PROCEEDINGS OF THE FIFTH CONFERENCE ON CURRENT VETERINARY PRACTICES

CONFERENCE ON CURRENT VETERINARY PRACTICES

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The Conference on Current Veterinary Practices aims at bringing equine veterinarians together to discuss the latest insights in veterinary surgery, medical imaging, drug treatment and horse care. In the present conference, we highlight optimal use of X-ray machines, hoof surgery, and overground endoscopy in the practical morning session.

In the afternoon we have a theoretical conference that covers cervical spine pathologies, internal medicine practice, regenerative treatments evaluated with UTC and local anesthesia pitfalls for lameness examination.

The conference is registered with the Order of Veterinarians (NGROD), and therefore, study points will be acquired. Partially supported by an educational grant from GST-Anacura, Eickemeyer and Orthopaedics.be.

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Time Practical Session 02: 09:00 am to 12:00 am

Time Practical Session 03: 09:00 am to 12:00 am

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Keywords: horse, veterinary practice, rehabilitation, medical imaging, regenerative therapies

CONFERENCE ON CURRENT VETERINARY PRACTICES

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Theoretical sessions
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PRACTICAL SESSION 1

Venue: Salisburylaan 133, 9820 Merelbeke, Belgium

Getting the Best Out of Your X-Ray Machine: Tips and Tricks to Improve Your Equine Radiographs

Katrien Vanderperren

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Radiographic examination of the locomotor system of horses is performed daily as this is a part of the routine diagnostic work-up. But good quality radiographs are essential for a correct interpretation. Poor radiographic technique can lead to underdiagnosis of disease but also to overdiagnosis where the presence of a lesion is mimicked by inadequate positioning or artefacts. Therefore, it is essential that the technical quality of a radiograph is critically assessed prior to radiological interpretation. This practical session will focus on radiographic technique, positioning, common errors, and image interpretation of the equine limbs (foot, fetlock, carpus, tarsus, and stifle).

Keywords: horse, radiography

Author Biography

Katrien Vanderperren graduated from the University of Ghent with great distinction in 2005. She received the "Belgian Equine Practitioners Society" for her master thesis. Fascinated by scientific research, she started in 2005 at the Department of Medical Imaging of the Animals and Orthopaedics of Small Animal as research fellow for the Research Foundation Flanders (FWO). In May 2009, she successfully completed her PhD on the possibilities and limitations of imaging the equine fetlock joint using different imaging techniques (radiography, ultrasonography, computed tomography, and arthroscopy). From 2011 to 2014, she worked as a post-doctoral fellow and since 2014, she is a Professor at the same department. She is responsible for the medical imaging of the large animals. At this moment she is following a residency program in large animal diagnostic imaging. She is (co)author of 37 publications in international and national journals.

PRACTICAL SESSION 2

Venue: Salisburylaan 133, 9820 Merelbeke, Belgium

Hoof Surgery for the Equine Practitioner: The Hoof Wall and Beyond…

Maarten Oosterlinck

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Lesions involving the equine hoof capsule are quite common and may affect a wide range of very closely related anatomical structures. While for example lesions affecting synovial structures definitely require specialized treatment, some selected lesions of the hoof capsule, the dermis, and even some penetrating injuries involving the distal phalanx may be effectively treated using skills and equipment readily available for the equine practitioner, without the need for general anaesthesia. An accurate diagnosis and appropriate case selection are the cornerstones of successful case management. This practical session will cover basic surgical preparation of the hoof, and the treatment of hoof cracks, keratoma-like lesions, and penetrating injuries of the solar surface extending to the distal phalanx. Finally, state-of-the-art application of a hoof cast will be practiced.

Keywords: podiatry, hoof wall surgery, lameness

Author Biography

Maarten Oosterlinck graduated from Ghent University in 2004 and has gained extensive experience in equine orthopaedics and surgery at the busy department of surgery and anaesthesiology of the faculty of veterinary medicine (Ghent University). In 2011, he earned his PhD on the use of pressure plate analysis for the objective evaluation of equine locomotion. In 2014, he passed the qualifying exam of the European College of Veterinary Surgeons (ECVS), gaining recognition as a European specialist in large animal surgery. He is an author or co-author of more than 50 scientific articles in peer-reviewed journals, and of more than 70 meeting abstracts on a variety of equine orthopaedic and surgical topics. He regularly lectures at international conferences. He is a scientific editor for The Veterinary Journal and a member of the editorial board of Equine Veterinary Education. In his current position as a postdoctoral staff member (head of clinic in equine orthopaedics), he enjoys equine orthopaedics, surgery, podiatry, clinical research, lecturing and consulting about various topics in his field of expertise.

PRACTICAL SESSION 3

Venue: Salisburylaan 133, 9820 Merelbeke, Belgium

Overground Endoscopy: Practical Considerations and Case Discussion

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Although lameness is without a doubt the number one cause of poor performance, the internal medicine aspect of performance is often neglected or turned to as a last resort. However, most people training horses for the top level would agree that many factors are required for a horse to reach its top level performance. Elements intrinsic to the horse, such as the heart, lungs, gastrointestinal system, as well as extrinsic factors such as the environment, nutrition, and training are all parts of the puzzle that make the picture complete. Different endoscopy cases will be discussed during this practical session.

Author Biography

Fe ter Woort graduated from the University of Liège (Belgium) in 2008. She did her internship at the Atlantic Veterinary College in Prince Edward Island (Canada) where she developed an interest in equine respiratory research. She pursued this further during her residency in Large Animal Internal Medicine at the University of Guelph (Canada), where she combined her clinical training with a graduate degree. Her research focused on Inflammatory Airway Disease in actively racing horses and in 2012 she defended her thesis to receive a DVSc degree from the University of Guelph. After becoming a Diplomate of the American College of Veterinary Internal Medicine in 2013, she decided to pursue her interest in equine sports medicine further. She completed a 2-year Equine Ultrasound and Cardiology Fellowship at New Bolton Center (USA). In 2015 she joined Equine Sports Medicine Practice in Belgium, providing specialist services across Europe. She works with equine athletes of all levels requiring varied approaches, from poor performance evaluations and pre-purchase exams of high level athletes, to routine annual echocardiograms of well-loved patients with heart disease. In addition to her clinical work, Fe's research focuses on exercise testing and training methods in sport horses.

ORAL PRESENTATIONS

Venue: Salisburylaan 133, 9820 Merelbeke, Belgium

Interactive Case Discussion on Equine Cervical Spine Pathology

Katrien Vanderperren

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Anatomically, the equine cervical vertebral column consists of seven vertebrae. The third through fifth cervical vertebrae have similar shape and dimensions, while vertebrae 1, 2, 6, and 7 have unique anatomical features (König and Liebich, 2009). A standard radiographic examination of the cervical vertebrae includes lateral–lateral images. Lateroventral–laterodorsal images give additional information concerning the articular process joints (Withers et al., 2009; Butler et al., 2017). When assessing cervical radiographs, it is important not only to examine each vertebra but also to evaluate the shape of the entire vertebral canal, the alignment of the vertebral bodies, the shape and size of the epiphyses, the regularity of both the intercentral articulations and the articular process joints, and the size of the intervertebral foramina (Butler et al., 2017). Cervical radiographs are obtained in horses with abnormal head and/or neck posture, swelling, stiffness or pain of the neck or back, trauma to the neck, ataxia, inability to stand, in horses with performance problems and in horses with forelimb lameness unrelated to primary forelimb pain (Butler et al., 2017). Radiographic abnormalities of the cervical spine may include cervical vertebral stenotic myelopathy, degenerative changes in the articular process joints, vertebral malformations, fractures, disc abnormalities, (sub) luxation, osteochondrosis, osteomyelitis, or neoplasia. More commonly, radiographs of the cervical spine are also a part of the pre-purchase evaluation. Interpretation of these radiographs is complicated by the fact that many horses develop degenerative changes that do not significantly affect performance. In addition, normal radiographic variations should not be mistaken for lesions. As radiography is the first imaging technique to diagnose cervical pathology, different cases of cervical pathology will be discussed with special attention to radiographic technique and anatomic variations.

Keywords: horse, cervical spine, radiography

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Author Biography

Katrien Vanderperren graduated from the University of Ghent with great distinction in 2005. She received the "Belgian Equine Practitioners Society award" for her master thesis. Fascinated by scientific research, she started in 2005 at the Department of Medical Imaging of the Animals and Orthopaedics of Small Animal as research fellow for the Research Foundation Flanders (FWO). In May 2009, she successfully completed her PhD on the possibilities and limitations of imaging the equine fetlock joint using different imaging techniques (radiography, ultrasonography, computed tomography, and arthroscopy). From 2011 to 2014, she worked as a post-doctoral fellow and since 2014, she is a Professor at the same department. She is responsible for the medical imaging of the large animals. At this moment she is following a residency program in large animal diagnostic imaging. She is (co)author of 37 publications in international and national journals.

The Internal Medicine Approach to Equine Sports Medicine

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Although lameness is without a doubt the number one cause of poor performance, the internal medicine aspect of performance is often neglected or turned to as a last resort. However, most people training horses for the top level would agree that many factors are required for a horse to reach its top level performance. Elements intrinsic to the horse, such as the heart, lungs, gastrointestinal system, as well as extrinsic factors such as the environment, nutrition, and training are all parts of the puzzle that make the picture complete. First of all, it is important to evaluate the horse as a whole and although each of the above elements will be addressed more in detail individually, it is important to evaluate the horse starting with an open mind and taking into account all the elements. In cases of poor performance, evaluating the horse during exercise in its usual environment is critical. A standardized exercise test can help objectively assess performance, and guide towards more advanced diagnostics.

- Airway: getting enough oxygen is critical to moving 600 kg of horse through an obstacle course. Signs of airway disease in high performing horses can be very subtle and undetectable during a resting clinical exam. Although many horses are able to compensate well for mild airway disease, at the top level of performance, this system needs to be fully functional.

- Heart: cardiac causes of poor performance are uncommon, but in those rare instances it has the potential for catastrophic damage.

- Gastrointestinal system: the effects of gastric ulcers are very variable, but can cause significant pain during exercise in horses. Aside from ulcers, performance horses also experience large colon dysfunction, which can produce discomfort and thus affect performance.

Again, the emphasis is on evaluating the horse as a whole and preferably during exercise. Although some cases are straightforward and a problem is easily identified, many cases require a multifactorial approach.

Keywords: horse, physiotherapy, rehabilitation

Author Biography

Fe ter Woort graduated from the University of Liège (Belgium) in 2008. She did her internship at the Atlantic Veterinary College in Prince Edward Island (Canada) where she developed an interest in equine respiratory research. She pursued this further during her residency in Large Animal Internal Medicine at the University of Guelph (Canada), where she combined her clinical training with a graduate degree. Her research focused on Inflammatory Airway Disease in actively racing horses and in 2012 she defended her thesis to receive a DVSc degree from the University of Guelph. After becoming a Diplomate of the American College of Veterinary Internal Medicine in 2013, she decided to pursue her interest in equine sports medicine further. She completed a 2-year Equine Ultrasound and Cardiology Fellowship at New Bolton Center (USA). In 2015 she joined Equine Sports Medicine Practice in Belgium, providing specialist services across Europe. She works with equine athletes of all levels requiring varied approaches, from poor performance evaluations and pre-purchase exams of high level athletes, to routine annual echocardiograms of well-loved patients with heart disease. In addition to her clinical work, Fe's research focuses on exercise testing and training methods in sport horses.

Ultrasound Tissue Characterization (UTC) for the Evaluation of Tendon Regeneration by Means of Platelet-Rich Plasma (PRP) and for a Guided Rehabilitation

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Introduction

Injuries of flexor tendons all too often threaten the athletic career as these elastic structures play a vital role in locomotor efficiency, acting as energy saving springs. This biomechanical function is based on the unique architecture with a matrix that is 3-dimensionally organized into secondary collagen bundles, so-called fascicles.

Tendon injuries may be due to single overloading of the collagenous matrix, but frequently the injury is the result of gradual matrix degradation that can remain unobserved for months or even years. In matrix degradation, besides repetitive structural micro-failure also the cellular response to loads is playing a major role. As a consequence of repetitive overstraining tenocytes may produce high-molecular glycosaminoglycans and pro-inflammatory metallo-proteinases (MMPs), bringing the tendon into a *continuum of pathology*: a so-called *degenerative "tendinosis cycle"* with insidious onset. *Signs of tendinopathy are frequently only the tip of the iceberg!*

When it comes to a rupture, tendons with underlying "tendinosis" have far less regenerative capacity leading to repair tissue that never completely regains its original characteristics. Although horses may come back to their previous level of performance, in many cases relapses occur that may end the horse's athletic career or limit the performance to a lower level. Besides the inferior quality of repair, relapses are frequently also caused by a misinterpretation of the stage of a lesion and its loading capacity during recovery.

Major spearheads to advance the management of tendinopathy are:

A. Monitoring of exercise-effects and early detection of matrix degradation.

B. Staging of lesions, monitoring tendon repair.

C. Improvement of regenerative capacities of tendon lesions.

D. Guided rehabilitation.

To reach these goals, a reliable and sensitive tool to measure and to monitor tendon integrity is prerequisite.

Ultrasonography

Ultrasonography (US) was introduced in the early 80s and appeared to have, like no other imaging technique, the potential to provide an inward view into the tendon's architecture (Rantanen, 1982). US can be used for the diagnosis of extensive injuries but for the early detection of small-scale disintegration, for monitoring of progressive degradation or repair processes, for evaluation of therapies and rehabilitation, US is not sensitive enough. Moreover, US suffers a poor reproducibility and is not reliable for the objective assessment of stages of integrity.

One of the main reasons for the lack of discriminative power of conventional US is that tendons have a 3-D ultra-structure that is not represented in 2-D images. As a consequence of limits of spatial resolution, every US image is a mixture of reflections and interfering echoes: only relatively large structures, like fascicles, generate "structural reflections," while smaller fibrils will result in "interference," leading to a substantial variation of dynamism in real-time ultrasonography. But dynamism is not reflected in single 2-D images.

Also US measurements of the tendon's cross-sectional area and/or the echogenicity (like mean gray levels) have shown little benefits for the monitoring of exercise effects and for the evaluation of stages of injury and quality of repair (Gillis et al., 1993; van Schie et al., 2000; Avella et al., 2009).

Ultrasound Tissue Characterization

Ultrasound Tissue Characterization (UTC) (UTC™ Imaging, Stein, Netherlands) was developed for the objective evaluation of integrity of a 3-dimensionally arranged ultra-structure. UTC is based on standardized data-collection by means of an ultrasound probe that moves automatically along the tendon's long axis, collecting transverse images at even distances of 0.2 mm (Figure 1). In this way, a 3-D ultrasound data-block is created that can be used for a. tomographic visualization (in transverse, sagittal, coronal, and 3-D coronal planes of view) and for b. quantification of tendon matrix integrity (Figure 2).

FIGURE 1: Standardized data-collection by means of UTC-tracking device.

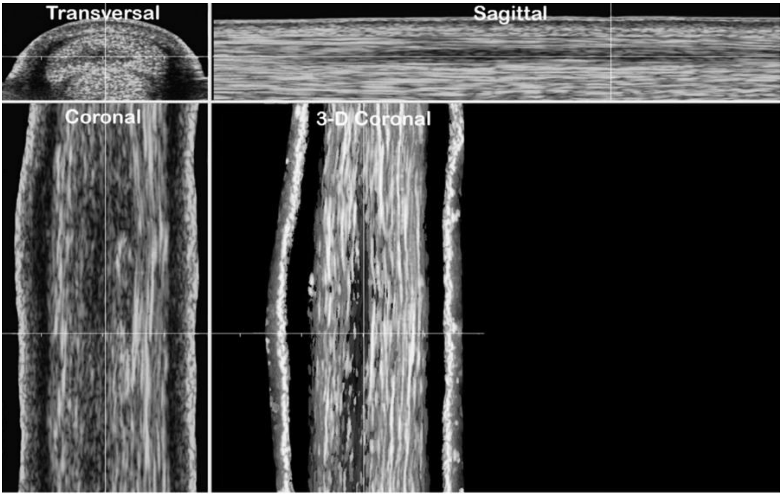

FIGURE 2: Tomographic visualization of tendon structure.

In this 3-D data-block, dedicated UTC-algorithms can quantify the dynamism of echo-patterns in contiguous images which allows the discrimination of four different echo-types, related to size and integrity of structures in the matrix (Figure 3):

- echo-type I, generated by structural reflections at intact and aligned fascicles with axial diameter ≥0.35 mm (Figure 3A)

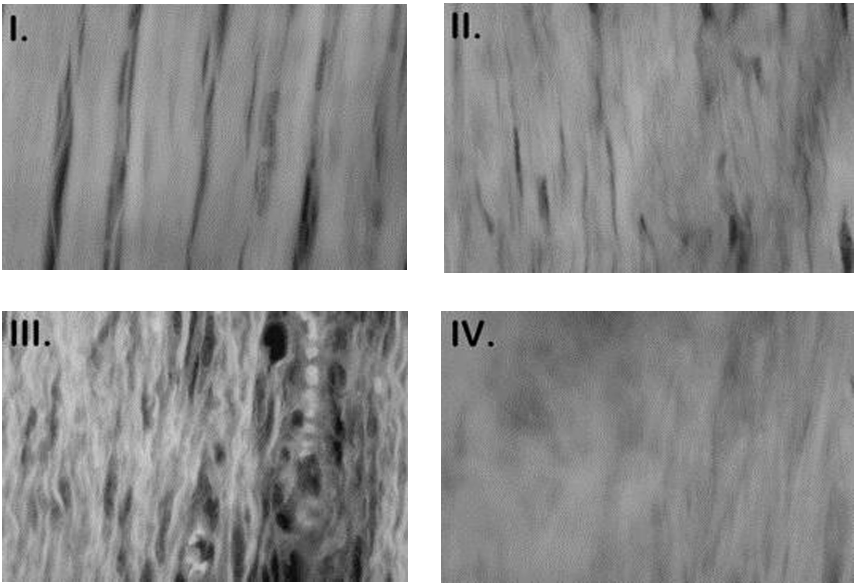

FIGURE 3: (**A**) tissue generating echo-type I, (**B**) tissue generating echo-type II, (**C**) tissue generating echo-type III, and (**D**) tissue generating echo-type IV.

- echo-type II, generated by structural reflections at discontinuous, waving and/or swollen fascicles with axial diameter ≥0.35 mm (Figure 3B)

- echo-type III, generated by interfering echoes from a matrix mainly consisting of fibrils with axial diameter <0.35 mm (Figure 3C)

- echo-type IV, generated by a mainly amorphous matrix and fluid (Figure 3D).

Fundamental research with isolated tendons revealed that the ratios of these four echo-types are highly correlated with the ultra-structural characteristics of tendon tissue, showing the discriminative power of UTC for tissue characterization (van Schie et al., 2001, 2009).

Normal superficial digital flexor tendons (SDF) in young mature horses are characterized by 85–90% type I, 10–15% type II and barely any III plus type IV echoes (van Schie et al., 2009; Bosch et al., 2011; David et al., 2011).

The reproducibility of measurements was tested extensively and both the intra- and inter-observer reliability appeared to have intra-class correlations (ICC) ranging

0.92–0.98, indicative for an *excellent reproducibility of UTC* (van Schie et al., 2009; Bosch et al., 2011; David et al., 2011).

Monitoring of Exercise-Effects and Early Detection of Matrix Degradation

The hypothesis was tested that a. exercise may lead to load-effects (either short-duration and reversible or persistent and non-reversible) and that b. cumulative effects of repetitive overstraining may lead to insidious degradation of the tendon matrix.

In young-mature race-horses (av. 3.8 years) subtle, though significant, changes were observed in the SDF tendons at 1 and 2 days post-race, namely a mild yet significant increase of echo-type II. These *reactive* changes, indicative for load-induced swelling of fascicles, may appear to be reversible within 3 days post-race (Docking et al., 2012). However, in tendons showing a significant increase of echo-types III and/or IV too, which is indicative for structural (micro)failure, the return to normal pre-race values takes much longer, if it happens at all.

In high-performance horses over 5 years of age in disciplines dressage, eventing and jumping the individual baseline values may show significant changes, compared to those in young-mature horses, even without clinical signs. These changes are either a localized increase of echo-types II and III in the central core-region, or a more scattered increase of echo-types III and/or IV.

In high-performance horses, the tendon loading during major events may lead to significant changes from individual baseline values within 4–7 days. This *overstraining* is characterized by significant increases of echo-type II, III, and/or IV; however, sometimes accompanied by short-duration clinical signs like moderate swelling and pain on palpation. Echo-types may still return to individual baseline within 4–12 weeks or otherwise extensive changes may persist which is indicative for a *continuum of pathology* leading to "*inferior repair*" (persistent increase of II and III) or "*degeneration*" (persistent increase of III and IV). These persistent changes frequently lead to intermittent flare-ups and ultimately even develop into a *(partial) rupture*.

It appeared that UTC is sensitive enough to detect small-scale changes long before clinical signs of tendinopathy become manifest (Docking et al., 2012).

Staging of Lesions, Monitoring Tendon Repair

As described in the introduction, tendon injuries may be the result of single overloading leading to macro-trauma with major structural and vascular damage and acute clinical symptoms due to a "*tendinitis*" (a "classical inflammation" with invading inflammatory cells). On the other hand, repetitive sub-maximal loading leading to structural micro-failure and/or cellular response may induce a "molecular inflammation" with resident tenocytes producing pro-inflammatory substances which results in matrix degradation too, however, with a much more insidious onset ("*tendinosis*").

So, there are multiple pathways leading to tendon pathology and tendon injuries frequently are multi-stage, containing several stages of pathology c.q repair (tissue types). *Presence and duration of clinical signs are no indication for the stage of the lesion.*

In order to design a schedule for staging, standardized lesions were created surgically in SDF tendons in both front limbs of young-mature horses (2–5 years of age). During longitudinal monitoring of tendon repair, a variety of stages of integrity can be quantified by means of UTC, and subsequently verified by means of postmortem histology and biochemistry. This resulted in a *schedule for staging of non-intervened repair after single macro-trauma:*

- post-rupture there is a rapid decrease of structure-related echo-types I plus II and a sharp increase of type IV which appeared to be related to a loose amorphous matrix and the presence of fluid. This stage is called *extension and demarcation of the lesion*. After acute rupture (single macro-trauma), this stage will take 2 weeks post-injury* *(see notice below)*

- subsequently there is a significant increase of echo-type III and a significant decrease of echo-type IV which can be related to the formation of a fibrillar matrix that is gradually becoming more densely arranged during the *fibrillogenesis* stage. After acute rupture (single macro-trauma), this stage may occur 3–8 weeks post-injury* *(see notice below)*

- gradually, within fields containing mainly echo-type III, islands of echo-types I and II are developing, indicative for fibrils getting organized into fascicles during the ***organization*** stage. After acute rupture (single macro-trauma), this stage may be expected from around week 9–12 post-injury* *(see notice below)*

- towards final stages of repair there is a continuing increase of echo-type I, a gradual decrease of echo-type II and echo-types III and IV tend to normal (<5%) during the so-called ***remodeling*** stage. After acute rupture (single macro-trauma), this stage may be expected from around week 13–24 post-injury* *(see notice below)*. In case echo-type II does increase instead of gradually decreasing this indicates poor remodeling which, complicated by the formation of non-reducible cross-linking, ultimately leads to an inferior quality of repair. As such, this stage can be used as an important prognostic indicator.

*Please notice that these stages of repair do not always follow this time-frame; especially in older horses (>5 years of age) repair may take longer and lead to less quality of repair, most probably as a consequence of ageing and/or degeneration c.q tendinosis.

Improvement of Regenerative Capacities of Tendon Lesions

Tendon injuries are notorious for their poor healing capacity. They heal slowly and the repair tissue never completely regains its original characteristics and functionality, leading to a high re-injury rate. *In particular injuries based on underlying tendinosis are lacking regenerative capacity.*

For many years, rest and non-steroidal anti-inflammatory agents (NSAIDs) have been the treatments of first choice. However, with growing insight that the problem with tendon injuries is less an inflammatory "tendinitis" and more a degenerative "tendinosis," the role for local anti-inflammatory corticosteroid injections is widely debated; they may lead to cell-death, necrosis and ultimately even to spontaneous ruptures. Therefore, NSAID injections should be used with great caution (never intra-tendinous, if at all indicated in the acute stage, then only peri-tendinous and short-acting!) or even discouraged.

To improve the regenerative capacity of injured tendons a variety of regenerative therapies have been introduced, cell- and/or growth factor-based, like *stem cells* and *platelet-rich plasma* (van Schie et al., 2009; Bosch et al., 2011; David et al., 2011; Spaas et al., 2012). In recent years, there have been quite some scientific publications about these regenerative therapies but effects were not in all studies unequivocal and undisputed. Most probably, this has to do with the fact that the great majority of the studies was done on non-standardized natural tendon injuries, frequently containing multiple histo-pathological stages.

To test the regenerative capacities of *platelet-rich plasma* (*PRP*), a placebo-controlled study was done, creating standardized lesions in SDF tendons in both front limbs. Seven days post-surgery, the lesion in one limb was injected with PRP and in the contra-lateral with sterile saline. Subsequently, tendon repair was monitored longitudinally, with *UTC* scans made at regular intervals. At the end of the study (24 weeks), horses were sacrificed and postmortem tissue specimen harvested for histology, biochemistry, and loading-tests (van Schie et al., 1999 and 2009; Bosch et al., 2011; David et al., 2011).

Major observations were:

a. postmortem *histological examination* showed that repair tissue in PRP-treated injuries showed advanced restoration of the regular crimp-wave and organization of the collagenous ultra-structure and signs of increased cellular metabolic activity, in comparison with placebo-treated repair.

b. postmortem *biochemical examination* revealed that repair tissue in PRP-treated injuries contained significantly higher collagen, glycosaminoglycan and DNA (indicative for cellularity), in comparison with placebo-treated repair.

c. postmortem *loading tests* revealed that repair tissue in PRP-treated injuries showed significantly higher strength at failure (plus 35%) and a higher elastic modulus (plus 66%), in comparison with placebo-treated repair.

d. monitoring repair at regular intervals during 24 weeks by means of *UTC* revealed that in PRP-treated tendons the stages of repair, as described earlier in chapter Staging, were advanced significantly compared to placebo treated tendons.

This means that:

- PRP has anti-inflammatory action.
- PRP promotes the formation of a dense fibrillar matrix.
- PRP promotes the organization of fibrils into fascicles.
- PRP promotes the remodeling of fascicles (arrangement into the lines of stress).

It is concluded that PRP advances tendon regeneration.

These results were gained in standardized induced injuries, thus single macro-trauma, in young-mature tendons. *Beneficial effects on tendon regeneration may be expected in natural injuries too but staging and discrimination of tissue types by means of UTC are prerequisite.*

Please notice that examinations mentioned under a., b., and c. can only be done at postmortem while monitoring can be done non-invasively at regular intervals by means of UTC. This provides essential information about the progress of repair c.q. regeneration and possibly about the necessity to intervene (re-treatment? and changing loading-protocol?).

Guided Rehabilitation:

Decades ago, rest was recommended for tendon injuries and indeed rest can affect clinical signs but, on the other hand, it may negatively influence the collagen content and the ultra-structural remodeling of repair tissue. *Loading of the tendon matrix induces multiple mechano-transduction pathways*, like:

a. straining and compression of the cytoskeleton increases the metabolism of fibroblasts c.q. tenocytes, up-regulating the production of collagen, glycosaminoglycans, cytokines and MMPs (there are good ones too, promoting remodeling) which is crucial for the formation of repair tissue.

b. loading stimulates the ultra-structure of repair tissue to organize and to arrange in the lines of stress (remodeling).

There is substantial evidence that *"Exercise is medicine too"!*

However, relapses are frequently caused by misinterpretation of the stage of the lesion and its loading capacity during recovery. It is intelligible that overloading is damaging. But underexposure to mechanical stimulation, on the other hand, may have negative effects on the quality of repair too: with time post-injury the formation of non-reducible cross-links is closing more and more "the window of opportunity to remodel repair tissue," leading to a rigid scar without physiologic visco-elastic properties.

To optimize the restoration of function of injured tendons "guided rehabilitation" may appear to be vital: providing the appropriate amount of mechanical stimuli, *not too much and not too little, based on the stage of repair* as measured by means of UTC.

Please notice that rehabilitation should not be based exclusively on clinical signs and duration of the injury, rather on staging. For instance, also chronic injuries, especially when multi-stage, may still contain young, still fragile, repair tissue that should be loaded with caution.

During guided rehabilitation, the loading of the tendon is increased block-wise, based on increasing intensity (increasing duration is less effective). For instance, increasing intensity by starting short canters within blocks trotting stimulates more than simply adding more minutes trotting. Of course, the decision to intensify should be based on precise staging and the effects should be monitored meticulously by means of UTC.

Besides the stage of the tendon also the discipline of sports and the overall condition and conformation of the horse has to be taken into account.

UTC scans are made regularly to monitor progress and quality of repair: initially with intervals 1–2 weeks, gradually increasing till 6 weeks. Based on successive UTC measurements, loading can advance to the next block (in case of improving integrity) or, if necessary, be reduced (back to previous block in case of worsening).

Recommended Schedule for Guided Rehabilitation

- Rehab Stage 1: the lesion contains no Echo-type I and II, mainly Echo-type V (75–100%) and some Echo-type III (0–25%). Ratio echo-type III/IV is extremely low. Recommended: REST, support, anti-inflammatory management

- Rehab Stage 2: the lesion contains no Echo-type I and II. Echo-type IV starts decreasing (50–75%). Echo-type III is gradually increasing (25–50%). Ratio echo-type III/IV is increasing, however, still <1.

- Rehab Stage 3: the lesion contains no Echo-type I and II. Echo-type III is progressively increasing and Ratio echo-type III/IV is now >1.

- Rehab Stage 4: echo-type III and IV are both decreasing significantly. From now, the lesion contains also clusters of Echo-types I and II (<25%) with relatively high% Echo-type II, thus Ratio echo-type I/II <1.

- Rehab Stage 5: both Echo-types III and IV are decreasing sharply (20–30%, mainly Echo-type III). Echo-types I and II are increasing (70–80%) with increasing Ratio Echo-type I/II around 1. Recommended: besides increased intensity resume discipline-specific exercise too. Start proprioceptive training.

- Rehab Stage 6: in the lesion Echo-type IV has disappeared and Echo-type III further decreased (<10%). Echo-types I and II further increased (>90%) with Ratio echo-type I/II >1. Recommended exercise: "back on track," however keep monitoring.

Guided rehabilitation allows a pro-active approach based on the functional properties of each stage in the continuum of repair. Of paramount importance are precise staging of lesions and meticulous monitoring of load-effects.

It is concluded that novel approaches for the management of tendinopathy, based on Ultrasound Tissue Characterization, regenerative therapies (like PRP), and guided rehabilitation, may advance tendon regeneration and improve chances to bring the equine athlete "back on track."

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Author Biography

Johannes (Hans) Theodorus Maria van Schie born May 6, 1947 in Maassluis, the Netherlands.

Academic Education

Utrecht University, Utrecht (Netherlands), Veterinary Medicine, 1972 Doctor Veterinary Medicine, with distinction. Utrecht University, Utrecht (Netherlands), 2004, thesis "Ultrasonographic Tissue Characterisation of Equine Superficial Digital Flexor Tendons; Development and Applications of Computer-aided Image Analysis," PhD with highest distinction Cum Laude.

Professional Career

UTC Imaging, since 2009

Co-inventor, co-founder, scientific director and currently CEO Research & Development of UTC Imaging, a spin-off company exploiting the ultrasound tissue characterisation technique. The company is an alliance with people that have already an impressive track-record in a variety of disciplines, creating a passionate team that has on board a whole arsenal of knowledge and expertise, ranging from fundamental and clinical orthopaedic research, computer science, image processing, electronics, engineering and ultrasound technology. While being the lead for scientific research, major spearheads are to initiate and coordinate multi-center research with several illustrious institutes world-wide. Furthermore, lead for innovations like development of a novel probe for the measurement of material properties like elasticity and fluid content. For more information: www.UTCimaging.com.

University College London (UCL), London, United Kingdom, Since 2015

Honorary Senior Clinical Research Fellow at Institute of Sport, Exercise and Health.

FC Barcelona, Barcelona, Spain, Since 2014.

Co-Director Tendinopathy Research.

Monash University, Frankston, Australia, 2012–2015

Adjunct Professor, Senior Principal Research Fellow at Department of Physiotherapy, Faculty of Medicine, Nursing and Health Sciences. Exercise effects in both professional athletes and racehorses are monitored by means of UTC, in order to detect which loads disturb tendon homeostasis, leading to either a short-term reactive phase or a long-term continuum of pathological changes. Main goal is the design of a UTC-guided loading protocol that (a) allows optimal training without risk of tendon injury and/or (b) facilitates an efficient rehabilitation schedule for restoration of functional capacities after tendon injury.

Utrecht University (Utrecht), 2007–2012

Associate Professor for Comparative Research of Tendinopathy at Equine Muskulo-Skeletal Biology, Department of Equine Sciences. *Liaison officer between Orthopaedic Research Lab at Erasmus University Medical Center and Department of Equine Sciences* *at Utrecht University*, investigating translational aspects of pathogenesis and novel approaches for regenerative medicine and rehabilitation of human and equine tendon disorders. A surgical model for a standardised tendon lesion was designed for the placebo-controlled evaluation of platelet-rich plasma releasate (at Equine Sciences, Utrecht) and of cultured fat-derived mesenchymal cells (cooperation with Tierarztliche Hochschule Hannover, Germany).

Erasmus University Medical Center (Rotterdam), 2005–2012

Senior researcher at the Orthopaedic Research Laboratory. Special interest in pathofysiology of tendon tissue (comparative aspects human versus equine), regenerative therapy, rehabilitation and ultrasound tissue characterisation (UTC), mainly of the Achilles tendon. Received an Erasmus Grant for Translational Research in order to validate and implement UTC, that was originally designed for equine flexor tendons, into human orthopaedics: a. UTC was correlated with MRI and b. pre-surgery UTC was compared with histo-morphology, biochemistry and molecular composition of per-operatively harvested specimen. UTC was applied for the monitoring of high-performance athletes and for the evaluation of interventions like eccentric exercises, surgery and regenerative therapies (focussed shockwaves, platelet-rich plasma releasate, autologous cultured tenocytes). In cooperation with the Departments of Rehabilitation Medicine, Physical Therapy and Sports Medicine research was done into relationship between tendon quality (quantified by means of UTC) and diabetes, aiming at the design of an exercise program for these patients. Another project was monitoring the exercise effects in Achilles tendons in running athletes and the relationship between tendon quality and dynamic center of plantar pressure.

Royal Dutch Equestrian Federation, 1996–2013

Consultant since 1996 and from 2000 to 2007 also *team-veterinarian* of senior teams representing the Netherlands at international events, e.g., world cups, European and World championships, Olympic Games. Coordinating consultant for orthopaedic disorders and supervisor of injury-prevention program including ultrasound tissue characterisation (UTC) for monitoring exercise effects in tendon and ligaments.

Raaphorst Equine Clinic, 1984–2001

Founder of equine clinic (Raaphorst Equine Clinic, Wassenaar, Netherlands) for orthopaedics, orthopaedic surgery and veterinary management of high-performance sports-horses. Special interest in diagnosis, treatment, and rehabilitation of injuries of tendons and ligaments.

Equine Racetrack Practice, 1979–1983

Founder of international ambulatory practice for veterinary management of high-performance sports-horses at professional stables and major racetracks in the Netherlands, Belgium, and Germany. Special interest in diagnosis and treatments of locomotor pathologies.

Utrecht University, 1972–1978

Assistant Professor, Department of Obstetrics and Gynaecology: clinical activities and lecturing. Special interest in fertility of broodmare and equine stud management.

Supervising Research

PhD research, 5 completed: de Mos (2009), de Vos (2010), and de Jong (2015) at Erasmus University Rotterdam (Department Orthopaedics), Bosch (2009) at Utrecht University (Department Equine Sciences), and Cadby (2013) in cooperation with Utrecht University (Department of Equine Sciences) and Zurich University (Institute for Biomechanics, Zurich, Switzerland).

PhD research, three ongoing: one at Tierarztliche Hochschule Hannover, Germany and two at Universitas Barcelona, Spain.

Scientific Publications

Fifty-eight scientific publications as of September 2017 in peer reviewed scientific journals. ResearchGate RG score 31.63, higher than 90.0% of RG members.

Presentations

Each year minimally 7–10 invited (keynote) lectures at international high-profile congresses for human and/or equine orthopedics, sports medicine, and imaging.

Courses

Each year 7–10 international courses or scientific symposia are organised and/or supervised, mainly about sports medicine, tendon pathology, ultrasound tissue characterisation, regenerative therapy, and rehabilitation.

The Labyrinth of Lameness: Pitfalls of Local Anaesthesia

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Diagnostic analgesia has been used for many years and, notwithstanding modern imaging technology, it is still the only diagnostic modality able to directly and unequivocally determine the site(s) of pain causing lameness. However, assumptions regarding which structures may or may not be desensitized may lead to misdiagnosis, and hence, over-diagnosed diseases but also overlooked conditions (Schumacher et al., 2013). Using experimental induction of lameness with intrasynovial injection of endotoxin or shoes with set-screws at various places of the hoof, studies have revealed that pain arising from the sole should not be immediately excluded when lameness is attenuated by analgesia of the navicular bursa, distal interphalangeal joint, or palmar digital nerves (Schumacher et al., 2000, 2001a, 2003). Analgesia of the distal interphalangeal joint results in analgesia of the navicular region, but not *vice versa*; importantly, pain arising from the distal interphalangeal joint can most likely be excluded when lameness is attenuated within 10 min by analgesia of the navicular bursa. Analgesia induced by perineural anesthesia of the palmar digital nerves is not limited to the caudal part of the hoof, as was once commonly believed, and can even attenuate pain arising from the proximal interphalangeal joint, especially when the injection is performed proximally to the proximal margin of the cartilages of the foot (Schumacher et al., 2004). Even the volume of anesthetic solution is important, as larger volumes may lead to increased diffusion and/or more distention and hence, closer contact with nerves. For the distal interphalangeal joint, not more than 5 mL is recommended (Schumacher et al., 2001b). For anaesthesia of the deep branch of the lateral plantar nerve, there is a risk of concurrent anaesthesia of the lateral plantar nerve (Hinnigan et al., 2014), and therefore, using not more than 2 mL has been recommended (Claunch et al., 2014). Analgesia of the digital flexor tendon sheath has little effect on lameness caused by pain originating in the sole, distal interphalangeal joint or navicular bursa (Harper et al., 2007). Studies on the diffusion of radiodense contrast medium after perineural injection of the palmar nerves (Nagy et al., 2009), the palmar metacarpal nerves (Nagy et al., 2010), the proximal metacarpal region (Nagy et al., 2012), and the proximal metatarsal region (Claunch et al., 2014) have revealed different and rather large degrees of diffusion, and even inadvertent penetration of synovial spaces like the carpometacarpal joint, the digital flexor tendon sheath, the tarsal sheath, and the tarsometatarsal joint (Nagy et al., 2010, 2012; Claunch et al., 2014). Therefore, aseptic technique should be used when performing these blocks. In a cadaver study comparing injection techniques of the digital flexor tendon sheath using methylene blue, it has been shown that the axial sesamoidean approach was most successful, had lower leakage scores and larger distance of the dye spot to the nerve (Jordana et al., 2012). In a subsequent in vivo study, it was shown that anesthesia of the palmar digital nerves occurred after analgesia of the digital flexor tendon sheath with 40% of injections, especially but not exclusively after injecting in the proximal recess of the sheath. Therefore, it is essential to always verify skin sensitivity at the heel bulbs after analgesia of the digital flexor tendon sheath (Jordana et al., 2014). In conclusion, it is of paramount importance to realize the possible confounding effects of local blocks on anatomical structures often quite distant from the site of injection. Specific combinations of blocks are often required to solve the diagnostic puzzle of localizing pain causing lameness.

Keywords: lameness examination, diagnosis, orthopaedics

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Author Biography

Maarten Oosterlinck graduated from Ghent University in 2004 and has gained extensive experience in equine orthopaedics and surgery at the busy department of surgery and anaesthesiology of the faculty of veterinary medicine (Ghent University). In 2011, he earned his PhD on the use of pressure plate analysis for the objective evaluation of equine locomotion. In 2014, he passed the qualifying exam of the European College of Veterinary Surgeons (ECVS), gaining recognition as a European specialist in large animal surgery. He is an author or co-author of more than 50 scientific articles in peer-reviewed journals, and of more than 70 meeting abstracts on a variety of equine orthopaedic and surgical topics. He regularly lectures at international conferences. He is a scientific editor for The Veterinary Journal and a member of the editorial board of Equine Veterinary Education. In his current position as a postdoctoral staff member (head of clinic in equine orthopaedics), he enjoys equine orthopaedics, surgery, podiatry, clinical research, lecturing and consulting about various topics in his field of expertise.