต ชัยบาล, คุณบิดา กำจร กุลไชยวัฒน์ ผู้ให้ชีวิตและเลี้ยงดูด้วยความรัก

แต่ คุณอาจารย์ ชำนาญ ตริณรงค์ ครูผู้สอนและครูผู้ให้โอกาสการเรียนรู้ทางด้านผ้า

แต่ สามีรนจิต รุ่งศรีผู้เป็นที่รัก, สนับสนุนและเป็นสายลมได้ปีกที่อบอุ่นเสมอ ขอบคุณที่ทำหน้าที่คุณพ่อที่ดีของลูกสาวระหว่างที่กำลังศึกษาอย่างอดทนและเยี่ยมที่สุด

แต่ ลูกสาว ปรณรค์ รุ่งศรีผู้เป็นดั่งดวงใจ, เป็นเด็กที่น่ารัก เข้มแข็ง อดทน และเป็นเด็กดีเสมอ

แต่แม่ ผู้เป็นครู ที่ทำให้เรียนรู้อย่างไม่มีความสิ้นสุด

แต่ พระธรรมที่หล่อเลี้ยงชีวิตอย่างมีสติ, เข้าใจ, และเกิดปัญญา

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1 Introduction

Forelimb lameness is very common in horses around the world. The crucial part of an orthopedic examination is to localize the source of pain because this is a prerequisite for an adequate treatment. Traditionally this is performed using diagnostic nerve and joint blocks. However, the major challenge for clinicians remains the assessment of the lameness after injection of the local anesthetic solution and comparison to a baseline, especially in horses with subtle lameness. Despite the facts that the subjective evaluation of horses with mild lameness has low reliability (Keegan et al. 2010) and un-blinded subjective assessment of lameness after perineural analgesia is also susceptible to bias (Arkell et al. 2006), most of the studies evaluating the response to nerve blocks have been based on subjective assessment of the gait of the horse (Dyson 1991, Schumacher et al. 2000, Schumacher et al. 2001). In this type of assessment, using a subjective scoring method (Adam 1974, Ross 2003) that describes lameness with a limited number of categories such as mild, moderate, or severe can make quantifying small changes difficult, especially in horses with low grade lameness.

In recent years, technology in various forms has been introduced in an attempt to objectively assess and measure lameness. Objective methods of lameness evaluation have the potential for increased sensitivity of measurement, with more precise differentiation of small differences and without potential bias of the observer (Keegan et al. 1997, Bidwell et al. 2004). Previous studies have used kinematic (measuring motion) parameters and kinetic (measuring force) techniques for objective measurement of equine lameness (Peham et al. 1999, Keegan et al. 1997, Bidwell et al. 2004, Weishaupt et al. 2006), however, most of these methods require a lot of equipment, are expensive, and are ultimately impractical in a clinical setting. Recently, body-mounted inertial sensor systems (BMISS) have been introduced that are easy to use and do not require expensive technology. Furthermore, these sensor systems

provide data immediately and are sufficiently repeatable and accurate for clinical use (Thomsen et al. 2010, Keegan et al. 2011a, Keegan et al. 2012). The BMISS^a used in this study was developed and validated by Keegan and team (Keegan et al. 2011a, Keegan et al. 2012). This system uses three inertial sensors (Fig. 1). One uni-axial accelerometer, each, is attached to either the head cap in the poll region, or to a piece of hook-and-loop tape fixed on the most dorsal part of the pelvis between the tubera sacrale. An additional gyroscopic sensor, which is used only as an event marker to time index right forelimb stance and swing phases, was attached in a special pouch to the dorsal part of the right forelimb pastern. The acceleration sensors measure head and pelvic vertical movement asymmetry. This data is collected and transmitted wirelessly to a tablet computer.

This system is an objective method of forelimb lameness evaluation using a head-mounted accelerometer that measures asymmetry of vertical head movement when the horse is trotting. All horses that were used in this study were determined to have forelimb lameness because they had vertical head movement asymmetry, as measured by the vector sum (VS) (Keegan et al. 2012) of maximum (HD_{max}) and minimum (HD_{min}) head height differences between the right and left forelimb stride phases that were above the estimated thresholds between sound and lame for this equipment. The system used in this study samples motion at 200 times per second, some ten times greater than the estimated temporal resolution of the unaided human eye, which theoretically provides for considerably higher sensitivity for detection of lameness than the naked eye. For this study the main advantage afforded by using this equipment was that it provided unbiased objective data. As all horses also had lameness on subjective visual examination, it was not the purpose of this study to determine the sensitivity of this equipment to detect lameness.

This study is a clinical research study using a body-mounted inertial sensor system-based method to objectively measure lameness in horses with distal forelimb lameness and compare the resulting response between the nerve block and joint block of the foot. This study is divided into two projects.

The first project is *Use of body-mounted inertial sensors to objectively evaluate the response to perineural analgesia of the distal limb and intra-articular analgesia of the distal interphalangeal joint in horses with forelimb lameness*. The aim of this study was to compare objectively the results of palmar digital and abaxial sesamoid peripheral nerve blocks to intra-articular anesthesia of the distal interphalangeal (DIP) joint in horses with distal forelimb lameness. It was hypothesized that the response to anesthesia of the DIP joint would be significantly different to perineural anesthesia of the distal limb in horses with distal limb lameness.

Foot pain is one of the most common causes of lameness in horses (Dyson et al. 2005). Even though the localization of the pain by means of perineural and intra-synovial analgesia is straightforward, the diagnosis of the specific site of injury within the foot is often difficult (Dyson et al. 2005). It has been claimed that intra-articular analgesia of the distal interphalangeal joint (DIP joint) can clearly localize the source of pain in the foot to the distal interphalangeal joint and/or the navicular bursa. On the other hand, it has been demonstrated that non-joint related structures such as within the foot can be desensitized after DIP joint analgesia (Bowker et al. 1993, Keegan et al. 1996, Schumacher et al. 2001), causing problems with a precise diagnosis. This effect has been explained by communication of the DIP joint with other synovial structures and/or local diffusion of anesthetic to different structures or local nerves (Bowker et al. 1993, Keegan et al. 1996, Schumacher et al. 2001, Manfredi et al. 2012). A positive response to diagnostic analgesia is a prerequisite for

confirmation that medical imaging findings accurately diagnose the cause of lameness (Dyson & Kidd 1993). Hence, one of the major challenges of a lameness evaluation is accurate assessment of the nerve and joint block response.

A recent comparison of BMISS to subjective evaluation for detection of lameness in horses reported only a moderate correlation (Keegan et al. 2013). However, a comparison of these systems to subjective evaluation has not been studied using years of experience of the evaluator as a variable. To address this gap in research regarding BMISS, the second project - *Agreement between a body-mounted inertial sensors system and subjective observational analysis when evaluating lameness degree and diagnostic analgesia response in horses with forelimb lameness* - specifically aimed to estimate the inter-observer agreement on subjective lameness evaluation by veterinarians of different experience levels. For this project, it was hypothesized that agreement between objective inertial sensor and subjective evaluations would be dependent upon years of experience, so agreement for improvement of lameness after blocking with experienced veterinarians would be high. A complete set of radiographs including lateromedial, dorsopalmar, and skyline of the navicular bone of both front feet were used for all the horses. There was some variation in the additional imaging techniques used. Imaging of 13 horses was performed using standard ultrasound diagnosis of the distal extremity (Carnicer et al. 2013, Coudry & Denoix 2013), and three horses underwent low-field MRI examinations in the sedated standing position using the Hallmarg system (Mair & Kinns 2005, Dyson 2008) .

2 Research publication in journals with peer-review

2.1 Use of body-mounted inertial sensors to objectively evaluate the response to perineural analgesia of the distal limb and intra-articular analgesia of the distal interphalangeal joint in horses with forelimb lameness

DOI: <http://dx.doi.org/10.1016/j.jevs.2014.05.002>

You can purchase this part online.

2.2 Agreement between a body-mounted inertial sensors system and subjective observational analysis when evaluating lameness degree and diagnostic analgesia response in horses with forelimb lameness

<http://www.hippiatrika.com/download.htm?id=20140603>

3 Declaration of own portion of work in the research publications

3.1 Use of body-mounted inertial sensors to objectively evaluate the response to perineural analgesia of the distal limb and intra-articular analgesia of the distal interphalangeal joint in horses with forelimb lameness

Authors: P. Rungsri, W. Staecker, P. Leelamankong, R. Estrada, T. Schulze,

C.J. Lischer

Year: 2014

Journal: Journal Equine Veterinary Science, 34 (2014) 972-977.

	Rungsri	Staecker	Leelamankong	Estrada	Schulze	Lischer
Study design	40%	15%	-	5%	-	40%
Data collection	70%	10%	10%	10%	-	-
Study execution	50%	10%	20%	10%	-	10%
Data analysis and Interpretation	60%	-	-	10%	10%	20%
Preparation of the manuscript	60%	5%	5%	15%	-	15%

3.2 Agreement between a body-mounted inertial sensors system and subjective observational analysis when evaluating lameness degree and diagnostic analgesia response in horses with forelimb lameness

Authors: P. Rungsri, W. Staecker, P. Leelamankong, R. Estrada, M. Rettig,
C.Klaus, C.J. Lischer

Year: 2014

Journal: Pferdeheilkunde, 30 (2014) 644-650.

	Rungsri	Staecker	Leelamankong	Estrada	Rettig	Klaus	Lischer
Study design	40%	10%	-	5%	-	5%	40%
Data collection	70%	10%	15%	-	-	5%	-
Study execution	50%	10%	10%	10%	10%	-	10%
Data analysis and Interpretation	60%	-	-	10%	10%	-	20%
Preparation of the manuscript	50%	5%	5%	10%	10%	5%	15%

4 Discussion

This thesis aimed to assess the quality of the clinical part of the lameness investigation of horses with pain arising from the hoof. The validated tool for the quantification of gait imbalance (Body-mounted inertial sensor system = BMISS) enabled the researchers (1) to objectively assess the effect of different techniques of diagnostic anesthesia used in the feet of horses with forelimb lameness and (2) to compare these findings with the subjective assessment of veterinarians with different experience levels.

In the first study it was hypothesized that response to anesthesia of the DIP joint would be significantly different than perineural anesthesia of the distal limb in horses with distal limb lameness. The results of the first study support the assumption that DIP joint blocking results in overlapping but inequivalent areas of desensitization compared to PD plus AS nerve blocks in the forelimb. It is possible that in some horses with forelimb lameness the diffusion of anesthetic out of the joint is sufficient to affect the PD nerves or dorsal branches, but this is not usual or predictable (Dyson et al. 2005, Dyson & Kidd 1993, Schumacher et al. 2004). In this group of horses with forelimb lameness, the amplitude of lameness after PD nerve block was not significantly different than after DIP joint block, but some horses had greater improvement in lameness after PD nerve block and some had greater improvement after DIP joint block. Also, in this group of horses with forelimb lameness, improvement in lameness after AS nerve block was significantly greater than after DIP joint block, and individually more than half of the horses had more improvement after AS nerve block compared to DIP joint block. The conclusion that DIP joint block has overlapping but non-equivalent areas of desensitization with PD and AS nerve blocks can only be made when using 5 ml of anesthetic solution for DIP joint block. Using larger volumes of anesthetic solution may give different results.

The time between application of joint block and the assessment of the effect is crucial. The improvement of lameness after a DIP joint block was greater after 5 and 10 minutes than after 2 minutes of intra-articular injection of Mepivacaine. Most of the horses that had at least 70% improvement of lameness after both PD nerve and DIP joint blocks exhibited this improvement within 2 minutes of the DIP joint block. Horses that improved at least 70% only after both PD and AS nerve blocks required at least 5 minutes after DIP joint blocking for full effect. This delayed full effect can either be due to greater penetration of the anesthetic to deeper articular structures or diffusion through the joint capsule to affect extra-articular structures. Our findings that most individuals had greater reduction of lameness after AS nerve blocks than after DIP joint block suggest that the former (greater penetration of the anesthetic to deeper articular structures) is more likely. Furthermore, the extent of the pathology within the tissues may affect the diffusion of local anaesthetic in the joint as well. Evaluation for lameness immediately after DIP joint block and comparing to subsequent later (5 and 10 minutes after block) evaluation may have some differential diagnostic utility, perhaps for determining depth or severity of distal interphalangeal joint pathology, but the full effect should not be expected for at least 5 minutes. This is certainly within a reasonable time frame that can be accommodated even under the most demanding clinical practice situations. It remains unclear why two horses in this study improved 5 minutes after DIP joint block but had lameness return to the baseline severity after 10 minutes.

The selection of the cases used in this study and the interpretation of the data were based on pain abolishment and not correlated to a specific diagnosis. Although a complete set of radiographs including lateromedial, dorsopalmar, and skyline of the navicular bone of both front feet were available for all the horses, the diagnosis remained inconclusive for the

majority of the cases (Appendix C). Even though the main goal of this study was to objectively demonstrate if there was a different blocking pattern between the perineural analgesia of the digit and the intra-articular DIP joint blocks, the lack of a final diagnosis affects the interpretation of the study's conclusions. The radiographic diagnosis has a limitation in identifying pathologic lesions of soft tissue in the hoof and cartilage lesions of the DIP joint, the subchondral bone defect, or osseous cyst-like lesions of the distal and middle phalanges. Even though ultrasound imaging can provide information for the diagnosis of the soft tissue around the hoof such as the collateral ligament of DIP joint, it still has limited ability to diagnosis the deeper structures within the hoof. Lesion at the insertion area of the deep digital flexor tendon (DDFT) to the distal phalanx, and lesion of the distal sesamoidean impar ligament can cause significant difficulties in performing ultrasound diagnosis.

Despite this limitation in ultrasound imaging, diagnostic imaging quality of the foot has improved substantially in recent years. The technical progress is most obvious in digital radiography and MRI, where subtle changes in the bone and soft tissues become visible (Mair & Kinns 2005, Dyson 2008). However, the ultimate diagnostic value of these imaging findings is inevitably linked to the ability of the veterinarian to localize the pain reliably to the foot or – even better – to specific areas within the foot. Whereas radiographs and MRI scan be sent easily to imaging specialists for a second opinion, the clinical examination of a horse with subtle lameness is left to the subjective assessment of the individual veterinarian.

Improvement of diagnostic quality is based on ongoing critical review of the process. MRI examinations have increased the knowledge about soft tissues (Schramme 2014), but part of this quality assessment is to know the limitations of diagnostic techniques. One such limitation is that MRI diagnosis is not possible for all the owners due to availability and/or

cost. This thesis aims to critically review the reliability of the lameness assessment in the horse for a better understanding of the limitations. For further study, if the correlation between the results of MRI examinations and results of response to diagnostic anesthesia using objective assessment techniques such as BMISS, it would fill a significant gap is established in veterinary knowledge that would lead to a better understanding of distal limb lameness.

The results of the second project support the hypothesis that agreement between objective inertial sensors and subjective evaluations would be dependent upon years of experience, so agreement for improvement of lameness after blocking with experienced veterinarians would be high. The results show the agreement between subjective lameness score of two experienced veterinarians in a clinical situation and the results of an inertial sensor system was moderate, both for detecting the lame limb or the absence of lameness and the assessment of the effect of regional analgesia in horses with mild to moderate forelimb lameness. Even though previous studies have shown a fair to moderate agreement between subjective and objective lameness evaluation (Keegan et al. 2013), the results of this study indicate that there is a moderate agreement between subjective and objective lameness examination when experienced veterinarians perform live forelimb lameness evaluation, trotting the horses in a straight line on a hard surface. The veterinarians used a standardized subjective scoring system to perform the lameness examinations (Appendix A) and to classify the response to the blocking (Appendix B). The evaluators focused on the head nod to detect forelimb lameness and change of the lameness after blocking compared to baseline lameness. The highest of baseline scoring of this study was 3 out of 5. However, the main goal of this study was not correlated to the severity level of lameness scoring of inter-evaluators; this study aimed to compare agreement of lameness detection between BMISS and evaluators with varying amounts of experience.

It was found that inter-observer agreement for detection of forelimb lameness was higher for live clinical evaluation than for video review and that inter-observer agreement for video review was dependent upon clinical experience. Inter-observer agreement was also higher for more experienced veterinarians. Both of these observations are understandable and logical. There are undoubtedly many factors that are difficult to completely describe that an experienced veterinarian takes into account when he/she is observing and assessing the patient; some factors are mastered by an individual only with experience and cannot be captured on video. For example, the sound of the horse's hooves hitting the hard surface, which was not preserved for video review in this study, can be used to detect lameness. In another study the intra-observer (Keegan et al. 1998, Fuller et al. 2006), but not the inter-observer, agreement was dependent upon experience, suggesting that experience increases consistency of lameness evaluation, but not necessarily accuracy. However, this previous study (Keegan et al. 1998) was limited to horses trotting on a treadmill, which is a highly controlled environment that may not have captured the intangible factors separating experience levels.

Overall agreement of the inertial sensor system with subjective video evaluation was also highest for the highly experienced veterinarians and decreased with decreasing level of experience. This is what would be expected if the inertial sensor system was providing relevant evaluation information indicative of forelimb lameness. However, some individuals in lower experience groups had higher agreement than some individuals in higher experience groups. Agreement with the highly experienced group ($\kappa = 0.52$, 74% total agreement) was considered moderate but higher than that previously reported using the same inertial sensor system compared to three experienced veterinarians performing live lameness evaluation on 106 horses ($\kappa = 0.41$, 65% total agreement) (Keegan et al. 2013). The smaller number of horses used in the current study along with the other factors previously discussed (working

together in the same practice, experience using the same equipment) perhaps contributed to this higher agreement.

The results show that agreement between this inertial sensor system and experienced veterinarians evaluating forelimb lameness response to blocking was relatively moderate to high. Because the categories for establishing agreement were ordinal with ranking from no response to greater amplitude of response, the method of agreement analysis (Kendall's T_b) was different than for simple detection of lameness and determination of side of lameness (Fliess' κ). Agreement was moderate for the entire group but substantial for two individuals. The results showed the average T_b of HE group was moderate. However, two of the highly-experienced veterinarians (HE) showed significance of T_b at 0.382 and 0.371; these results indicate strong agreement of the improvement after blocking of inertial sensor system positively related to the subjective score by HE2 and HE4. As this inertial sensor system assessment improvement increased, so did the subjective score by HE rating of improvement of lameness. In horses with scores of 1 (no improvement to <25% improvement), there was clear agreement with the HE score, and horses with scores of 4 (76-99% improvement) and 5 (100% improvement) showed the same trend. However, the scores of 2 and 3 were difficult for HE to differentiate and assign consistently.

This study compared agreement of lameness detection evaluated only trotting in a straight line on a hard surface and response of blocking between objective and subjective systems. It would be interesting for further study to compare other conditions such as soft or hard surfaces in a circle. The video films and BMISS results of lameness detection and response to blocking would also be interesting for further study on how to improve the training of inexperienced veterinarians or veterinary students for lameness detection.

Manufacturers' addresses

^a Lameness locator, Equinosis LLC, Columbia, Missouri, USA.

5 Summary

Distal forelimb lameness is very common in horses around the world. The crucial part of a lameness examination is to localize the source of the pain. A practical and objective forelimb lameness evaluating tool without bias is needed to support clinical research study. Using a body-mounted inertial sensor system-based method in this clinical research study had two purposes: (1) to objectively assess the effect of different techniques of diagnostic anesthesia used in the feet of horses with forelimb lameness and (2) to compare these findings with the subjective assessment of veterinarians with different levels of experience.

A total of fifty-four horses with forelimb lameness were presented to the Equine Clinic, Free University Berlin, between March 2012 and June 2013. Complete standard lameness evaluations were performed for all horses; trotting the horse in a straight line was the method used for data collection. Owner permission for collection of body-mounted inertial data, video recording, and for its use in this study was obtained for every case. This clinical study was divided into two projects. The first project was *Use of body-mounted inertial sensors to objectively evaluate the response to perineural analgesia of the distal limb and intra-articular analgesia of the distal interphalangeal joint in horses with forelimb lameness*. It was published in *Journal Equine Veterinary Science*, 34 (2014) 972-977. There were six co-authors, of which was Porrakote Rungsri was the primary author.

Twenty-two horses (12 Warmbloods, 3 Standardbred Trotters, 3 Ponies, 1 Thoroughbred, 1 Friesian, 1 Fjord and 1 mixed Arabian) aged between 4-25 years old (mean = 14) were selected for the first project as follows: Each had (1) lameness in a forelimb when trotted on a straight line on a hard surface on both day 1 and day 2 of the study and (2) positive response to perineural analgesia of the foot. The Horses were divided into two

groups. Horses with definitive decrease in lameness after only the PD block were designated as group 1. Horses with definitive decrease in lameness after only the AS block (after failure of the PD block to decrease lameness) were designated as group 2. Amplitude of lameness improvement after blocking was determined as a percentage decrease in VS from the baseline (before block) evaluation. Improvement in lameness after blocking was examined using the Friedman's test with the percentage of improvement (dependent variable) and the blocking procedure (independent variable) (i.e. PD, AS, DIP2, DIP5, and DIP10).

The second project was *Agreement between a body-mounted inertial sensors system and subjective observational analysis when evaluating lameness degree and diagnostic analgesia response in horses with forelimb lameness*. It was published in *Pferdeheilkunde*, 30 (2014) 644-650. There were seven co-authors, of which was Porrakote Rungsri was also the primary authors. In the project study, 24 horses (12 Warmbloods, 5 Standardbred Trotters, 5 Ponies, 1 Thoroughbred, and 1 Appaloosa) aged between 4-24 years old (mean = 13.7) were used to assess lameness on a straight line before and after diagnostic anaesthesia by body-mounted inertial sensor systems and by two experienced veterinarians. For further study, video clip test units (n = 101) of all the trials were used. The lameness evaluators were blinded from the results of the BMISS. The inter-observers agreement and agreement of lameness evaluation between the BMISS and observers were classified into three categories: 1) right forelimb lameness or right forelimb lameness greater than left forelimb lameness, 2) left forelimb lameness or left forelimb lameness greater than right forelimb lameness, and 3) sound or equal right and left forelimb lameness. The Kappa statistic (κ), percentage of inter-observers agreement, and agreement between BMISS and subjective system (examiners opinion) were reported. The response of anaesthesia agreement was determined by six categories between body-mounted inertial sensors system and highly- experienced observers. This data was analyzed by calculation of the Kendall's tau (T_β) test.

For the conclusion of the first study, the results indicated that the intra-articular anaesthesia of the DIP joint using low volumes of local anaesthetic solution desensitizes a different region than the perineural analgesia of the digit. Moreover, the time-dependent gradual improvement of lameness observed in some patients suggests that the diffusion of the local anaesthetic plays an important role in the pain abolishment of the lameness in the foot; therefore, early re-evaluation of the lameness after 2 and 5 minutes is recommended to further differentiate the source of pain. Larger clinical studies with advanced imaging modalities should be performed to determine if there is a correlation between the time-dependent blocking pattern of the DIP joint and the pathological findings in the foot.

The second study indicated that the detection of mild to moderate lameness and response to regional or joint anaesthesia of horses obtained by use of a body-mounted inertial sensor system-based system did significantly agree with the subjective system, but variation of subjective lameness evaluation was based on experience. This study supports that the body-mounted inertial sensors system can be a practical tool for objective lameness detection and the effects of regional or joint anaesthesia in horses in clinical situation without bias.

6 Zusammenfassung

Anwendung eines mittels Körpersensoren arbeitenden Lahmheitsuntersuchungssystems zur Untersuchung von Vorhandlahmheiten beim Pferd, und zur Beurteilung der Ergebnisse der diagnostischen Anästhesie der distalen Gliedmasse

Lahmheiten der distalen Gliedmaßen werden weltweit sehr häufig gefunden. Der schwierigste Teil der Lahmheitsuntersuchung besteht darin, den Schmerz an der Gliedmaße zu lokalisieren. Die Untersuchungen dieser klinischen Studie wurden unterstützt durch die Anwendung eines Lahmheitsuntersuchungssystems, das objektiv und gleichzeitig praxisorientiert ist. Der Vorteil einer Untersuchung mittels Einsatz eines Sensorgestützten Untersuchungssystems(hier genannt Lameness Locator= BMISS= body-mounted inertial sensor system) bei dieser klinischen Studie liegt (1) in der Objektivierung verschiedener Techniken der diagnostischen Anästhesie bei der Evaluierung von Vorhandlahmheiten und (2) im Vergleich dieser Befunde mit der subjektiven Befundung von Tierärzten mit unterschiedlicher klinischer Erfahrung. Insgesamt wurden 45 Pferde mit Vorhandlahmheit zwischen März 2012 und Juni 2013 in der Klinik für Pferde der Freien Universität zur Lahmheitsuntersuchung vorgestellt. Alle Pferde wurden einer vollständigen Lahmheitsuntersuchung unterzogen. Die Untersuchung im Trab auf gerader Linie war die Standardmethode zur Erlangung der Daten für den Lameness Locator(LL). Die Erlaubnis der Besitzer der Pferde für den Einsatz des Lameness Locators unter Anwendung der am Körper zu befestigenden Sensoren, für die Videoaufzeichnung und für die Verwendung der Pferde in der Studie, wurde für jeden einzelnen Fall eingeholt.

Die Studie wurde aufgeteilt in zwei Studien. Der Titel der ersten Studie lautet: Einsatz von am Körper befestigten Sensoren zur objektiven Beurteilung von Leitungsanästhesien an der distalen Gliedmaße und bei intraartikulären Anästhesien der distalen Zehengelenke bei Pferden mit Vorhandlahmheit. Diese Studie wurde veröffentlicht im Journal of Equine

Veterinary Science, 34(2014) 972-977. Es gibt 6 Mitautoren, von denen Porrakote Rungsri der erste Autor ist.

Fünfundzwanzig Pferde(12 Warmblüter, 3 Traber(Standardbred) , 3 Ponys, 1 Vollblüter, eine Friesse, ein Fjordpferd und ein Araber-Mix im Alter von 4 bis 25 Jahre(Durchschnitt = 14 Jahre) wurden für das folgende Projekt ausgewählt: Jeder Proband(1) zeigte eine Lahmheit einer Vordergliedmaße beim Vortraben auf gerader Linie und hartem Untergrund am Tag 1 und Tag 2 der Studie und eine positive Leitungsanästhesie des Hufes. Die Pferde der Studie wurden in zwei Gruppen aufgeteilt. Die Pferde mit einem deutlichen Rückgang der Lahmheit nach Anästhesie der Rami pulvinii(TB-Block) wurden der ersten Gruppe zugeordnet. Pferde mit einem deutlichen Rückgang der Lahmheit nur nach Mittlerer Palmarnervenanästhesie(MPA) wurden der zweiten Gruppe zugeordnet. Die Verbesserung der Lahmheit nach Leitungsanästhesien wurden untersucht unter Anwendung des Friedman's Tests, der als Parameter den Prozentsatz der Verbesserung nach Anästhesie(abhängige Variable) und die Art der Anästhesie(unabhängige Variable)(TPA, MPA; Anästhesie des Hufgelenkes nach 2,5 und 10 Minuten)nutzt.

Das zweite Projekt lautet: Übereinstimmung zwischen einem System(BMISS= LL), das durch am Körper befestigte Bewegungssensoren einen Lahmheitswert ermittelt und der subjektiven, auf Beobachtung basierenden Lahmheitsuntersuchung bei Pferden mit Vorhandlahmheit. Die Studie wurde veröffentlicht in der Pferdeheilkunde, 30(2014) 644-650. Es gab sieben Mitautoren mit Porrakote Rungsri als Hauptautor. An der Studie waren 24 Pferde im Alter von 4 bis 24 Jahren(Durchschnitt 13,7 Jahre) beteiligt(12 Warmblüter, 5 Standardbred Traber, 5 Ponys, 1 Vollblüter und ein Appaloosa)). Sie wurden von zwei erfahrenen Tierärzten einer Lahmheitsuntersuchung unterzogen. Die Untersuchung fand unter Einsatz des Lameness Locators auf gerader Linie vor und nach diagnostischer Anästhesie

statt. Für weitere Studien wurden Videosequenzen von allen Untersuchungsschritten(n = 101) verwendet. Die Untersucher befanden sich in einer Doppelblindstudie hinsichtlich der Ergebnisse des Lameness Locators.

Die inter-Beobachter Übereinstimmung und die Übereinstimmung der Lahmheitsuntersuchung zwischen dem Lameness Locator-Ergebnissen und den Ergebnissen der Untersucher wurde in drei Kategorien aufgeteilt: 1) das Pferd ist vorne rechts lahm oder die Lahmheit vorne rechts ist stärker als die Lahmheit vorne links, 2) das Pferd ist vorne links lahm oder die Lahmheit vorne links ist stärker als die Lahmheit vorne rechts, und 3) die Lahmheit ist vorne beidseits vorhanden und genau gleich stark. Die Kappa statistik, der Prozentsatz der inter-Beobachter Übereinstimmung und die Übereinstimmung zwischen den Lameness Locator-Ergebnissen und den Ergebnissen der Untersucher wurden beschrieben. Die Ergebnisse der Anästhesie des Lameness Locator(Lameness Locator=LL= BMISS) und den Ergebnissen der sehr erfahrenen Untersucher wurden in sechs Kategorien eingeteilt. Die Daten wurden mittels des Kendall`tau test analysiert.

Die Ergebnisse der ersten Studie lassen den Schluss zu , dass die intraartikuläre Anästhesie des Hufgelenkes unter Verwendung kleiner Volumina des Anästhetikums(5 ml) eine andere Region desensibilisiert als die entsprechende Leitungsanästhesie(Anästhesie des R.pulvinus des N. palmaris digitalis). Weiterhin lässt die zeitabhängige Verbesserung der Lahmheit bei gewissen Patienten den Verdacht zu, dass die Diffusion des Anästhetikums in benachbarte Strukturen eine wichtige Rolle spielt bei der Reduktion des Schmerzes der Lahmheit und damit der Reduktion des Lahmheitsgrades. Aus diesem Grund wird empfohlen eine frühzeitige Begutachtung der Lahmheit nach Anästhesie durchzuführen um einer Diffusion zuvorzukommen. Die Begutachtung der Lahmheit in dieser Studie fand nach jeweils 2, 5 und 10 Minuten nach Anästhesie statt. In einer größeren Studie mit einer

erweiterten Bildgebung(MRT= Magnetresonanztomographie) sollten die zeitabhängigen Ergebnisse der Anästhesie mit den Befunden der MRT verglichen werden.

Die zweite Studie belegt , dass die Befundung einer gering- bis mittelgradigen Lahmheit nach Leitungsanästhesie oder Gelenkanästhesie durch den Lameness Locators(LL= BMISS) signifikant übereinstimmt mit den Ergebnissen der Untersucher(subjektive Befundung). Es wurde eine Abweichung der Ergebnisse innerhalb der Untersuchergruppen festgestellt, die abhängig war von der Erfahrung der Untersucher. Die Studie unterstützt die Annahme, dass der Lameness Locator(BMISS= LL) eine sinnvolle Technik darstellt um eine objektive Lahmheitsuntersuchung durchzuführen und um die Wirkung von Leitungsanästhesien und Gelenkanästhesien bei klinischen Lahmheitsuntersuchungen festzustellen.

7 References

- Adam, O.R. (1974) *Diagnosis of lameness* 3rd ed., Philadelphia. pp.91-118.
- Arkell, M., Archer, R.M., Guitian, F.J., May, S.A. (2006) Evidence of bias affecting the interpretation of the results of local anaesthetic nerve blocks when assessing lameness in horses. *The Veterinary Record*, 159(11), pp.346–349.
- Bidwell, L.A., Brown, K.E., Cordier, A., Mullineaux, D.R., Clayton, H.M. (2004) Mepivacaine local anaesthetic duration in equine palmar digital nerve blocks. *Equine Veterinary Journal*, 36(8), pp.723–726.
- Bowker, R.M., Rockershouser, S.J., Vex, K.B., Sonea, I.M., Caron, J.P., Kotyk, R. (1993) Immunocytochemical and dye distribution studies of nerves potentially desensitized by injections into the distal interphalangeal joint or the navicular bursa of horses. *Journal of the American Veterinary Medical Association*, 203(12), pp.1708–1714.
- Carnicer, D., Coudry, V., Denoix, J.-M. (2013) Ultrasonographic examination of the palmar aspect of the pastern of the horse: Sesamoidean ligaments. *Equine Veterinary Education*, 25(5), pp.256–263.
- Coudry, V. & Denoix, J.-M. (2013) Ultrasonographic examination of the palmar aspect of the pastern of the horse: Digital flexor tendons and digital sheath. *Equine Veterinary Education*, 25(4), pp.196–203.
- Dyson, S.J. & Kidd, L. (1993) A comparison of responses to analgesia of the navicular bursa and intra-articular analgesia of the distal interphalangeal joint in 59 horses. *Equine Veterinary Journal*, 25(2), pp.93–98.
- Dyson, S.J. (1995) Comparison of responses to analgesia of the navicular bursa and intraarticular analgesia of the distal interphalangeal joint in 102 horses. *In Proceedings of American Association of Equine Practitioners.*, 41, pp.234–239.
- Dyson, S.J. (2008) Radiological interpretation of the navicular bone. *Equine Veterinary Education*, 20(5), pp.268–280.
- Dyson, S.J. (1991) Lameness due to pain associated with the distal interphalangeal joint: 45 cases. *Equine Veterinary Journal*, 23(2), pp.128–135.
- Dyson, S.J., Murray, R. Schramme, M.C. (2005) Lameness associated with foot pain: results of magnetic resonance imaging in 199 horses (January 2001-December 2003) and response to treatment. *Equine Veterinary Journal*, 37(2), pp.113–121.

- Easter, J.L., Watkins, J.P., Stephens, S.L., Carter, G.K., Hague, B.A., Dutton, D.W., Honnas, C. M. (2000) Effects of regional anesthesia on experimentally induced coffin joint synovitis. In *Proceedings of the Annual Convention of the AAEP 2000*. pp. 214–216.
- Keegan, K.G., Kramer, J., Yonezawa, Y., Maki, H., Pai, P.F., Dent, E.V., Kellerman, T.E., Wilson, D.A., Reed, S.K. (2011a) Assessment of repeatability of a wireless, inertial sensor-based lameness evaluation system for horses. *American Journal of Veterinary Research*, 72(9), pp.1156–1163.
- Keegan, K.G., Wilson, D.A., Kramer, J., Reed, S.K., Yonezawa, Y., Maki, H., Pai, P.F., Lopes, M.A.F. (2013) Comparison of a body-mounted inertial sensor system–based method with subjective evaluation for detection of lameness in horses. *American Journal of Veterinary Research*, 74(1), pp.17–24.
- Keegan, K.G., MacAllister, C.G., Wilson, D.A., Gedon, C.A., Kramer, J., Yonezawa, Y., Maki, H., Pai, P.F. (2012) Comparison of an inertial sensor system with a stationary force plate for evaluation of horses with bilateral forelimb lameness. *American Journal of Veterinary Research*, 73(3), pp.368–374.
- Keegan, K.G., Wilson, D.J., Wilson, D.A., Frankeny, R.L., Loch, W.E., Smith, B. (1997) Effects of anesthesia of the palmar digital nerves on kinematic gait analysis in horses with and without navicular disease. *American Journal of Veterinary Research*, 58(3), pp.218–223.
- Keegan, K.G., Wilson, D.A., Wilson, D.J., Smith, B., Gaughan, E.M., Pleasant, R.S., Lillich, J.D., Kramer, J. Howard, R.D., Bacon-Miller, C. (1998) Evaluation of mild lameness in horses trotting on a treadmill by clinicians and interns or residents and correlation of their assessments with kinematic gait analysis. *American Journal of Veterinary Research*, 59(11), pp.1370–1377.
- Keegan, K.G., Wilson, D.A., Kreeger, J.M., Ellersieck, M.R., Kuo, K.C., Li, Z. (1996) Local distribution of mepivacaine after distal interphalangeal joint injection in horses. *American Journal of Veterinary Research*, 57(4), pp.422–426.
- Keegan, K.G., Dent, E.V., Wilson, D.A., Janicek, J., Kramer, J., Lacarrubba, A., Walsh, D.M., Cassells, M.W., Esther, T.M. Schiltz, P. (2010) Repeatability of subjective evaluation of lameness in horses. *Equine Veterinary Journal*, 42(2), pp.92–97.
- Mair, T.S. & Kinns, J., (2005) Deep Digital Flexor Tendonitis in the Equine Foot Diagnosed by Low-Field Magnetic Resonance Imaging in the Standing Patient: 18 Cases. *Veterinary Radiology & Ultrasound*, 46(6), pp.458–466.
- Maliye, S., Voute, L., Lund, D., Marshall, J.F. (2013). An inertial sensor-based system can objectively assess diagnostic anaesthesia of the equine foot. *Equine Veterinary Journal*, 45, pp.26–30.
- Maliye, S. & Marshall, J.F., (2013) An inertial sensor-based system can objectively assess diagnosis anaesthesia of the equine foot. In *ECVS proceedings 2013*. 22nd Annual Scientific Meeting. Ergife Palace Hotel Rome, Italy, p. 35.

- Manfredi, J.M., Boyce, M., Malone, E.D., Anderson, C., Anderson, L.B., Trumble, T.N., (2012) Steroid diffusion into the navicular bursa occurs in horses affected by palmar foot pain. *The Veterinary Record*, 171(25), p.642.
- McGuigan, M.P. & Wilson, A.M., (2001) The effect of bilateral palmar digital nerve analgesia on the compressive force experienced by the navicular bone in horses with navicular disease. *Equine Veterinary Journal*, 33(2), pp.166–171.
- Murray, R.C., Walters, J.M., Snart, H., Dyson, S.J., Parkin, T.D.H. (2010) Identification of risk factors for lameness in dressage horses. *The Veterinary Journal*, 184(1), pp.27–36.
- Peham, C., Licka, T., Girtler, D., Scheidl, M. (1999) Supporting forelimb lameness: clinical judgement vs. computerised symmetry measurement. *Equine Veterinary Journal*, 31(5), pp.417–421.
- Pleasant, R.S., Moll, H.D., Ley, W.B., Lessard, P., Warnick, L.D. (1997) Intra-articular anesthesia of the distal interphalangeal joint alleviates lameness associated with the navicular bursa in horses. *Veterinary Surgery*, 26(2), pp.137–140.
- Ross, M.W., (2003) Chapter 7 - Movement. In Mike W. Ross, DVM, & M. Sue J. Dyson, eds. *Diagnosis and Management of Lameness in the Horse*. Saint Louis: W.B. Saunders, pp. 60–73.
- Sardari, K., Kazemi, H., Mohri, M., (2002) Effects of analgesia of the distal interphalangeal joint and navicular bursa on experimental lameness caused by solar pain in horses. *Journal of Veterinary Medicine. A, Physiology, Pathology, Clinical Medicine*, 49(9), pp.478–481.
- Schramme, M.C., (2014) Common MRI Diagnosis in Palmar Foot Syndrome. In *International Congress of the German Equine Veterinary Association Proceeding 2014*. Munich, Germany, pp. 99–105.
- Schumacher, J., Schumacher, J., DeGraves, F., Steiger, R., Schramme, M., Smith, R., Coker, M. (2001) A comparison of the effects of two volumes of local analgesic solution in the distal interphalangeal joint of horses with lameness caused by solar toe or solar heel pain. *Equine Veterinary Journal*, 33(3), pp.265–268.
- Schumacher, J., Schumacher, J., Schramme, M.C., DeGraves, F.J., Smith, R., Coker, M. (2004) Diagnostic analgesia of the equine forefoot. *Equine Veterinary Education*, 16(3), pp.159–165.
- Schumacher, J., Steiger, R., Schumacher, J., DeGraves, F., Schramme, M., Smith, R., Coker, M. (2000) Effects of analgesia of the distal interphalangeal joint or palmar digital nerves on lameness caused by solar pain in horses. *Veterinary Surgery*, 29(1), pp.54–58.

- Schumacher, J., Taintor, J., Schumacher, J., DeGraves, F., Schramme, M., Wilhite, R. (2013) Function of the ramus communicans of the medial and lateral palmar nerves of the horse. *Equine Veterinary Journal*, 45(1), pp.31–35.
- Thomsen, M.H., Persson, A.B., Jensen, A.T., Sørensen, H., Andersen, P.H. (2010) Agreement between accelerometric symmetry scores and clinical lameness scores during experimentally induced transient distension of the metacarpophalangeal joint in horses. *Equine Veterinary Journal. Supplement*, (38), pp.510–515.
- Weishaupt, M.A., Wiestner, T., Hogg, H.P., Jordan, P., Auer, J.A. (2006) Compensatory load redistribution of horses with induced weight-bearing forelimb lameness trotting on a treadmill. *Veterinary Journal (London, England: 1997)*, 171(1), pp.135–146.
- Weishaupt, M.A., Wiestner, T., von Peinen, K., Waldern, N., Roepstorff, L., van Weeren, R., Meyer, H., Johnston, C. (2006) Effect of head and neck position on vertical ground reaction forces and interlimb coordination in the dressage horse ridden at walk and trot on a treadmill. *Equine Veterinary Journal. Supplement*, (36), pp.387–39

II List of abbreviations

AS	Abaxial Sesamoideal
BMISS	Body-Mounted Inertial Sensor Systems
DDFT	Deep Digital Flexor Tendon
DIP	Distal Interphalangeal joint
et al.	et alii (latin for “and others”)
HD_{max}	Head maximum height Differences
HD_{min}	Head minimum height Differences
HE	High Experience
I	Interns
κ	Kappa
ME	Moderate Experience
MRI	Magnetic Resonance Imaging
Min	Minute
ml	Milliliter
PD	Palmar Digital nerve block
VS	Vector Sum

III Appendices

Appendix A

Table 1: Lameness grading scale adapted from a text book (Ross 2003). Scoring from 0 to 5 or sound to non weight bearing are based on observation of the horse at a trot in hand, in a straight line, on a firm or hard surface.

Score	Description
0	Sound
1	A subtle head nod is observed may be inconsistent at times.
2	Obvious lameness is observed. The head nod is seen consistently.
3	Pronounced head nod is seen several centimeters.
4	Severe lameness with extreme head nod. The horse can still be trotted.
5	The horse does not bear weight on the limb. If trotted, the horse carries the limb. Horses that are non–weight bearing at the walk or while standing should not be trotted.

Appendix B

Table 2: Description of degree of improvement of the response to anaesthesia (perineural nerve or DIP joint block) used in clinical situation in Equine Clinic, Faculty of Veterinary Medicine, Free University of Berlin.

Description in words for subjective evaluation (clinical use)	Score	Grading in percentage of improvement of the VS
Negative	1	no improvement to <25% improvement
Less than 50% improvement	2	26 – 50% improvement
More than 50% improvement	3	51-75% improvement
Positive with residual lameness	4	76 – 99 % improvement
Positive	5	100% improvement
Positive with switching lameness to the contralateral side	6	100% improvement

Appendix C

The Imaging

For all participant patients, shoe removal was important, for standard radiographic projections. Standard ultrasound diagnosis of the distal extremity was performed for 13 horses (Carnicer et al. 2013, Coudry & Denoix 2013). Three horses underwent low-field MRI examinations in the sedated standing position using the Hallmarq system (Mair & Kinns 2005, Dyson 2008). Diagnostic imaging included standard radiography of the feet. Images were taken of the lateromedial (LM), dorsoproximal-palmarodistal oblique (DPr-PaDio), and palmaroproximal-palmarodistal oblique (PaPr-PaDio or Skyline).

Table 3: Response of regional nerve block and DIP joint block and diagnosis from imaging

Horse#	Local anesthesia		DIP joint anesthesia			Diagnosis from imaging
	PD 10-15 min	AB 10-15 min	2 min	5 min	10 min	
1	100%	100%	100%	100%	100%	Tendinopathy of the DDFT at zone P1C
2	100%	100%	0%	100%	100%	Radiographically no diagnosis
3	100%	100%	100 %	100%	100%	PIP J Arthrosis
4	73.4%	83.5%	100%	100%	100%	Chronic navicular disease
5	100%	51%	100%	100%	100%	Mild changing of osteoarthritis of DIP joint, PIP joint Mild navicular disease
6	84.8%	96.4%	77.3%	80.1%	12.4%	Osteoarthritis PIP joint

Horse#	Local anesthesia		DIP joint anesthesia			Diagnosis from imaging
	PD 10-15 min	AB 10-15 min	2 min	5 min	10 min	
7	64.6%	100%	80.2%	100%	100%	Chronic navicular disease
8	66.6%	100%	53.3%	95.7%	77.5%	Radiographically no diagnosis
9	56.3%	100%	-	87.4%	-	Radiographically no diagnosis
10	41.5%	100%	51.7%	100%	100%	Cyst- like lesion at the sagittal ridge of the flexor surface of navicular bursa
11	0%	100%	13.7%	0%	96.3%	MRI: Cyst –like lesion at proximal in the first phalanx
12	54.1%	100%	47.6%	62.7%	91%	OCD DIP joint Arthrosis PIP joint Chronic navicular disease, Distal border fragment of the Navicular bone
13	13%	83.6%	65.9%	76.2%	85.6%	Arthrosis of PIP joint

Horse#	Local anesthesia		DIP joint anesthesia			Diagnosis from imaging
	PD 10-15 min	AB 10-15 min	2 min	5 min	10 min	
14	100%	100%	0%	0%	34%	Radiographically no diagnosis
15	100%	100%	24.9%	65.9%	60.5%	Chronic navicular disease
16	99.2%	100%	34.2%	56.3%	56.9%	Radiographically no diagnosis
17	100%	86.9%	37.7%	68.6%	24.9%	Radiographically no diagnosis
18	84.4%	91.9%	0%	28.2	32.1	MRI:DIP joint Arthrosis
19	60.6%	100%	11.9%	0%	7.9%	Flat conformation of the third phalanx within the hoof capsule
20	0%	100%	0%	13.2%	0%	Radiographically no diagnosis
21	9.9%	94.3%	0%	30.1%	43.8%	Radiographically no diagnosis
22	0%	100%	31.4%	54%	59.7%	MRI :Tendinopathy in the lateral lobe of the DDFT and Navicular bursa adhesion

Appendix D



Fig.1: Horse instrumented with the inertial sensor system: accelerometer at the head (1), accelerometer at the pelvic (2) and gyroscope sensor for the right forelimb (3).
Pferdeheilkunde, 30 (2014) p. 646.

IV List of publications

Rungsri PK, Staecker W, Leelamankong P, Estrada RJ, Schulze T, Lischer CJ. (2014) Use of body-mounted inertial sensors to objectively evaluate the response to perineural analgesia of the distal limb and intra-articular analgesia of the distal interphalangeal joint in horses with forelimb lameness. J Equine Vet Sci 34,972-977

Rungsri PK, Staecker W, Leelamankong P, Estrada RJ, Rettig M., Klaus C., Lischer CJ. (2014) Agreement between a body-mounted inertial sensors system and subjective observational analysis when evaluating lameness degree and diagnostic analgesia response in horses with forelimb lameness. Pferdeheilkunde 30, 644-650

Oral presentation

The 13th WEVA Congress in Budapest

ID number: 123

Title: Use of a wireless, inertial sensor-based system to objectively evaluate the response to local anaesthetic nerve blocks and intra-articular analgesia of the distal interphalangeal joint in horses with fore limb lameness

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Presenting author: Dr. Porrakote Rungsri

Date and time of the session: DAY1, Thursday, 3rd October, 12:00-13:00, Musculoskeletal

Name of the session room: Session 3, Room Lehár

Time of the presentation: 12:45-13:00

Moderator: Dr Harry Werner

The Abstract of the oral presentation in WEVA 2013 Congress in Budapest

Use of a wireless, inertial sensor-based system to objectively evaluate the response to local anaesthetic nerve blocks and intra-articular analgesia of the distal interphalangeal joint in horses with fore limb lameness

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Introduction: The assessment of the gait of lame horses before and after local analgesic techniques is a crucial part in diagnosing lameness. The use of diagnostic anaesthesia of the palmar digital nerves (PD), abaxial sesamoid (AB) and the distal interphalangeal (DIP) joint analgesia theoretically helpful to further localise the source of pain in the foot. However due to close anatomical relationship of the DIP joint capsule to the neurovascular bundles the diagnostic value of this intra-articular analgesia is questionable.

Objectives: To evaluate the response of the DIP joint analgesia in horses with foot lameness in the forelimb.

Methods: Pain in the forelimb of 13 horses was abolished with a PD or AB nerve blocks when trotting in a straight line on a hard surface. The next day, the response to application of 5ml Mepivacain in the DIP joint was objectively evaluated after 2, 5 and 10 minutes using a wireless inertial sensor system (Lameness Locator). An improvement of more than 60% compared to baseline lameness was considered as a positive response. Diagnostic imaging included standard radiography of the feet, ultrasound and MRI in selected cases.

Results: Five out of 13 (38.46%) horses were negative to DIP joint analgesia after 10 minutes. In 5 horses lameness was abolished after a PD blocks, 2 of those showed a positive response to the DIP joint analgesia after 2 minutes and 1 after 5 minutes, respectively. In 8 horses lameness was abolished after AB nerve blocks, 3 of those had a positive joint block after 5 minutes and 2 after 10 minutes.

Discussion: Lameness arising from the foot showed a variable response to the DIP joint analgesia over time suggesting that nerve and joint blocks do desensitise different regions in the foot. These results can potentially improve the interpretation of MRI findings in this region.

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VI Selbstständigkeitserklärung

Hiermit bestätige ich, dass ich die vorliegende Arbeit selbstständig angefertigt habe. Ich versichere, dass ich ausschliesslich die angegebenen Quellen und Hilfen in Anspruch genommen habe.

Berlin, den 4. Juni 2014

Porrakote Rungsri