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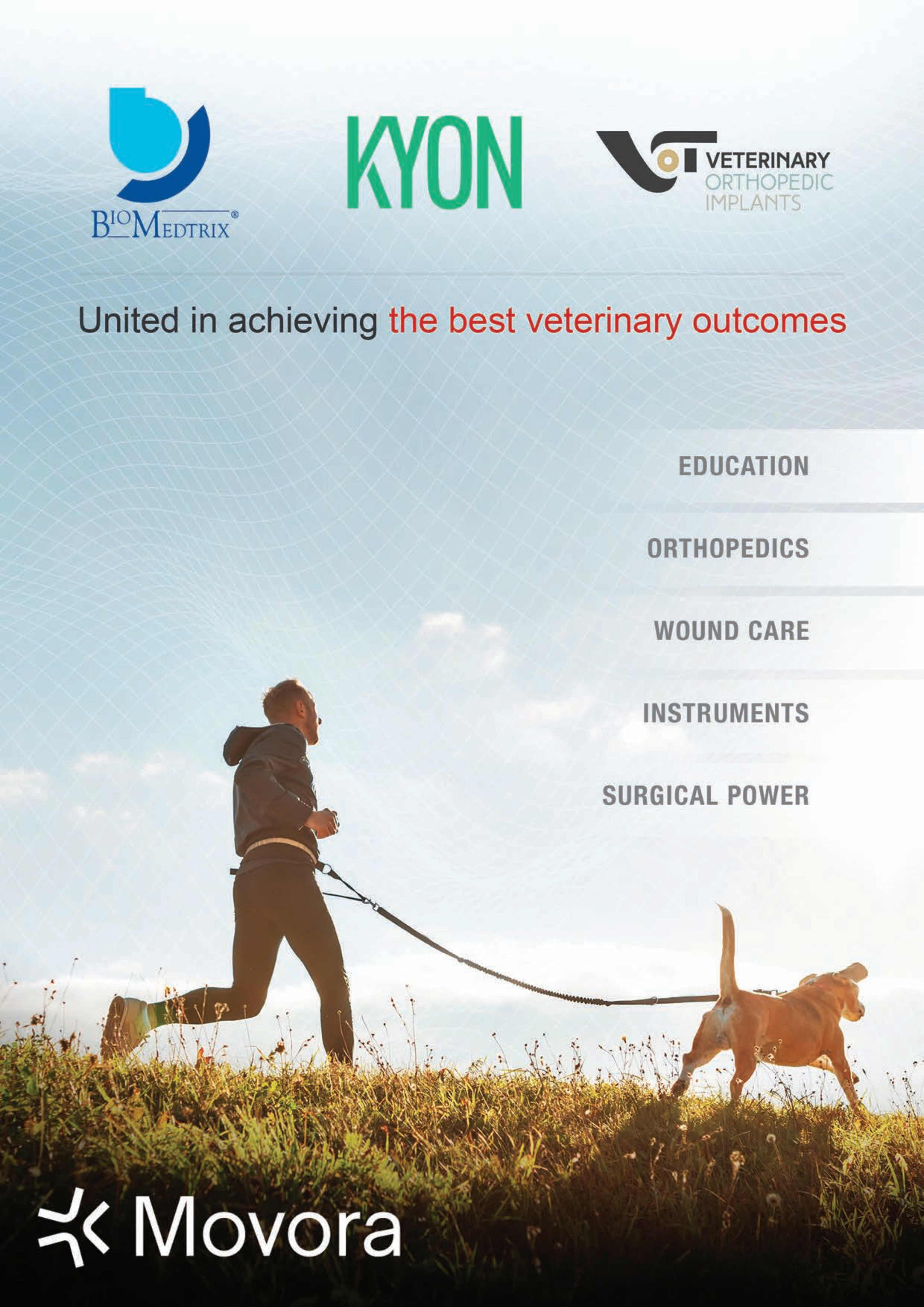
Proceedings - Large Animals

8-10 July 2021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1. RCP Tildren - 2. Tiludronate as a new therapeutic agent in the treatment of navicular disease: a double-blind placebo-controlled clinical trial J. -M. DENOIX, D. THIBAUD*† and B. RICCIO‡ Equine vet. J. (2003) 35 (4) 407-413. Etude réalisé sur 21 chevaux au Cirale à Goustranville France en 2003 - 3. Pharmacological effects of tiludronate in horses after long-term immobilization. C. Delguste, H. Amory, M. Doucet, C. Piccot-Crézollet, D. Thibaud, P. Garnero, J. Detilleux,O.M. Lepage. Bone 41 (2007) 414-421 Etude réalisée sur 16 chevaux à l'École Nationale Vétérinaire de Lyon en 2007.

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Large Animals

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Thursday 08 July, 2021

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Ex vivo comparison of a UV-polymerizable methacrylate adhesive versus a two-layer hand-sewn jejuno-jejunal anastomosis in horses

Lenoir A[1], *Perrin BRM*[2], *Lepage OM**[1]

[1]Center for Equine Health, Ecole Nationale Veterinaire de Lyon, VetAgro Sup, Lyon, France, [2]Cohesives, Laboratoire de recherche et développement, Université de Bourgogne, Dijon, France.

Introduction
Jejunal anastomosis in horses with two-layer conventional technique can lead to leaks at the anastomosis site and the possibility of severe septic peritonitis. Surgical adhesives are being developed in human surgery to seal anastomosis, prevent leakages and related complications. A UV-polymerizable methacrylate adhesive (UV-PMA) has recently been designed to anchor into the biological tissues' top surface to offer greater sealant and adhesive properties. In this study a single-layer continuous pattern sealed with this UV-polymerizable methacrylate adhesive (1L-UV-PMA) and a two-layer conventional technique (2L-CT) are compared in terms of sealing properties, luminal reduction, and anastomosis time.

Material and Methods
Fresh harvested jejunum segments (n=15) were used to perform jejuno-jejunal resection and anastomosis, using a 2L-CT or a 1L-UV-PMA. Anastomotic construction time of the second layer was recorded. Bursting Strength Pressure (BSP) was evaluated and Luminal Diameter Reduction (LDR) at the anastomotic site was calculated.

Results
1L-UV-PMA was faster to perform than 2L-CT (P<0.001). A significant difference was found in BSP between negative control and 1L-UV-PMA (P=0.04). There was no significant difference in BSP between negative control and 2L-CT (P=0.13) or 1L-UV-PMA and 2L-CT (P=0.65), nor in LDR between 1L-UV-PMA and 2L-CT (P=0.26).

Discussion/Conclusion
1L-UV-PMA application is faster to perform than a 2L-CT. The UV polymerizable methacrylate adhesive showed similar results compared to the conventional technique in terms of luminal reduction and sealing properties. However, some changes in the technique of application are needed to improve the compliance of the bowel after anastomosis before clinical trial.

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Prevalence and characteristics of osteochondrosis in Lusitano Purebred horses

Coelho Ramos AS[1], Pinto A[1], Crespo J[2], Marques JP[3], Bettencourt E[1], Gama LT[4], Monteiro S[1]*

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Objectives
This is the first comprehensive study in Lusitanos that aims to study the radiographic prevalence and localisation of osteochondrosis in different joints.

Methods
A radiographic protocol of the metacarpo/metatarsophalangeal, tarsocrural and femoropatellar joints was done in 302 Lusitanos, and findings were classified using a 0-4 scale: 0 - normal joint contours; 1 – minimal (minimal and smooth flattening); 2 – mild (irregularly flattening); 3 - moderate (presence of a small fragment, presence of a small rounded defect) and 4 – severe (large or multiple fragments, with a large irregular defect). Scores 1 and 2 were considered to represent OC while scores 3 and 4 corresponded to OCD.

Results
Abnormal findings were present in 53.31% of the horses. Most were stallions (88.74%), and the mean age was 5.14 ± 2.48 years (range of 1 to 12 years old). The prevalence of OC (36.75%) was higher than OCD (16.56%). The most affected joint were hocks (39.74%), followed by fetlocks (31.79%) and stifles (3.3%). OC was registered in 26.16% in hocks, 16.56% in fetlocks and 1.49% in stifles. The presence of fragments (OCD) was recorded in 5.14% of the cases in the hock, 5.13% in the fetlocks and 0.83% in the stifle.

Conclusions
This Lusitano horse population has presented a high prevalence of osteochondral lesions, with a low prevalence of OCD. This study is important to ensure a rational use of Lusitano and a prospective study is required to determine the genetic variability regarding OC/OCD in this breed.

A standardized protocol for optimum volume of iodinated contrast at a constant concentration for use in computed arthrography of the equine antebrachiocarpal and middle carpal joints.

McQuillan SMQ[1], Kearney CK[1], Hoey SH[1], Connelly SC[2], Rowan CR[3]*

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Introduction
This ex-vivo study aims to identify a threshold volume of contrast for computed tomography arthrography (CTA) of the antebrachiocarpal (ABC) and middle carpal (MC) joints for assessment of articular surface defects.

Materials and Methods
Cartilage defects were created arthroscopically in the ABC and MC joints of 20 cadaver limbs. Each joint was injected with 5ml increments of a 150mg iodine/ml non-ionic contrast media, from 0 to 50ml per joint, with a CTA acquired at each increment. Images were reviewed by 2 blinded veterinary radiologists and their measurements compared to measurements from gross examination. For each volume, the interrater reliability for presence of defects and the radiologists' detection of defects were calculated using Gwet's AC measure. A linear mixed effects model was used to determine the minimum volume of contrast beyond which improvement in detection of the defect was not seen.

Results
With 10ml contrast, no significant differences between either observer and the gross analysis were detected for either joints. No significant differences between observers and pathology were noted with higher volumes for either joint.

Discussion/Conclusion
We found that 10ml of contrast allowed for consistent accurate detection of cartilaginous defects on CTA in the ABC and MC joints. Increasing the volume of contrast further did not result in an increase in defect detection.

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Ninety one Ovariectomies for Granulosa Cell Tumor: Breeding Performance of the Mares and Histopathological Features of the Ovaries.

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Introduction
Granulosa Cell Tumor (GCT) is the most common ovarian neoplasia in mares. Histopathology is the gold standard for diagnosis and ovariectomy is the treatment of choice. Reports describing breeding performance post ovariectomy are scares. The purpose of this study was to describe the breeding performances, histopathology features and owners' satisfaction for mares undergoing ovariectomy due to suspected GCT.

Materials and methods
Medical records were retrospectively collected. Inclusion criteria were mares undergoing ovariectomy due to suspected GCT between 2009 and 2020. Post surgical fertility parameters were obtained and compared with a control group. Comparison was done by T-test or by Mann-Whitney Signed-Rank Test. Owners' satisfaction was graded on 1-5 scale. Histopathology findings were recorded. Significance was set as $p<0.05$.

Results
The GCT group included 91 mares, consisted mainly Arabian mares with a mean age of 7.8 years. Breeding performance were not significantly different between groups; 86% mares had normal estrus cycles post ovariectomy ($P=0.28$), Mean number of breeding attempts was 1.21 ($P=0.06$) among the normally cycling mares post ovariectomy and 89.7% of them carried a foal to term. Mean score for owners' satisfaction from surgical treatment was 4.6. Histopathology showed typical GCT characteristics but also revealed an undescribed feature; vacuoles with amphophilic liquid.

Discussion
Inability to conceive is the most common indication for ovariectomy. This study was the first to show normal breeding performances in large number of mares post ovariectomy due to GCT. Analysis of the histological reports revealed a new GCT characteristic, vacuoles of amphophilic liquid.

Ex vivo comparison of single layer interrupted, single layer continuous and double layer suture techniques for equine jejunal end-to-end anastomosis.

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Introduction
An important factor related with post-operative complications after small intestinal resection in horses is the technique of creating the anastomosis. The objectives of this study were to evaluate differences in construction time, lumen reduction and leakage resistance between a single layer interrupted modified Lembert (SI) according to Freeman, a single continuous modified Lembert (SC), and a double layer simple continuous with Cushing oversewn (DC).

Materials and Methods
Jejunum of slaughtered horses were used for performing the anastomosis (n=27 for each group). Intestines were filled with contrast agent and distended with air at 500 ml/min. Radiographs were taken at 20 mmHg intraluminal pressure. Luminal reduction was calculated in percentages. Leaking pressure was recorded when air bubbles appeared. Statistics were performed using linear mixed models with a post hoc Tukey method ($P<0.05$). Results are presented as least square means.

Results
The SC pattern took significantly less time to create than SI and DC (16.7; 21.1; 22.3 minutes, respectively). SI and DC construction times were not significantly different.
SI resulted in least lumen reduction (27.2 %), DC gave most reduction (47.2 %) and SC in between (32.2 %). Differences were significant between all 3 groups.
Leaking pressure was significantly higher in DC than in SI and SC (102.3; 43.8; 51.8 mmHg). Leaking pressures for SI and SC were not significantly different.

Discussion/Conclusions
The SI pattern is preferable with regards to lumen reduction. Whether this outweighs a longer construction time and reduction in leaking pressure needs to be further evaluated in vivo.

Bilateral Castration with Electrosurgical Scrotectomy and Primary Closure in the Horse.

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Introduction
Despite being routinely performed in a variety of techniques, equine castrations are still associated with significant complication rates. The purpose of this study was to describe an elective castration technique involving electrosurgical scrotectomy, with primary closure, and to report outcomes in 69 horses.

Methods
Cases presented for elective castration (bilaterally-descended testes and unilateral inguinal cryptorchids) and performed under general anesthesia were included. Electrosurgical scrotectomy, semi-closed or closed castration using transfixing ligatures, and 2-layer primary closure with dead space reduction was performed. Surgery time was recorded. Horses received procaine penicillin (22,000IU/kg IM BID for 24h), flunixin meglumine (1.1mg/kg IV for 24h) and meloxicam (0.6-0.3mg/kg PO SID, 6 doses) with 1 week of rest and 1 week of hand-walking. Retrospectively-analyzed cases were evaluated for complications and client satisfaction by telephone/email survey. Prospectively-analyzed cases were monitored q48h for the first 14 days and thereafter, at 1 month and 6 months post-surgery.

Results
Sixty-nine horses (8 Thoroughbreds, 61 Arabians; 37 prospective, 32 retrospective) were included, ranging from 6months – 7years. Average surgery time was 47.36 minutes. Overall surgical-related complication rate was 4.35%: subcutaneous scrotal hematoma (1.45%) and deep surgical site infection with secondary wound dehiscence (2.90%). A high incidence of self-limiting wound crusting or moistening (43.24%), likely associated with loose feces dripping, was detected in cases analyzed prospectively but not retrospectively.

Discussion/Conclusion
Ease of execution, low complication rate and short convalescence, with possibility to remove inguinally-retained testes through the same scrotal, incision make this technique an appealing alternative for use in equine hospitals.

Outcome analysis of 95 harness racehorses with confirmed dorsal displacement of the soft palate treated with laryngeal tie-forward surgery

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Introduction

The laryngeal tie-forward (LTF) procedure is commonly used to treat intermittent dorsal displacement of the soft palate (iDDSP). There is a wide range in reported efficacy of treating horses with and without a definitive diagnosis of iDDSP. Our aim was to evaluate racing performance of harness racehorses in which iDDSP had been definitely diagnosed and treated solely with the LTF procedure.

Materials and Methods

Ninety-five harness racehorses with a definite diagnosis of iDDSP were treated with LTF. A definite diagnosis of iDDSP was made with high-speed treadmill or overground endoscopy. Upper respiratory tract (URT) disorders, short-term complications and horses returning for recurrence of URT problems were recorded. Performance before and after LTF was assessed by reviewing career race records and comparing performance index (PI) and racing speed marks from the baseline, preoperative and postoperative period. The effect of basihyoid-cricoid (BC) net distance shortened on racing performance was assessed.

Results

Performance index decreased prior to diagnosis/surgery in 75% of horses. Postoperatively, PI increased in 67%, and 66% established or improved their racing speed mark. As a group, PI decreased by 1.05 points ($P<0.001$) prior to diagnosis/surgery. Postoperatively, PI increased by 0.5 points ($P=0.004$) and racing speed improved by 0.82 seconds ($P<0.001$). Net BC distance shortening did not affect performance postoperatively. Twenty of 95 horses (21%) had confirmed recurrence of iDDSP postoperatively.

Discussion/Conclusion

This study provides scientific support for the continued use of LTF to treat iDDSP in harness racehorses, though iDDSP seems to affect harness racehorses differently as individuals.

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Evaluation of villous synovium from unaffected metacarpophalangeal joints of adult and juvenile horses

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Introduction
Synovial explants are increasingly used in in-vitro studies using the equine species as a model for orthopaedic research such as osteoarthritis. Further, histological analysis of the synovial membrane is also considered as the gold standard in clinical trials as the synovium is involved in the initiation and progress of joint diseases. To establish possible disease and age-related parameters for future histological analysis, the study aimed to evaluate the mean intimal lining dimensions, cellularity and the vascularization of equine villous synovium of non-affected metacarpophalangeal joints in juvenile and adult horses.

Materials and Methods
One hundred synovial samples from villous synovium of non-diseased metacarpophalangeal joints from juvenile and adult horses were analyzed. Digitalization of histological slides was followed by the analysis of the following parameter: intimal synovial lining dimension, cellularity of the intimal synovial lining and vascularity of the subintimal layer.

Results
The width of the intimal synovial layer did not show significant differences between juvenile and adult horses. Differences were seen in the number of cells composing the intimal synovial layer and regarding the vascularity of juvenile and adult horses.

Discussion
This study provides detailed histo-anatomical references of non-affected villous synovium of the metacarpophalangeal joint in juvenile and adult horses for future in vivo and in vitro studies. Age-related differences regarding intimal synovial layer dimensions, cellularity and vascularity must be considered when equine synovium is used for histological studies. It has to be proven whether the metacarpophalangeal joint is representative of other diarthrodial joints.

Electromyographic study of the sternomandibularis muscle ahead of laryngeal reinnervation with the spinal accessory nerve

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Introduction

The sternomandibularis muscle is a long fusiform muscle ventrolateral to the trachea responsible for head and neck flexion. Motor innervation is provided by the ventral branch of the spinal accessory nerve. Our objective is to conduct an electromyographic study of the sternomandibularis muscle in order to gather normative data in horses at rest and during exercise. Muscle recruitment, relative to posture, gait and respiratory cycle, will be determined from electromyographical signals of the sternomandibularis muscle activity induced by physiological accessory nerve stimulation.

Materials and methods

Surface electromyography of the sternomandibularis muscle was performed in warmbloods, trained thoroughbreds and standardbreds. The myoresearch software was run with sensors for the left and right sternomandibularis muscle, a ground sensor, an accelerometer and a pharyngeal pressure recording sensor. Electromyography was performed in different feeding postures and at exercise, which included standardized treadmill exercise tests, lunged and ridden work in different head neck positions.

Results

Qualitative signal analysis enabled to identify patterns in the timing and magnitude of sternomandibularis muscle contractions. The sternomandibularis muscle is strongly activated when the horse is grazing. At trot, the muscle contracts in phase with the stride. At gallop, contraction is not only correlated with timing of the stride but also the respiratory cycle. Signal amplitude increases with speed.

Discussion

On top of the anatomic proximity of the spinal accessory nerve to the larynx, this study puts forward electrophysiological advantages to grafting the spinal accessory nerve to the cricoarytenoideus dorsalis muscle in selected cases of laryngeal hemiplegia.

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Cannabinoid receptor are expressed in equine synovium and upregulated with synovitis

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Introduction
Osteoarthritis (OA) is an important cause of equine pain and disability. Toxic side-effects and lack of response are challenges with many OA pharmacological therapeutics. Cannabinoids are promising targets in human rheumatologic disease, but little is known about the equine endocannabinoid system. Our objectives are to assess the presence and expression pattern of cannabinoid receptor 1 (CB1) and 2 (CB2) in the synovium of healthy and OA joints, and to investigate the relationship between cannabinoid receptor expression, synovitis and OA severity.

Method
Twenty-five metacarpophalangeal joints were dissected, and macroscopic articular cartilage lesions were scored. Synovial membrane specimens (n=45) were harvested, and synovitis was scored histologically. Synovium immunohistochemical staining with polyclonal CB1 and CB2 antibodies were performed for each specimen. Five regions of interest were blindly scored for positive immunoreactive staining by 2 observers. Interobserver agreement was calculated with intraclass correlation (ICC). Relationships between CB1 and CB2 immunoreactive scores, synovitis histological and OA macroscopic scores were interrogated with mixed linear models.

Results
The ICCs for CB1 and CB2 scores were 84.6% and 92.9% respectively. CB1 was expressed in all specimens studied by both observers whereas CB2 expression was identified in 94% of specimens. Significant positive interactions were found between the CB1 (p=0.038) and CB2 (p=0.027) immunoreactive scores and the synovitis score.

Discussion/Conclusion
Equine synovial intimal cells constitutively express CB1 and CB2, revealing a functional endocannabinoid system in the equine joint. The positive correlation between cannabinoid receptor expression in synovial cells and synovitis holds great promise for treating osteoarthritic pain by targeting inflammation with cannabinoids.

Large Animals

In-depth: Arthroscopy

Friday 09 July, 2021

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Arthroscopic Repair of Full Thickness Cartilage Defects

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Introduction
Cartilage resurfacing of full-thickness defects implies repair to an organized hyaline architecture not evident in simple manipulative techniques used in mature horses. Methods that may enhance the quantity and hyaline characteristics of cartilage repair tissue, while at the same time maintaining the efficiencies of arthroscopic surgery, allow the surgeon to improve the long-term outcome when debriding cartilage lesions. No system routinely provides all of these advantages. Indeed, those with inherent simplicity such as cartilage debridement, forage, and microfracture meet many of the criterion for simplicity, economy, and minimal delay between diagnosis and repair, but provide less assured hyaline cartilage and cartilage durability. Techniques for cartilage repair that strive to improve chondrocyte preponderance and organized matrix architecture include cell and tissue engineered transplantation techniques. Most are better than local debridement or marrow stimulation procedures, but add complexity to the surgery.

Transplantation Procedures
The use of supplemental free cells, various vehicles containing cells, or entire tissues such as periosteum, cartilage, or osteochondral grafts have been advocated to improve the modest impact that local manipulative procedures have on both the quality and quantity of cartilage repair tissues. Transplantation procedures can be divided into several currently acceptable areas, according to the type of transplant tissue: 1) osteochondral transplantation (mosaicplasty, 2) chondrocyte transplantation, 3) pluripotent stem cell transplantation, 4) macerated cartilage implantation, and 5) bone marrow aspirate concentrate (BMAC) implantation.

Implantation of whole tissues and tissue engineered products usually requires arthrotomy approaches which are unsatisfactory in most equine joints. These include chondrocytes cultured on collagen (MACI), polyglycolic acid (PGA), or PGA/polylactic acid (PGA/PLA), or newer synthetic materials such as hyaluronan membranes. This serious practical limitation has tempered interest in using these implants.

Pluripotent Mesenchymal Stem Cell Transplantation
The use of a pluripotent cell to enhance cartilage repair has been investigated for over 20 years. Initial studies in the rabbit indicated MSCs could enhance cartilage repair. Studies in the horse indicate bone marrow-derived MSCs can be harvested and directed down the chondrocyte lineage.[1] However, in vivo studies in the horse indicate early robust repair, but later less dramatic improvement in tissue quality compared to spontaneous healing.[2] Moreover, bone marrow-derived stem cells from horses are tedious to culture, and accumulation of sufficient numbers to graft large articular defects can take up to a month. Additionally, the yield from mature horses (representing the majority of a clinic caseload) is reduced over yields from immature animals, making the accumulation of sufficient cells for grafting age-dependent but generally quite slow. However, methods to induce chondrogenesis in MSCs are becoming better defined[3], and exposure to TGF-β1, 2, or 3, Sox transcription factors, and BMP-2 or -7, all induce chondrocytic transformation when applied as recombinant protein or used in gene transfer systems to autogenous bone-marrow derived MSCs (Watts & Nixon, Doctoral Thesis, 2012). Moreover, the addition of anabolic growth factors to the cell mixture, including IGF-1 and several from the transforming growth factor superfamily, particularly BMP-7 and/or BMP-2, may promote long-term matrix synthesis and MSC persistence.[4] Fat-derived stem cells may also be a useful source of MSCs for cartilage repair, although simple overnight isolation of nucleated cells from fat and implantation or injection to cartilage defects has not achieved significant cartilage healing compared to bone marrow derived MSCs or longer-term ADSC cultures, and even the long-term cultured fat derived stromal cells have been slow to form chondrocyte lineages.[5]

Clinical Applications of MSC Transplantation
The current cell type of choice for cartilage repair is an autologous MSC. Previous clinical work used chondrocyte allografts for stifle subchondral cyst repair for older or arthritic horses and long term followup indicated this approach was clearly better than debridement alone or intralesional steroid injection.[6]However, allograft chondrocytes occasionally resulted in subtle

immune reaction. Autologous MSCs avoid this problem, but result in further issues with inadequate chondrogenesis at the time of application. Bone marrow-derived MSCs can be harvested and directed down the chondrocyte lineage.[1] In vivo studies in the horse indicate improved early healing in a femoral trochlear ridge healing model.[2] Methods to induce chondrogenesis in MSCs are becoming better defined [3], and exposure to TGF-β1, 2, or 3, and Sox5,6 & 9, all induce chondrocytic transformation.[7]Presently, exposure to TGF-β3 for 24-48 hours is used to induce chondrogenesis in clinical cases where MSCs are used for directed cartilage repair. This is based on the enhanced chondrogenesis with reduced propensity for hypertrophic terminal differentiation resulting from TGF-β3, compared to TGF-β1 and -2 (Figure 1).

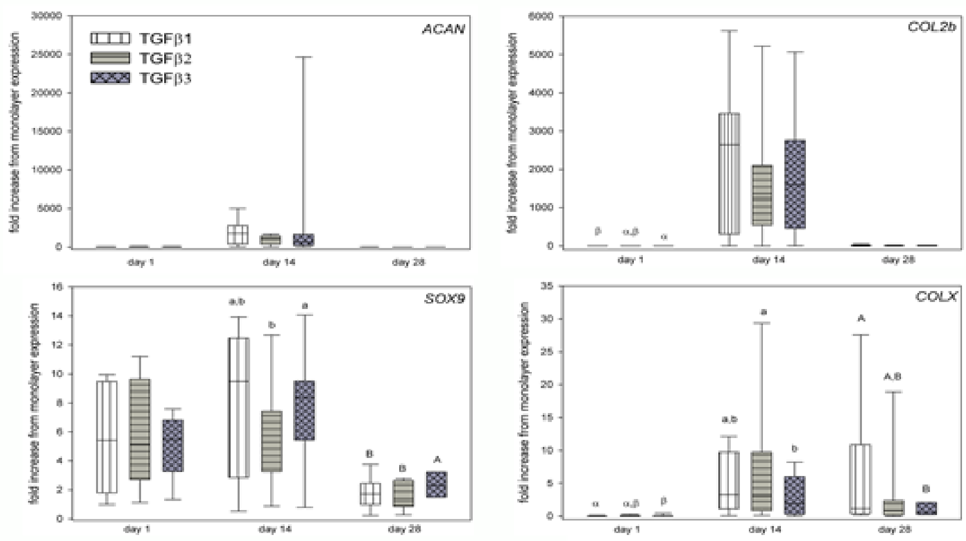
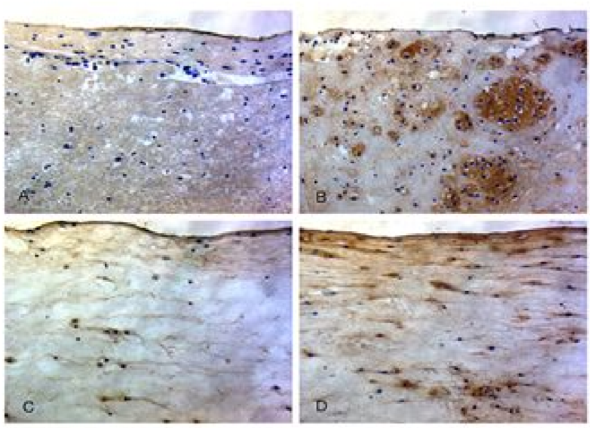


Figure 1. Assessment of TGF-β isoforms for MSC chondrogenesis. There were no differences in gene expression of chondrogenic markers (COL2B and ACAN) in pellet cultures exposed to TGF-β1,2 or 3, but there was significantly higher SOX9 and significantly lower COLX expression in TGF-β3 treated pellets versus TGF-β1 or -2, indicating prevention of hypertrophy by TGF-β3 supplemented cultures.

Clinical cases are then grafted with autogenous fibrin or PRP containing 20 to 30 million transformed MSCs/ml of vehicle. Fibrin remains the best vehicle for its adherent and resilient vehicle properties, but is slow to prepare and requires -80C freezer facilities.

MSC Clinical Application

At the time of surgery the MSC pellet is mixed with 7 ml BMAC or PRP. Activated thrombin (1k or 5K units) in 0.7 ml CaCl2 is used to provide a two-component system for immediate injection. PRP is rich in growth factors and provides support for chondrogenesis and cartilage matrix formation (Figure 2&3).



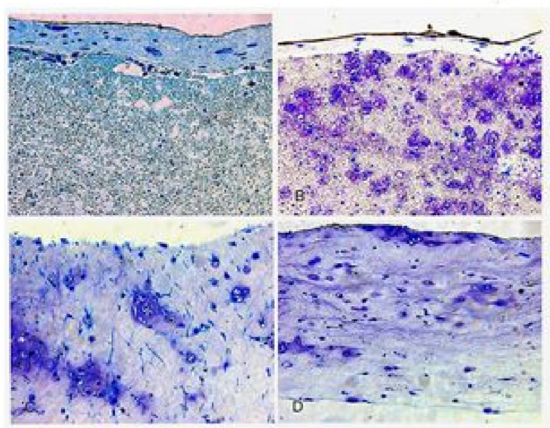


Figure 2. Collagen type IIB immuno showing no type II collagen in PRP-no cells (A), significant nodules in PRP with chond (B), and lesser amounts in PPP (C), and fibrin (D) containing chondrocytes.

Figure 3. Toluidine blue reaction to indicate cartilage is minimal in PRP-no cells (A), prolific around nodules in PRP with chond (B), and lesser amounts in PPP (C), and fibrin (D) with chondrocytes

Thrombin is obtained from MP Biomedicals, and the lyophilized powder reconstituted with calcium chloride (40 mM), and sterilized by filtration through a 0.2 micron millipore syringe filter. At surgery, the polymerization process develops immediately upon injection of the two components into the articular defect (9 parts PRP/stem cells and 1 part thrombin). Arthroscopic application is routinely performed, using gas insufflation for the few minutes required for fibrinogen in PRP or BMAC to polymerize (Figure 4).

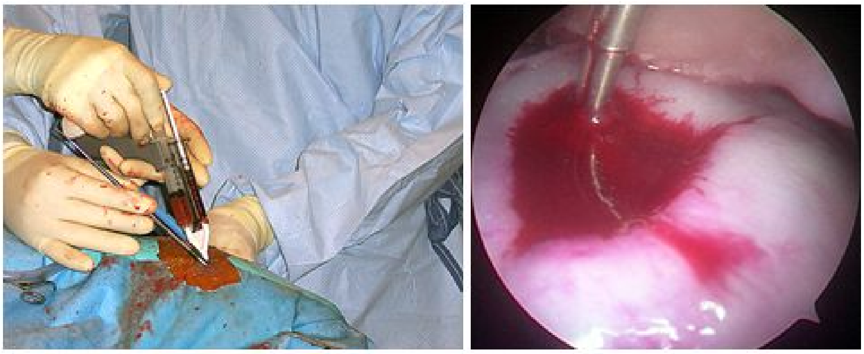


Figure 4. (Left) PRP containing cultured stem cells in larger syringe and thrombin in smaller syringe, being injected into stifle cyst. PRP gels in 20 to 30 seconds to form confluent surface in cartilage (right).

Gas insufflation units such as those from Arthrex or Stryker are useful for distension of the joint, although for short term gas arthroscopy, several 60 ml syringes of room air suffice to dry the cartilage bed and allow injection of the MSC laden PRP. Gas allows drying of the defect using surgical sponges applied to the end of a hemostat. Drying of the subchondral bed and surrounding intact cartilage allows better application of the naturally adhesive properties of fibrin. The polymerizing liquid nature of PRP or BMAC allow contouring of the cell transplant to the irregularities of many joint surfaces.

Clinical application of TGF-β3 modified MSC grafting in horses has included traumatic cartilage lesions of the fetlock metacarpal condyles and proximal P1, OCD or subchondral cystic lesions of the shoulder, fetlock, and stifle, and third carpal bone lysis and bone cysts of other carpal bones. Results for stifle OCD and subchondral cyst grafting of the stifle and fetlock have been generally good. Many have been re-operation of previous failed therapies, including simple debridement with or without microfracture and steroid injection. Too few cases of shoulder and carpal graft cases are available to comment on outcome, although many improve.

Direct MSC Injection

The direct intra-articular injection of autologous stem cells to the joint space has been proposed as a simple, cost effective approach to the treatment of OA.[8,9] Direct injection of stem cells to a joint has been clinically applied in medical practice with the expectation that these cells would "home" to damaged cartilage, reform a stem cell niche capable of forming a progenitor population in cartilage, and participate in repair by chondrogenesis and matrix synthesis.[10,11]Additionally, injected MSCs may stimulate constitutive cells to proliferate and participate in chondrogenic repair.[12]Evidence is growing that this does indeed happen.

Stem cell tracking after Direct Injection

Stem cells have a unique ability to home to specific sites of cartilage damage and the synovial recesses after joint injection (Figure 5).

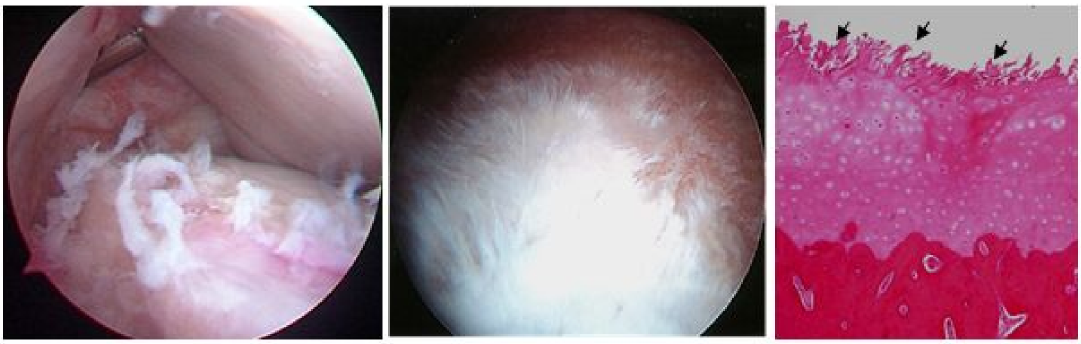


Figure 5. (Left) Arthroscopic image from the carpal joint showing carpal bone chip with extensive coarse fibrillation; and **(Mid)** a femoral condyle showing fine fibrillation over the entire surface. Both are targets for stem cell injectable therapy, where the cells potentially fill the fibrillar clefts, shown by arrows **(Right)**. Some MSCs adhere and repopulate fibrillated cartilage and synovial tissue and deliver cytokine suppression and lessen OA.

Quantum dot nanoparticles were used to label equine MSCs in culture, and labeled cells were identified in cartilage and synovial membrane 72 hours after injection into OA. While most injected stem cells populated the synovial intimal and sub-intimal layers, a few settled and adhered to fibrillated cartilage in joints (Figure 6). Tracking studies in a total of 11 OA and 13 normal joints found sparse stem cells adhered to cartilage, and many localized into the synovial recesses.[13]These findings indicate MSC intra-articular injection has minimal direct impact on surface cartilage cell populations, with the bulk of MSCs settling into the synovial intimal layers. There they may still have powerful impact on joint homeostasis, through numerous progenitor and other anabolic mechanisms, described in the next section.

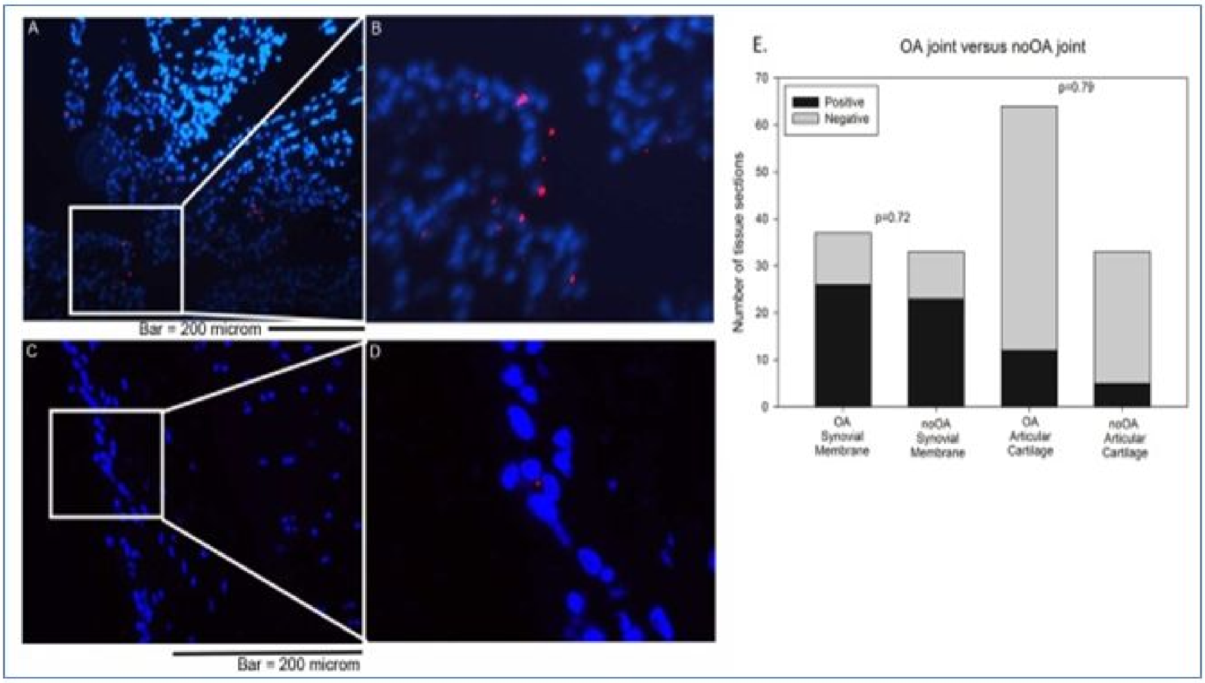


Figure 6. Injected MSCs (red qdots) predominate in synovial tissue (A,B) with fewer cells in cartilage (C,D). Cell counts (E) verified the subjective appearance. Cell nuclei of all cell are labeled with DAPI (blue).

Other Mechanisms of MSC Action in OA

MSCs have been thought to have more generalized anti-inflammatory, anti-apoptotic, and cell signaling effects that reflect influences on constitutive cells.[14-17] MSCs home to and engraft injured tissues and modulate the inflammatory response through synergistic down-regulation of pro-inflammatory cytokines and up-regulation of both pro-survival and anti-inflammatory factors.[14,15,18,19]In addition, MSCs possess remarkable immunosuppressive properties, suppressing T-cell, NK cell functions, and also modulating dendritic cell activities.[14,18] These constitutive anti-inflammatory effects may be vital in controlling joint disease.

Application in Stifle Disease

Application in stifle conditions is the best example of MSC direct injection in the horse.[20]Frisbie and others at Colorado State University have been injecting femorotibial joints with culture expanded MSCs after confirmatory arthroscopy and debridement of lesions in the cartilage or meniscus. Cells are presumed to home to the defect but other mechanisms clearly apply to add to the result. In summary, 39 horses had long-term follow-up, and 77% returned to some level of work. This included 14 of 39 (36%) that achieved the same or better athletic capability, another 14 (36%) that struggled to work with medication, and 11 of 39 (28%) that failed to return to work.[20] Many of the cases had meniscal injury which included grade 3 tears, which had traditionally done poorly (6% return to function). [21]After MSC injection, athletic function was evident in 60% of cases.[20]

The incidence of flare after MSC injection was 8%, which is similar to flare associated with HA injection. Reaction to autologous cells should be minimal. However, the culture of MSCs in bovine serum supplemented media may be the risk issue for joint flares in the horse.

Bone Marrow Aspirate Concentrate (BMAC) alone for Cartilage Repair

The development of patient-side centrifugation techniques for intraoperative stem cell isolation and purification for immediate grafting have significant advantages in time savings and immediate application of an autogenous cell and growth factor mix for cartilage repair (Fig 7).[22] When considered together, cartilage studies reveal that three components are required for cartilage regeneration; cells, scaffold, and growth factor/s. Recent work has generated a stem cell concentrate from sternal bone marrow aspirate which can be centrifuged to concentrate the cellular population and platelets in bone marrow aspirate (Figure 7).

Figure 7. Techniques for centrifugation of bone marrow aspirate and concentration of pluripotent cells and growth factors for cartilage repair. Top panel: harvest of bone marrow (left), injection into separation device, and placing into programmable centrifuge. Lower panel: drawing off bone marrow derived MSC enriched fraction (left), debriding medial femoral condyle erosion in 5 year-old Warmblood with concurrent meniscal tear (center), and injecting bone marrow stem cell enriched product mixed with thrombin to clot in full-thickness cartilage defect (right).

Using flow cytometry, research data indicate that the final total nucleated cell population contains approximately 15% stem cells (Radcliffe & Fortier, unpublished data, 2008). The concentrate also contains a large number of platelets which are the body's natural reservoir of several growth factors such as IGF-I, TGF-B, and FGF, which are known to enhance cartilage matrix synthesis. The concentrate can be mixed with thrombin to cleave the fibrinogen into a fibrin scaffold to hold the milieu of MSCs and growth factors. This method has the advantages of being a point-of-care technique (no laboratory culture period is necessary) that is completely autogenous, arthroscopically applicable, and delivers all three components believed to be important for cartilage regeneration; cells, growth factors, and a scaffold.

In vivo data, using 10 research horses in which 15 mm full thickness defects were made on the lateral trochlear ridge of the femur, revealed no post-operative synovitis or other detectable adverse reaction. In the research cases, the grafted limb had a significantly better score at 3-month recheck arthroscopy and the control limb. At 8 months (euthanasia) 3T MRI indices, gross score, and histologic scores were all significantly better in the grafted limb compared to the control limb.[22] Subsequently 18 clinical cases have used BMAC as a sole graft product. Although the BMAC graft is slower to gel than PRP laden with MSCs, adherence can develop and results in clinical cases mirror the modest improvement evident in the controlled study (Fig 8).[22]

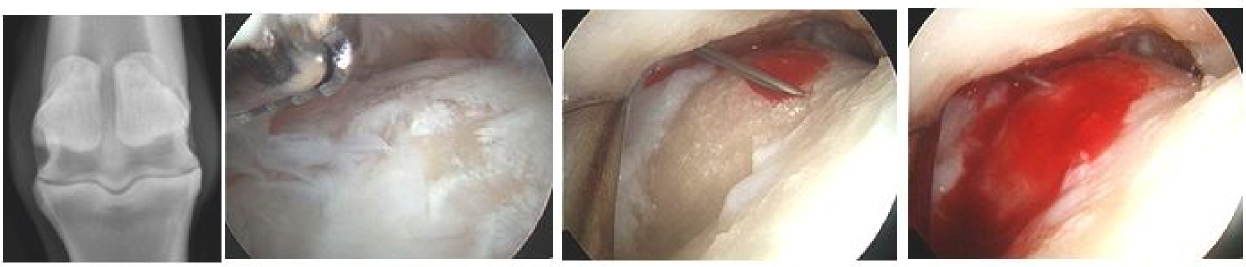


Figure 8. Horse 11, yr old with RF lameness and early OA. Radiographs show medial joint space narrowing and MC3 condyle remodeling. Arthroscopy revealed extensive cartilage erosion on dorsal and distal surfaces of the MC3 medial condyle. The cartilage was debrided to bone and grafted with BMAC under gas distension. The horse was able to jump for an additional 3 years.

There are major advantages in point-of-care preparation of BMAC for cartilage and meniscal repair but at this stage it does not achieve the benefit of MSC supplementation in long term clinical assessment.

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Recent Advances on Arthroscopic techniques of the human knee

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The topics of ‘Recent Advances on Arthroscopic Techniques of the Human Knee’ are ACL repair, Anterolateral extra-articular procedure, Meniscal repair and Cartilage repair.

The past decade ACL repair has regained popularity with the modern ACL repair techniques. The (dis)advantages of ACL repair and four different techniques will be discussed.

Another advancement this past decade is the improved understanding of the anterolateral complex. Different techniques are increasingly being used, complementary to ACL reconstruction or repair, to improve the rotational stability and reduce the ACL re-rupture risk.

Less surgery is being performed on degenerative meniscal lesions, while there is an increase traumatic meniscal repair. Special attention is given to the meniscal root and ramp lesion.

Knee osteoarthritis is an increasing burden for patients and society, especially for patients younger than 65 years as they are “too young” for a knee arthroplasty. Knee joint distraction is discussed, a novel joint-sparing surgical procedure for younger patients with knee osteoarthritis which could be an alternative instead of knee arthroplasty.

Comminuted proximal phalanx fractures: Transfixation cast vs Human Femoral Plate

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Highly comminuted fractures of the proximal phalanges, affecting all breeds and all activities, are common, serious injuries, that do not allow accurate reconstruction and stabilization of all the fragments. One of the greatest challenges in managing such fractures is the need to achieve immediate and durable weight bearing following surgical treatment to prevent laminitis development in the contralateral limb while providing stability to the fracture site.

Although there are some anecdotic reports of successful conservative management (by immobilization in a standard cast) collapse of the metacarpus/metatarsus through the displaced proximal fragments of the proximal phalanx usually inevitably occurs, leading to instability, angular limb deviation, chronic pain and support limb laminitis.

Transfixation cast (TFC)
Lag screw fixation alone does not allow accurate reconstruction and stabilization of severely comminuted fractures due to the absence of a bony strut extending from the metacarpus/metatarsus to the proximal interphalangeal joint and an additional external fixator is required. Reported techniques include the Nunamaker external fixator and transfixation pin cast, which allow transfer of the axial weight-bearing forces from the limb through the pins to the cast or fixator. Two 6.3 mm positive profile centrally threaded pin (Imex®, Longview, TX) are placed in the distal metaphysis and the cast is applied. It is important to reduce the padding at the pinbone interface, in order to prevent pin bending and breakage. The cast and pins were left in place for 6 - 8 weeks and were removed with the horse in standing position (6 horses) or under general anesthesia (5) and a standard cast was applied in a normal weight bearing position and maintained for 3-4 weeks. At this time, healing was assessed using radiographs and the cast was replaced by a Robert-Jones bandage. The technique is relatively easy to perfom and, as any external fixator, carry a low risk of infection

However, this procedure is a temporary fixation until pins are removed, and still carry some post-operative risks. Complications following a TFC are related to pin problems (pin loosening, pin breakage, infection of the bone surrounding the pin, pathologic fracture of the third metacarpus/metatarsus), early removal of the transfixation pins (risk of collapse of the proximal phalanx construct and / or re-fracture). Delayed postoperative arthropathy of the metacarpus/metatarsus joint (MCP/MTP) or proximal interphalangeal joint (PIP) are common, resulting in chronic lameness and contralateral support laminitis that may require a secondary MCP/MTP arthrodesis. The overall success of the technique is about 70% in terms of fracture healing and discharge from

Human Femoral Plate
The LCP Distal Femur Plate (DFP) is a pre-shaped, low profile plate that features combi holes along the shaft accepting 4.5 mm and 5.5 mm cortex screws in the dynamic compression unit portion, 5.0 mm locking screws in the threaded portion. The threaded locking holes in the plate head accepts 5.0 mm locking screws and 4.5- and 5.5-mm cortex screws. The LCP DFP, available in a left and a right version, was initially used for distal shaft, supracondylar, intraarticular, extraarticular as well as periprosthetic fractures in humans. The implants and instruments of the LCP DFP are fully compatible with the 4.5/5.0 mm LCP Systems.

Recently, the LCP DFP (9 and 11 holes, left and right) has been approved for veterinary applications, specifically for comminuted fractures of the proximal phalanx in horses. The wide and flattened head of the plate has several locking holes which provides a strong fixation in the proximal aspect of the middle phalanx and the distal aspect of the proximal phalanx, distal to the area of major comminution (Fig 1). Furthermore, the curved shape allows abaxial fixation into one of the major fragments in P1 or in the medial or lateral condyle of the distal metacarpus /

metatarsus when associated with a concomitant condylar fracture. The low profile of the plate permits placement using less invasive fixation techniques.

Application of the LCP DFP

Prior to fixation, articular cartilage is debrided using a 4.5 mm drill bit and curettes through stab incisions. The frontal plane fracture in the proximal aspect of the proximal phalanx is reduced and stabilized with 5.5 mm cortex screws placed in lag fashion from dorsal to palmar.

The plate is contoured to the desired 15° of dorsiflexion at the level of the fetlock joint to provide an appropriate joint angle of 30°.

Plate fixation is accomplished using a less invasive soft tissue approach. Three, approximately 4 cm long dorsal midline incisions were performed through the skin and extensor tendon at the level of the proximal end of the plate, the metacarpophalangeal joint, and at the distal end of the plate overlying the proximal interphalangeal joint. Using a combination of sharp dissection and a large periosteal elevator, a tunnel is created between the bone and overlying soft tissues including the extensor tendon extending from distal to proximal incisions. The plate is inserted into the tunnel and appropriate plate positioning and cortical alignment is confirmed radiographically. After temporary fixation using two push pull devices, five 5.0 mm locking screws are inserted in the expanded head of the plate to purchase the distal aspect of the proximal phalanx and the proximal aspect of the middle phalanx. To ensure plate-bone contact proximally, two, 5.5 mm cortex screws were placed into the distal aspect of the metacarpus (plate shaft holes 4 and 5). The remaining holes overlying the metacarpus were filled with 5.0 mm locking screws or 5.5 mm cortex screws. Finally, two, 5.5 mm cortex screws were placed in lag fashion abaxial to the plate to engage the medial and lateral proximal sesamoid bones. Screws placed outside of the previously mentioned incisions, were placed through stab incisions (Fig 2).

The incisions were closed routinely. The distal limb is placed in a cast, and the patient is assisted in recovery. Typically, the cast is kept for 4 to 6 weeks after discharge with one cast change, usually at suture removal, and replaced by a Robert-Jones bandage for one additional month. The horse undergoes controlled activity (hand walking) for two to three more months before returning to pasture. Adequate trimming and shoeing are essential to improve breakover, minimize the posterior phase of the stride and reduce stress on the DIP joint. A rocker shoe with silicone padding appears to be well adapted.

At the time of writing, 13 horses have been operated with this technique with 67 % of survival which is similar to TFC. Double arthrodesis was well tolerated. Complications included screw loosening and screw breakage especially in the hindleg, infection, and limb support laminitis. It is very likely that both cases with surgical site infection got infected at suture removal.

Both TFC and LCP DFP techniques have advantages and limits, that need to be balanced according to the case, surgeon experience and facility. Contrary to an external fixator, LCP DFP maintains stability during fracture healing. Double arthrodesis is tolerated and prevents delayed pain due to inevitable arthropathy. Experience of the surgeon with the technical steps and postoperative management, including strategies to prevent infection, should improve the success rate when using the LCP DFP.

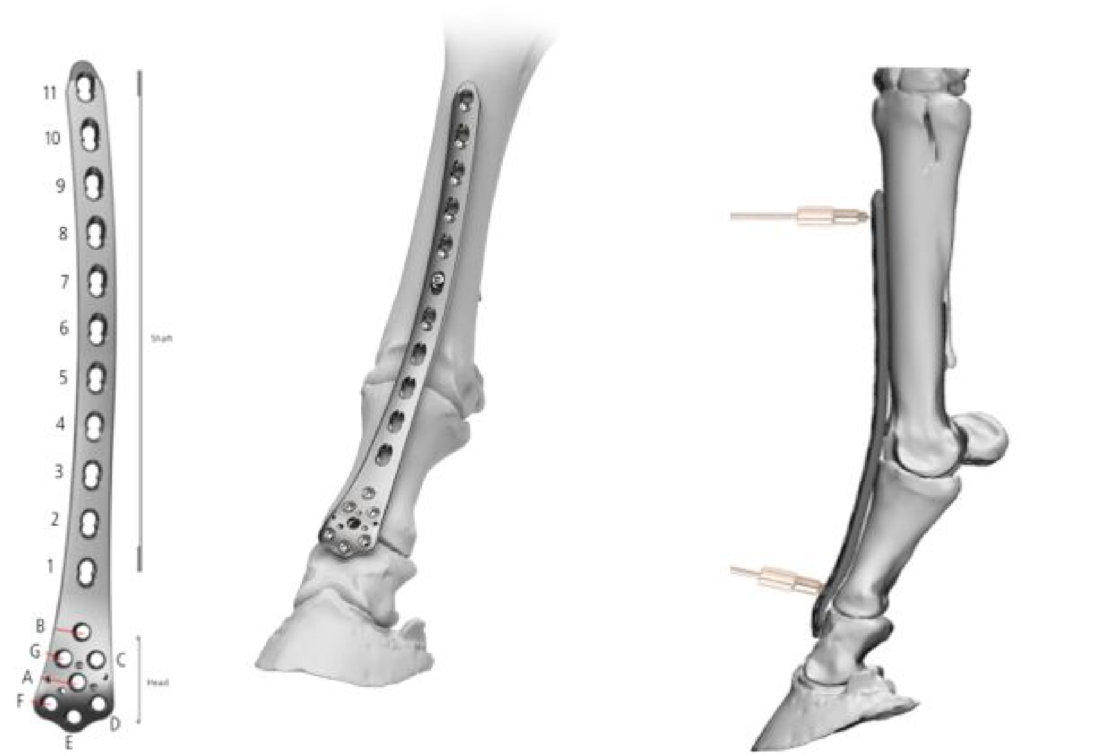

Fig 1. DePuy Synthes Vet 4.5 mm LCP® Distal Femur Plate. Combi Holes accept 5.0 mm locking screws in the threaded section or 4.5 mm and 5.5 mm cortex screws in the long section. Distal Combi Holes in expanded plate head accept 5.0 mm locking screws or 5.5 mm and 4.5 mm cortex screws.

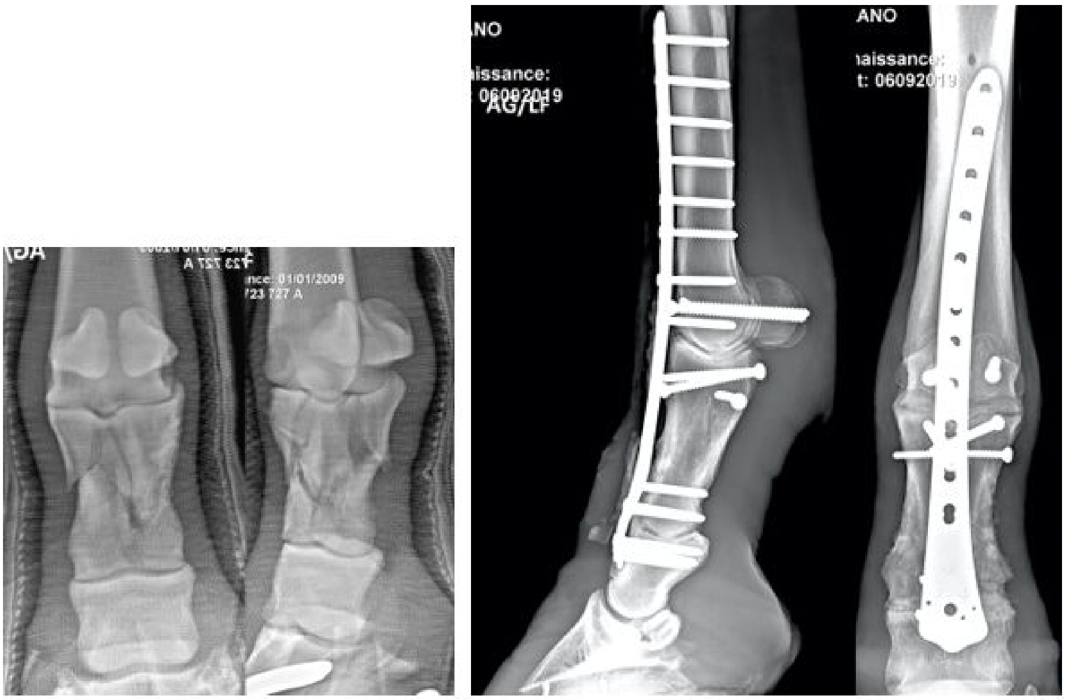

Fig 2: preoperative and 1 year postoperative x-rays of a comminuted P1 fracture in a 8 year old gelding.

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Date/Time: **09-07-2021 (16:00 - 16:20)** | Location: **Online**

Treatment of Radial Fractures

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Overview of Fractures of the Radius
Fractures of the radius can develop in horses of all types and ages. Foals appear to fracture the radius more frequently than adults, and are generally also small enough to attempt repair by internal fixation. In adults, higher energy fractures often result in more comminution with little hope of effective reconstruction. The only adult radius fracture with a good chance of repair or healing is a non-displaced spiral fracture of the distal and mid diaphyseal region.

Fractures of the radius can result from a kick by another horse, a fall during high-speed work, an abrupt stop during high speed activity, or for foals, being stepped on by the mare during lateral recumbency.

Approach for Fixation
The radius has a cranial bow which provides a tension band side along the cranial and craniolateral surface. This is generally the preferred site for application of one of the LCP or DCPs. The placement of the second plate should generally be in a plane at least 90 deg perpendicular to the cranial/ craniolateral plate, which usually necessitates a lateral or medial plate. In most instances the selection of a curved craniolateral approach to the radius allows placing a lateral plate (Fig 1). Based on fracture configuration, a medial plate may be required; the risk here is the limited coverage of the medial plate (skin only). For oblique metaphyseal/diaphyseal fractures, the large "spike" of the larger proximal diaphyseal fragment extending down the medial or lateral cortex needs to be "captured" under a plate applied to the medial or lateral surface of the radius (see Fig 4), and a second plate applied to the cranial region. The position of the medial or lateral plate dictates whether a craniomedial or craniolateral based approach is used. All things being equal, a craniolateral approach is the preferred method. This approach uses a linear incision through the skin from the elbow to the antebrachiocarpal joint. The separation between the extensor carpi radialis and common digital extensor muscle bellies is palpated and dissected to allow retraction of both muscles (Fig 1). In displaced complete fractures considerable hematoma and trauma to the muscles is common. A single or several lag screws are placed in oblique fractures to initially stabilize the fracture. A lateral and a cranial plate are applied, or alternatively a lateral dynamic condylar screw plate and a cranial LCP are used in combination.

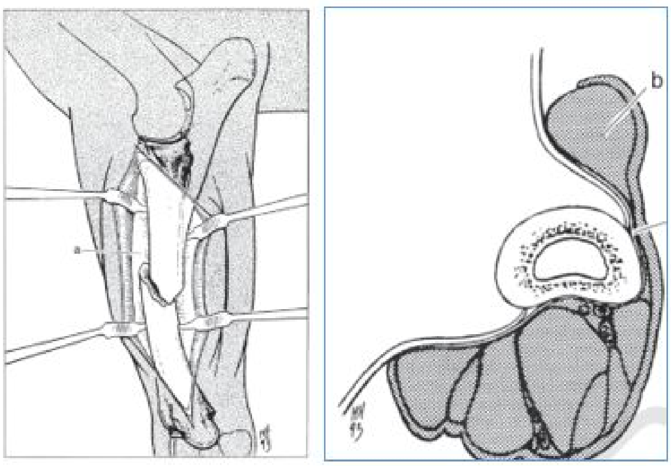

Fig 1. Craniolateral approach to the radius. (From Auer. Fractures of the radius. In Nixon AJ *Equine Fracture Repair*, 2nd Ed, 2020)

Diaphyseal fractures

Foals

Most diaphyseal fractures in foals tend to be short oblique simple or slightly comminuted mid shaft fractures. They are the most amenable radial fracture to plate repair. Young foals (<4 wks) with a stable transverse fracture can be stabilized by a single LCP or DCP applied to the cranial curvature of the radius; this takes advantage of the tension band side of the bone. Where the fracture is located more toward distal or proximal metaphyseal ends of the bone, two plates are required or use of an expanded end plate such as a Cobra head DCP (Fig 2), LCP T-plate, or femoral condylar LCP.

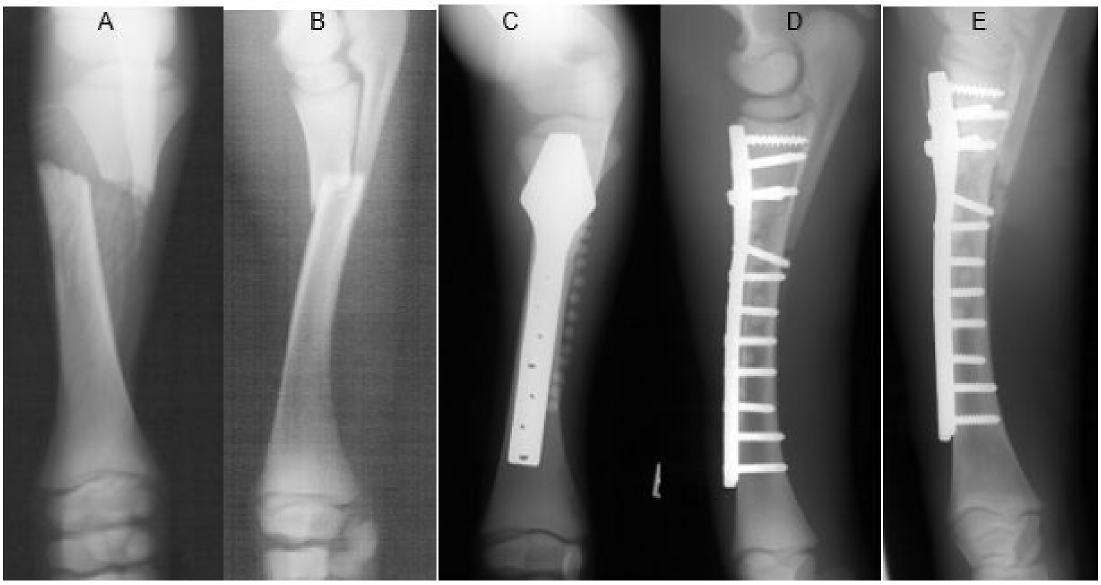

Fig 2. (A,B) Fracture of the radius in a 2mth old Quarter Horse, involving the proximal diaphyseal/metaphyseal junction. (C,D) Repair day 2 with a Cobra head DCP, allowing fixation of the short proximal segment with 6 screws. E) Fracture healing at 5 weeks, showing primary bone union and reconstruction of the ulnar shaft. Plate was removed 5 months after repair.

Two plates should be applied to foals >8 weeks old or >150kg with radius fractures, regardless of configuration (Fig 3).

Fig 3. (A,B) Fracture of the radius in a 4mth old Throughbred foal, involving the mid diaphyseal region with minor comminution along the end of the oblique fracture. (C,D) Repair with two LCPs applied to the craniolateral and craniomedial side of the radius. The broad 5.5mm LCP was removed at 8 months and the narrow LCP 6 weeks later.

Adults

Diaphyseal radius fractures in adults can be repaired if the plane of fracture is transverse or slightly oblique; this unfortunately is rare. Many are long oblique or comminuted. Stabilization with a 5.5mm broad LCP cranially and a condylar screw DCP/LCP or curved human femoral LCP applied laterally provides good stability and should be tried in a sensible smaller stature adult (Fig 4). If the fracture is long oblique or comminuted in a horse > 400kg, success is rare. External co-aptation to support these repairs is detrimental.

Fig 4. A comminuted long oblique fracture in a 480kg horse showing A) Severe overriding, and (B,C) repair with a medial condylar screw plate and cranial broad DCP. D,E) 3 mths showing repair breakdown.

Incomplete Spiral Fractures
Incomplete spiral shaft fractures of the radius in adults are usually the result of a direct kick to the radius from another horse (Fig 5). Some may result from a twisting fall.

Fig 5. Incomplete spiral fracture in a 500kg TB treated by cross-tying for 2 months. A) At presentation, B) 1 month, and C) 2.5 mths after diagnosis.

Lameness can initially be quite severe, but improves in the days after the fracture. As a consequence of improved lameness and minimal swelling, presentation can be delayed until days or weeks after the fracture. Most incomplete fractures by definition have some inherent stability and many can be managed by stall rest for 2 months and limitation of stress on the fractured bone by cross-tying to prevent the horse from lying down. A sling should be used if there is evidence of complete cortical interruption in multiple planes. Occasionally, splint bandages, extending to the top of the olecranon, are applied during the immediate postinjury period. However, applying splints and bandages introduces risk of exacerbating an incomplete fracture. Cross-tying and nonsteroidal anti-inflammatory agents to control pain are generally the most suitable treatment methods. Repeated radiographs are used to determine when adequate healing has developed to allow the horse to be removed from the cross-ties. Lameness decreases relatively rapidly with stall confinement, and pasture exercise must be prevented for at least 3 months. Prior to starting hand-walking exercise, follow-up radiographs should be taken to determine the progress of fracture healing. Most heal without complications or residual lameness.

Surgical fixation of carpal bone fractures

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Surgical fixation of carpal bone fractures is performed under arthroscopic guidance in all cases. The principal fractures treated with internal fixation include:

Frontal fractures of radial facet of third carpal bone
These are typically repaired with a 3.5 or 4.5 mm diameter cortical bone screw using lag technique. The arthroscope is placed laterally and an instrument portal used medially to debride any loose articular cartilage and bone. The fracture is reduced with flexion and 18 ga needles are placed at the lateral and medial edges, followed by an 18ga spinal needle in the central portion; another 18 ga needle in the carpo-metacarpal joint. Arthroscopically the needles indicate ideal lateral to medial positioning and the proximal-distal positioning and direction are guided radiographically. A stab incision is made, a 4.5 mm glide hole drilled until beyond the fracture line and a 3.2 mm threaded hole drilled beyond this followed by counter-sinking and tapping. Typically, a 32 mm cortical bone screw is used.

Frontal fractures of both radial and intermediate facets
These fractures typically occur in the racing Quarter Horse in the author's practice. They are the most common catastrophic injury of the racing QH and internal fixation is required for salvage of the horse's life. The same arthroscopic approach as for radial facet fractures is used, except two spinal needles beng used, with one across the radial facet and the other across the intermediate facet. Typically, lag screw fixation is done with two 36 mm long, 4.5mm diameter cortical bone screws with one through each facet. Horses are recovered from anesthesia in a sleeve cast, which is removed after returning to the trainer's barn.

Sagittal fracture of third carpal bone
These fractures are typically repaired with a 3.5 mm lag screw. Radiographic monitoring is more difficult than the previous fractures and placement of the screw needs to be between C2-C3 articulation and the dorsal limits of the fracture. Healing with conservative treatment has been reported, but in the author's opinion, surgical fixation is more predictable.

Frontal fractures of radial carpal bone
These are less common than third carpal bone fractures but do occur. The fixation principles using arthroscopic guidance with radiographic monitoring apply and needles are placed into both the middle carpal and antebrachiocarpal joint. Fixation is typically done with one 4.5 mm screw.

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An Update on Metacarpophalangeal Arthrodesis

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The usual indications for fetlock arthrodesis are intractable osteoarthritis and all forms of suspensory apparatus failure, i.e. displaced fractures of both proximal sesamoid bones, complete disruption of the distal sesamoidean ligaments and (least commonly) complete failure of the origin, body or both branches of the suspensory ligament. Of these, the distal sesamoidean avulsions are the most serious because the proximal interphalangeal joint also may require stabilization. All forms of acute suspensory apparatus failure should be managed immediately with a splint that aligns the metacarpus and phalanges, i.e. eliminates the need for suspensory apparatus support. Prefabricated splints such as the Kimzey LifeSaver splint (or similar designs) are now owned by most racetrack practices. Routine first aid measures are otherwise recommended for horses with this injury. It is generally NOT a good practice to take a horse with a suspensory apparatus breakdown immediately to surgery unless it is an open injury. The splints are extremely effective in providing immediately relief and it is invaluable to give an excited, anxious racehorse the opportunity to settle down and adapt to its lameness overnight so that anesthetic induction and recovery can be optimized. Also, this is a surgery that benefits from having well-rested and well-prepared staff and surgeons.

Surgical Approach

The surgical approach is the same for fusion of a suspensory breakdown injury or an osteoarthritic joint. A dorsal incision should be made along the lateral edge of the common digital extensor tendon leaving enough dense tissue on either side of the incision that closure is facilitated. At least four or five scalpels are typically used to complete the open exposure of the joint. The scalpels are used to peel off the lateral collateral ligament from the distal metacarpus. If this is done properly, the ligament and its loose attachments to the surrounding connective tissues remains intact. The general concept of the approach is to perform as little dissection as possible between the skin and the underlying tissues. The incision and "peeling" dissection away from the bone is extended in a similar manner down onto the lateral aspect of the proximal phalanx. The resulting dissection should result in a nearly intact "sleeve" of tissue that can be easily displaced laterally with a Hohman retractor and the fetlock is completely luxated. With the fetlock luxated, an oscillating saw (18-22 mm) is used in a "paint brush" manner to remove the articular surface. This is done with heavy irrigation; a conscientious effort is made to avoid removing the subchondral plate. If excessive bone is removed, the congruity of the denuded bone surfaces will be less than optimal and stability will be compromised. A curette should be used to remove any cartilage that difficult to remove with the saw from highly contoured surfaces. The bone saw or a curette is also used to remove the full thickness of the articular surface of the proximal sesamoid bones. In a joint with severe erosion of one compartment (usually the medial side with resultant varus), the saw or motorized burr can be used more aggressively on the "high" side of the joint until the limb axis is closer to normal. Do NOT try to make big wedge-shaped cuts with a saw because it is nearly impossible to get congruity after doing so. Simply maintain the existing contours as you gradually remove bone. Then use the bone saw to make numerous shallow cuts ("cross-hatch") in the subchondral bone to further expose the deeper bone without losing the contour of the original joint surfaces. The subchondral bone is then perforated with a 3.2mm drill bit spaced at about 1cm intervals over the proximal phalanx and distal metacarpus. The cross hatching with the saw removes more of the dense subchondral bone and it helps prevent skidding of the 3.2 mm bit when the forage is performed. It is absolutely worth the time and trouble to fully remove the articular cartilage.

When Larry Bramlage first described the technique, he advocated the use of the distal sesamoidean ligaments as the tension band IF there was an intact suspensory apparatus, i.e. the typical osteoarthritic joint fusion. This was done by engaging transverse screws through the metacarpus into the proximal sesamoid bones with the fetlock very slightly flexed so the sesamoids are slightly displaced proximally. Although this has proven to be a successful technique in the hands of experienced surgeons, my opinion is that a true tension band with stainless steel wire or cable is a superior choice. The tension band is more adjustable, much stronger, invulnerable to the creep behavior of collagenous tissues and also lessens the risk of an implant entering the flexor tendon sheath. A cable is <u>clearly</u> superior to monofilament wire in terms of the ease of placement.

The figure-8 tension band should be placed before the plate is placed. If there are not intact proximal sesamoid bones and distal sesamoidean ligaments, i.e. for those cases with shattered sesamoids or avulsed distal sesamoidean ligaments, a tension band wiring technique *MUST* be used. I now routinely use 1.7 mm cable and strongly advocate its use but 1.5 (or even 1.25mm) wire is adequately strong if placed with good technique. An essential piece of equipment is a large curved wire-passer (DePuy Synthes cat# 391.130). It is a reasonably well-designed instrument for this procedure.

A 4.0 mm hole is drilled transversely across the distal metacarpus about 2 cm proximal to the physeal scar. Another 4.0 mm hole is also drilled transversely across the proximal phalanx at about the junction of the proximal and middle thirds of the bone. The cable is passed transversely through the metacarpus from lateral to medial and retrieved on the medial side with a needle holder. It may be necessary to dissect some soft tissue to do so. Tunnel the wire passer from the lateral aspect of P1 (adjacent to the P1 drill hole) up into the palmar joint space. The tip of the wire passer must exit exactly at the palmar edge of the mid-sagittal groove of P1. A small stab incision may be needed to expose the wire passer tip. Place the cable into the wire passer and push it through as the passer is withdrawn. Pass the cable from lateral to medial through the drilled hole in P1. At each stage, pull out the slack and make sure there are no kinks/loops in the cable. Tunnel the passer from the same stab incision behind P1 distally and medially. Push the cable proximally. Retrieve it and place behind the lateral condyle to complete the figure-eight. Put the cable through the crimp pull out any slack. Grasp the cable with needle holders or vise grips a few cm on each side of the crimp. Pull hard to be sure there is no slack anywhere in the figure-8. Unlike monofilament wire, this is almost never a problem, however. THIS is the judgment portion of the procedure. Holding the cable taut, put the fetlock into about 10-12 degrees of dorsiflexion. A major advantage of the cable is that it can be safely adjusted UNTIL you crimp it. If the cable looks like it will be taut at that angulation, relax the fetlock back into extension or even slight palmar flexion then use the crimping tool to secure the cable. (It is worth mentioning that you do NOT need the expensive cable tensioning equipment for this use of this cable.) Cut the excess cable. When you then force the fetlock back into dorsiflexion, the cable should be very tight with the angle at 10-12 degrees. When the prebent plate is applied and the tension device tightened, there are usually another few degrees of dorsiflexion obtained.

Currently, I use a broad 4.5 mm 10-hole locking compression plate (LCP) for an average sized horse MCP arthrodesis. Larger horses or MTP may need longer plates. Although 5.5 mm locking plates are available, they should not be necessary if good technique is used. The plate should be placed exactly on the dorsal aspect of the limb. The plate should be initially positioned with the joint at 180°. The plate should have the fifth hole from its distal end just above the proximal articular rim of the proximal phalanx in an average sized Thoroughbred. The plate is then gently bent just above that point about 15°. The bent plate can then be checked by placing it back on the limb without any screws in it. With the fetlock in perfect extension (180°), the proximal edge of the plate should be off the bone approximately 2.5-3 cm. The plate should be contoured distally to match the slight concavity of the dorsal aspect of P1. It is then attached to the proximal phalanx with a single 5.5 mm cortex screw in either the second or third most distal screw hole in the plate. That decision is made after checking the position of the transversely passed cable. If the position of the plate allows a locked screw in the 3rd hole up, the second is preferred for the cortex to lag the plate against P1. After the cortex screw is fully tightened, three 5.0mm screws are placed in P1. BEFORE PLACING THE FIRST LOCKING SCREW, make absolutely certain that the plate is exactly aligned longitudinally. This is critical!! Once the second screw is placed in a malaligned plate, it is impossible to properly attach the plate to the metacarpus without twisting the proximal portion of the plate and that is both annoying and time-consuming. This alignment issue is also less of a problem with the shorter plate. Two 5.5 mm oblique glide holes are made on either side of the plate through the proximal phalanx aiming proximally towards the condyles. They should be directed in the sagittal plane, not axially.

Pulling the plate against the cannon bone then forcefully extends the fetlock. This must be held in place manually while the plate tension device is positioned. It is VERY useful to have a digitally strong assistant. A 3.2mm bit and an approximately 24-26mm 4.5mm diameter screw are then used in the tension device. The tension device is maximally tightened (How tight is too tight? I don’t know but the 4.5 mm screw should be bent when you later remove it.) It will impress you how much the plate can move and therefore how much compression can be applied at the joint surface using the tension device. A 5.5mm screw is then inserted through the third most proximal hole in the bone plate. The measurement for the screw length should be made in consideration of the gap under the plate. The screw can be placed with a neutral guide. A second screw is then inserted and fully tightened before the tension device is removed. If the plate is not pulled down close to the bone with the combination of the tension device and the cortex screw, use a second cortex screw closer to the center of the plate. Remove the tension device and fill the remainder of the screws with 5.0mm locking screws. THE ONLY CONCERN (a big one…) is that you must always pay attention to the cable; don’t hit it with a drill bit, tap or screw. Place an insert sleeve in the pre-drilled transarticular glide holes and place 5.5 screws. These screws can potentially hit the tension band so keep them short/within the condyles. Antibiotic-impregnated polymethylmethacrylate is prepared and stuffed in every screw hole and under the margins of the plate wherever possible. Keep the PMMA out of the joint space and be sure to remove it from all screw heads

Tension Band Wiring
An important thing to remember when using tension band wiring in this procedure is to be very careful with drill bits and screws around the wires. It is often necessary to angle a screw sharply if the hole in the plate lies directly above the wire. Planning is even more important with locking plates. If a locked hole lies directly over the tension band, you cannot avoid it with a locking head screw; you must use a cortical screw angled slightly away from it. It is not always easy to feel that you

have hit the tension band with a bit, tap or screw but you must do enough imaging to be certain that the tension band is intact. The transarticular lag screws also may hit the tension band.

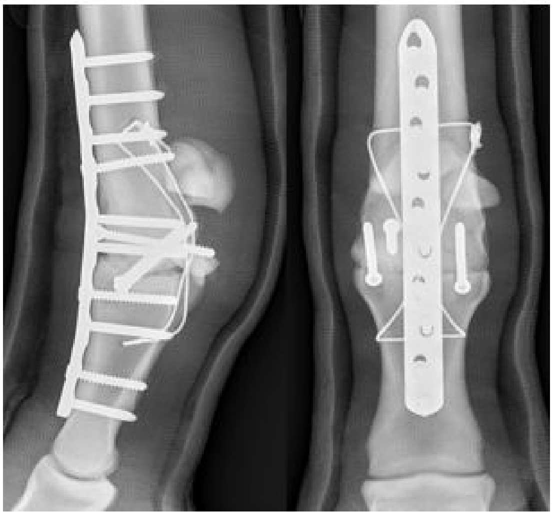
Closure
The tendon edges are apposed with interrupted cruciate sutures of 0 or #1 Vicryl. A continuous subcuticular suture is placed and the skin edges sutured with continuous or interrupted absorbable monofilament material such as Monocryl. The absorbable material is preferred because the surgical cast may end up left on the horse for 3-4 weeks or longer. The cast is placed with the foot positioned in a fairly normal weightbearing position, i.e. not in a heel-up ("equinus") position. If it is difficult to position the foot, a wire mattress suture should be placed across the foot near the heel and a hoof rasp positioned under it. The leverage of the rasp on the wire should allow adequate extension to be rigidly maintained while the cast is applied. The horse should be recovered with assistance on a deep foam mat (or sling or pool if available).

Aftercare
This fixation technique is extremely stable if done properly thus external coaptation is probably not even necessary, especially after anesthetic recovery. However, the incision is easily and well protected by a cast and a well-applied and comfortable cast provides support and protection for less money than heavy bandaging. The cast can be removed at any time if the horse seems uncomfortable. If, on the other hand, the horse remains comfortable in the cast placed at the time of surgery, it may be left on the limb for two weeks or so then removed. It is rare that a second cast would ever be necessary in a technically correct fetlock arthrodesis. Stall rest with carefully controlled hand grazing is maintained until there is convincing radiographic evidence of solid fusion. Using the described technique (barring complications), it is expected horse with a routine fusion for osteoarthritis will be in a paddock in 10-12 weeks.

Left- Avulsion of the distal sesamoidean ligaments. Middle- comminuted fractures of both proximal sesamoid bones. Right- Complete failure of the suspensory body.
All are indications for fetlock arthrodesis.

Large Wire Passer

After removal of the cartilage, the oscillating saw is used to crosshatch the subchondral bone. Then multiple ~2 mm deep holes are drilled with a 3.2 mm bit to further expose more vascular bone.



Postoperative radiographs in a TB filly with medial and lateral sesamoid fractures. Current technique usually employs a 10 or 12 hole broad LCP with a round (stacked) hole distally. I also use a single 1.7 mm cable as the tension band. The cable is much easier to place in position and is more easily adjusted than monofilament wire. Note that the plate and cable should be positioned such that the transverse element of the tension band is between screws. In this filly, a lag screw also was placed to engage a basilar portion of the medial sesamoid bone

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Internal Fixation of Intra-articular Fractures

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This presentation will include general principles for internal fixation of intra-articular fractures, other than carpal slab fractures. The ability to perform internal fixation of all intra-articular fractures under arthroscopic guidance has greatly improved success rate due to minimal surgical morbidity. The more common intra-articular fractures will be addressed:

Fractures of the distal metacarpal/metatarsal condyles in the metacarpo-/metatarsophalangeal joint
The most common fractures are those of lateral condyle and they can be displaced or non-displaced. Non-displaced fractures can be repaired under radiographic monitoring without arthroscopic guidance, but the author always arthroscopes both the dorsal pouch and the palmar (plantar) pouch to ascertain the presence of associated pathologic change and to make more accurate prognoses. All surgeries are done by the author in dorsal recumbency and, with displaced fractures, arthroscopic examination is performed initially and used to monitor reduction of the displaced fracture, which is done with a combination of flexion/extension and rotation. A distal lag screw is placed through a lateral condylar fossa with lateral fractures using 4.5 mm glide hole, followed by a 3.2 mm threaded hole and also includes counter-sinking. The typical screw is 52-54 mm long. The author does not use a 5.5 mm distal screw as has been recommended for displaced fractures by some surgeons. A second screw and third screw are placed more proximally depending on the length of the fracture. Fractures of the medial condyle more often occur in the hind limb with the fracture line not exiting and requiring varying levels of fixation proximally. Reduction is simple. The author typically uses a neutralization plate proximal to the two lag screws, after compressing the fracture distally.

Proximal dorsal P1 fractures of proximal phalanx
These fractures are typically in the sagittal plane and screw fixation is typically done lateral to medial using 4.5 mm lag screws. More distally the fracture can be oblique and a direction of the lag screw will be changed appropriately.

Slab fractures of the central and third tarsal bones
Internal fixation of all slab fractures of the tarsal bones is recommended. These fractures are repaired using radiographic monitoring and this is typically performed with 4.5 mm cortical bone screws. Radiographic monitoring is critical for accurate placement of the lag screws. Fractures of the third tarsal bone are the most common. When the fracture involves the central tarsal bone, the tarsocrural joint is arthroscoped to assess the proximal margins of the fracture.

Extremity-mounted gait analysis systems

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Gait analysis tools in horses have been the subject of interest in the equine industry for many years. Equine veterinarians spend up to 40% of their working time assessing lameness with economic costs estimated between $680 million and $1 billion in the USA alone. In the other hand gait quality and its evaluation not only occupies veterinarians but also breeders, owners, trainers and riders.

The use of electronic devices to examine lameness is not without controversy. Based on the Roger's curve of innovation and adaptation to progress and new technologies, only 16% of the people are innovators or early adaptors while 50% of the people are late adopters or skeptics (lagaards). The resistance of these 50% is well illustrated through personal comments, published criticisms and the slow pace that the technology initially encountered, although this is finally quickly changing. The main objective is to teach people to use the technology and to learn that any diagnostic tool is only as good as the person implementing it. New technologies in gait assessment may not entirely replace the veterinarian's role but in the author's opinion have the potential to make people better lameness diagnostician's, as long as the technology is properly used and within the limits of its applicability. The main reasons for this progress is the fact that the human eye evaluation of gait is essentially subjective, highly variable and imperfect. A better system is therefore needed. Currently, although commercial sensor systems available are become more prevalent amongst equine practitioners, most veterinarians rely on subjective visual examination of gait to detect movement asymmetries that are the common clinical sign of lameness but this has been shown to be potentially very unreliable and subjective. In fact, many research studies where lameness is an outcome parameter are routinely reporting now the use of any kind of objective device to assess and quantify lameness. These objective means can be classified in 2 broad categories: kinetics and kinematics. The former deals with the analysis of the forces resulting from movement and the latter with the actual movement patterns of different body segments. Most kinematic studies have addressed only the study of an extremity or segment at a time, but simultaneous analysis of the entire horse are scant, therefore we miss a real representation of how a horse moves in its entirety as a whole. This is the gap that extremity mounted gait analysis systems are trying to bridge as an alternative to the many impracticalities of 3D kinematics. The use of sensor technology is quickly being developed and becoming widespread in equine practice for the purpose of lame- ness investigations and the objective assessment of gait quality. Sensor technology has the following characteristics: portability, endurance, ease of use, accuracy, fastness, and a reasonable price for an equine practice. These sensors are called IMU's (Inertial measurement units) and are assembled in groups to produce different data sets. Inertial sensors measure acceleration, angular rate and the magnetic field vector in their own three-dimensional local coordinate system. They are composed of triaxial rate gyroscopes, accelerometers, magnetometers and a thermostat. These units allow for kinematics to be collected in the local reference frame of the sensor (and the part of the horse where the sensor is attached), and then with the input of the magnetometer, they can be rotated into a global reference frame with true cranial-caudal, medial-lateral, and vertical axes, which are aligned with the earth. The IMU is especially exciting since it allows investigation of both linear and angular components of motion. IMUs have been investigated in humans to evaluate a wide range of motions, including stride characteristics during walking and running, joint range of motion (both upper and lower limb), and change in trunk vertical displacement and posture. In the horse, the IMU has been examined as a body-mounted sensor for assessing stride parameters, hind-limb lameness, back movement, and center of mass movement in the horse. IMUs have been investigated to a limited extent for motion analysis in the horse. One research group has investigated a human designed IMU system mounted on the body of the horse to examine trunk movement at the gallop, hind limb lameness, back movement, and evaluation of hind-limb flexion tests. When examining center of mass displacement and orientation at the walk, trot, and canter, the IMU was found to be accurate compared to an optical kinematics system (median errors were < 3.5% of the range of total motion). While this study demonstrated that the IMU can be useful for evaluating motion of the horse's body, this particular commercial IMU system (Equigait) used does not have a large enough acceleration range (+/- 10G) to be used on the distal limb of the horse and a limitation exists to determine the moment of landing and take-off. In addition, when examining hind-limb lameness, the IMU showed high sensitivity (100%) and moderate specificity

(66%) for discriminating mildly lame (grade 1-2 out of 10) from non-lame horses. Thus, this IMU did not classify a sound horse as lame, but also did not identify all of the lame horses. In the development of a useful clinical tool to objectify the equine lameness examination, we would want an instrument with high specificity, so as not to miss the cases with subtle lameness.

An equine inertial sensor system developed in the United Kingdom (Pegasus) has been applied for use on the limbs of horses (metacarpus/metatarsus, and tibia) to monitor distal limb kinematics in the spatial and temporal dimensions, such as stride length, stride duration, and speed. The system includes a software, eight sensors and a delivered laptop. Each IMU records six-degrees-of-freedom (6 DOF), linear and rotational on three orthogonal axes. They are mounted into a brushing boot and tibia and radius straps. Each IMU (total weight 54 grams and size 73x36x19mm) contains a tri-axial 5g accelerometer and three single axis 1200 deg/s gyroscopes followed by anti-aliasing hardware filters with a cut-off frequency of approximately 50 Hz. No magnetometer is included. Sampling is done with a 12 bit analogue-to-digital converter at a frequency of 102.4 Hz. Each IMU is factory set to within 1ppm (3.6 ms per hour) of a reference time, achieving less than 10 ms per hour relative drift between units after synchronization. The IMU's are time stamped and synchronized at the start of each horse's trials by a simultaneous pulse being sent to the respective units, using specifically written software.

The sensors contain a precision clock and a memory storage service card (SD card). The sensors are programmed to determine the cycle associated with each stride via a proprietary algorithm. The metacarpus sagittal ROM outputs produced by this system have been compared in the past to an optical system. Precision bias has therefore been reported and has shown the ability of this system to measure subtle changes in phasing with no bias and a precision of 0.025% and ROM with a bias of 1.6°+/-1.9°. There are previous publications supporting the accuracy of this technology when measuring segment displacement, angular range of motion and stride frequency.

This system is capable of simultaneously capturing the entire motion cycle of the metacarpi/metatarsi and tibias and radii of all extremities. The spatial-temporal variables reported by the system define some aspects of the kinematic characteristics of the trot and include:

Temporal variables
The temporal phase-lag between respective limbs, also known as limb phasing variables (Phasing is defined through a cross-correlation approach of the rotation velocity around the lateromedial ax- is of the inertial sensor, on a stride by stride basis. Therefore, phase-lag is expressed as a percentage of the stride duration on a reference limb for each limb), stride duration (in seconds), timing for maximal protraction and retraction of third metacarpal and metatarsal bones (as expressed by percentage of the stride). The diagonal asymmetry is the difference between the diagonal limb phasing timing couplets: diagonal asym- metry (%) = (LF-RH) - (RF-LH), where LH is always 0 as it is the reference limb.

Spatial variables
The range of motion (ROM) in degrees referring to the sagittal angles of hock, carpus and segment angles of metacarpi/tarsi, radius and tibia, the coronal movement of metacarpi/tarsi, radius and the tibia in degrees, the symmetry (%) of each segment ROM which is calculated as the difference of left minus right divided by the mean of both measurements.

With the exception of the tarsus and carpus, the rest of the angles, which define the ROM are sagittal and coronal segment angles. A sagittal segment angle is the resulting angle that the segment subtends from its maximum retracted position to its maximum protracted position. A coronal angle is the maximum range the segment moves through the stride in the frontal plane. A negative coronal ROM indicates medial movement or adduction, and a positive angle indicates lateral movement or abduction. The tarsus and carpus angle are a joint angle which is the angle subtended between two segments, tibia or radius and metatarsi or metacarpi. Another spatial variable that can be calculated is stride length (m)and with the addition of a GPS sensor, speed and stride duration.

The author first documented its use at the 8th International Symposium on Veterinary Sports Medicine, Therapy and Rehabilitation in 2014 and since then many publications have followed documenting the reliability of the system and the influence of external conditions such as speed, surface, shoes, etc…

In essence, extremity mounted IMU's have the capability of mapping the entire movement cycle in its spatio-temporal domains and much work needs to be done to determine movement patterns associated with different pathologies and the use of this technology for future assessment of gait quality in equestrian sports during training and competitions as well as use of movement analysis for the purpose of genetic selection of individuals with specific movement patterns. The use of extremity mounted IMU's opens a whole new world of possibilities in clinical practice, research and teaching. For example, as an indication, the aim of dressage is the development of movement quality partly defined by symmetry, rhythm and regularity in all gaits, which could be objectively assessed by gait analysis tools. Quality of movement has also been studied for selecting a young horse with potential, or for the expected performance of horses in training. In the future we will see the streamed use body mounted IMU's for assistance during lameness investigations and extremity-mounted IMU's for more detailed diagnostic work and for the evaluation of gait quality or early adaptation patterns of specific injuries, allowing their early detection.

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Pitfalls of objective gait analysis

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The limitations of human perception for the visual evaluation of lameness have been well described, whereby not only classification of mild to moderate lameness but also the correct classification of sound horses as sound poses a challenge, even for experienced veterinarians (Starke and Oosterlinck, 2019). Nowadays, practical tools for quantitative (often referred to as objective) evaluation of lameness are available and this technology has unquestionably increased our understanding of the biomechanics of lameness (Keegan, 2007; Pfau et al., 2016; Greve and Dyson, 2020). A preliminary inventory of perceived pros and cons in equine practice revealed that users of quantitative gait analysis tools were motivated by objectivity, transparency, documentation and client service, whereas non-users mentioned costs and complexity of data interpretation as main issues (Hardeman et al., 2021). However, there are some common misconceptions on the use of objective methods for lameness evaluation, and it should be emphasized that the use of measurements is not replacing the clinician but rather augmenting the clinician's toolbox. All measurements must be evaluated within the context of the presenting complaint and history, complimentary to further clinical assessment or diagnostic tests (Adair et al., 2018, 2019).

To date, no visual or quantitative lameness assessment approach can claim 100% reliability in classifying a horse correctly. When applying quantitative methods, one should therefore be aware of pitfalls that may confound data and the assessment. Before looking at those pitfalls specific to objective gait analysis, quantitative evaluation may increase one's awareness of issues which are also often encountered during visual evaluation, and which should therefore not be regarded as pitfalls of solely objective analysis. For example, 'unstable' lameness varying in intensity during an evaluation session or between successive days of evaluation can confound both visual and quantitative analysis. Also, variation in trotting speed may confound the assessment of especially hindlimb lameness (Moorman et al., 2017a). Furthermore, quantitative evaluation of lameness has revealed a high prevalence of potential multi-limb lameness and the confounding effects of compensatory movements (Reed et al., 2020). It is plausible to assume that many of the mysterious lameness cases that 'cannot be blocked' are, in fact, compensatory movements by a primary lameness in another limb.

A first potential pitfall of solely objective methods for evaluation of lameness is erroneous marker or sensor placement that would lead to erroneous conclusions as the recorded data track the wrong location. In the Equinosis Q system for example, human error can mainly occur in the placement of the right forelimb sensor and the pelvic sensor. According to Moorman et al. (2017b), rotation of the right forelimb sensor less than 2 cm away from midline did not significantly affect data, but they did not evaluate more severe rotation. According to the manufacturer, rotation of more than 30-45 degrees will reduce the signal, impacting on the accuracy of stride segmentation and derived metrics. Rotation to the back of the pastern or mounting the sensor upside down will even result in classifying the horse lame in the opposite from the true limb (e.g., left fore rather than right fore). For the sacrum, left/right misplacement away from the midline affects the measured asymmetry to a much greater magnitude in comparison to cranial/caudal misplacement: in their study using optical motion capture, Serra Bragança et al. (2018) reported that each cm of marker placement left/right off the midline leads to an average difference in minimum position of the pelvis of 1.67 mm. Similarly, Moorman et al. (2017b) showed significant effects of a 2-cm sidewards change in the location of the pelvic sensor of the Equinosis Q system. These placement errors result in data that either falsely indicate lameness in a sound horse, soundness in a lame horse or lameness disproportional to what is present. In essence, studies show that if markers or sensors are not placed accurately, results of qualitative gait assessment are inaccurate, too.

A second potential pitfall is bilateral lameness. Obviously, when using head and pelvis displacement asymmetry as a lameness indicator on the straight line, symmetrically bilateral conditions can remain undetected if only looking at the data. Where visual assessment may note a choppy gait or stiffness in movement, the data will only report back on the anatomical landmark which they are attached to. This again underlines the need to use objective gait analysis not as a substitute for visual assessment, but an addition to a holistic approach based on visual observation and measurements. In the case of bilateral lameness, further clinical assessment (lunging, ridden evaluation, diagnostic anesthesia, …) should be used.

A third pitfall is a bias in asymmetry data during lunging and ridden exercise. On the circle, a sound horse presents with movement that is by default asymmetrical (Starke et al., 2012), where the asymmetry depends on circle radius, trotting speed and conformation (Pfau et al., 2012). Care should be taken because circle-induced asymmetry may mask or mimic forelimb or hindlimb lameness (Rhodin et al., 2016), with expected patterns even potentially depending on surface characteristics. For quantitative lameness assessment on the circle, the common approach is currently to compare data for the horse trotting on the left and right rein, trying to keep circle diameter and trotting speed identical between conditions. This area remains subject to further research. Moreover, the presence of a rider, interaction between rider and horse, and rider seating style can also affect vertical movement parameters, with the sitting trot being the least potentially confounding activity and posting commonly causing movement akin to a push-off type lameness in the contralateral limb to which the rider is posting on (Persson-Sjodin et al., 2018).

The final pitfall relates to imperfect classification thresholds and heuristics that must be applied to quantitative methods to make decisions. While decades of biomechanics research allow to approximate reference values for the vertical displacement asymmetry of head and pelvis above which a horse is likely clinically significantly lame, these reference values are not perfect. At present, all indications suggest that for subtle and mild lameness, we are facing an overlap between horses that present with natural and insignificant asymmetry and those that present with asymmetry due to a painful focus in the limb. This results in a 'signal detection' problem of finding the best threshold to discriminate between the two. It is unavoidable that around this threshold, some classifications as sound or lame will be incorrect. In addition, the assignment of lameness to left or right limb depends on signal features derived from the recorded data, in the process turning 'rich' data into simplified asymmetry measures. How this is done varies between systems. To date, no single metric or approach has proven 100% reliable in indicating the correct limb as lame. Finally, since lame horses present with a range of lameness patterns that affect the derived asymmetry measures and signal shapes, in some instances horses may be misclassified, and for some lameness patterns it even remains unclear how to interpret them.

Even in the absence of errors in sensor placement, discrepancies between the visual and quantitative evaluation may arise. On the one hand, it is not surprising to measure subtle asymmetries which are below the visual detection threshold. On the other hand, there is still a lack of knowledge regarding the interpretation of these subtle asymmetries, opening the debate on what degree of asymmetry can be considered normal (van Weeren et al., 2017). In this respect, breed differences should be considered, as significantly larger values of baseline asymmetries have been reported for example in Thoroughbred racehorses (Pfau et al., 2020) and Standardbred trotters (Kallerud et al., 2021). Moreover, several studies on objective evaluation have shown a high prevalence of what would be classified as a mild lameness in horses perceived as sound by their owners (Rhodin et al., 2016, 2017). However, this has also been reported in a study based on comprehensive clinical examination (Dyson and Greve, 2016), and agrees with clinical experience. Therefore, the accurate and objective detection of subtle asymmetries should warrant further clinical examination or at least follow-up, rather than lead to skepticism of the technique. Undiagnosed lameness is a major reason for poor performance, and the increased sensitivity for detecting subtle asymmetries should be used to as a tool to guide further clinical assessment and is very valuable for monitoring horses over time. This may facilitate earlier detection of changes in baselines asymmetry as afforded by solely visual assessment, as shown in an experimental study by McCracken et al. (2012).

With the systems currently available, there is no barrier anymore to clinical everyday use: very little time is required to put the sensors on the horse, measurements can be performed under a variety of clinical conditions and there is no need to focus on a computer screen instead of looking at the patient, so there should be no fear of losing clinical details. As a great benefit, the clinician is provided with data often captured hundred times per second, has access to instant feedback on clinical observations and can track and measure the response to any interventions with increased sensitivity and objectivity. Yet using objective, quantitative tools is not a reason to stop looking at the whole horse and performing a comprehensive clinical evaluation. As with any tool, there definitely is a learning curve in interpreting data, and there is ongoing research to increase our understanding of how we perceive and how we should interpret these movement alterations. With appropriate training in the use of the technology and progressive insights gained by further research in this exciting field, the potential pitfalls or limitations should not discourage clinicians from exploring this application of modern technology. Clinicians should learn to use the technology to their advantage, striving for superior clinical judgement of our equine athletes, as summarized in the statement of Emeritus Professor Derek Knottenbelt: *"Technology won't replace vets… but vets who use technology logically and carefully will replace those who don't"* (Knottenbelt, 2017).

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Objective gait analysis under saddle

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Abstract
Quantitative gait analysis is gaining popularity in equine practice as an objective tool to aid veterinarians during lameness examination. Complementing the standard lameness exam with gait analysis increases the accuracy of detecting subtle lameness, reduces the bias effect in the interpretation of diagnostic analgesia and allows proper documentation of the entire examination. Several technologies have been developed in the last few years that can have practical application in daily practices, such as optical motion capture and inertial measurement units (IMUs). The latter has gained popularity in the last few years as a more practical and affordable application for daily use, allowing for an objective examination of the ridden horse.

Modern gait analysis systems designed to quantify lameness are used alongside the standard protocol for lameness examination and can be used in trot on a straight line and lunge to quantify lameness. In cases of single-limb lameness, asymmetries of the vertical displacement of the head, withers and pelvis can be used to localize and quantify lameness, and several asymmetry variables have been extensively investigated and validated to be used to quantify lameness [1]. Gait analysis can even be used to distinguish between primary and compensatory lameness [2].

Performing a lameness examination under the saddle can help veterinarians to diagnose specific cases where lameness might not be apparent when trotted in hand. It can also be used to exacerbate subtle lameness [3]. In many cases, complementing the ridden exam with gait analysis can aid in quantifying motion symmetries related to lameness.

The ridder has a significant influence on the motion symmetry of the horse. This effect is also depending on the trotting style (sitting or rising). In general, it has been demonstrated that the rider increases movement asymmetry of several biomechanical parameters at both the walk and also at the trot[4]. There is also a considerable influence of the ridding style that can affect several variables used for objective lameness assessment.

Sitting trot
Regarding the biomechanical variables commonly used in lameness assessment (MinDff and MaxDiff, Fig 1), sitting trot on a straight line does not significantly influence motion symmetry of sound horses[5,6]. In lame horses, it has been described that experienced riders can increase the magnitude of the measured hindlimb asymmetry [5].

Rising trot

Pelvis
In contrast to the sitting trot, the rising trot has a considerable influence on motion symmetry. The pelvis reaches a lower minimum position during the stance phase when the rider is sitting, affecting the MinDiff and mimicking an impact lameness [6]. This is related to increased loading of the hindlimb and the same ridder effect has also been demonstrated on measured ground reaction forces on the sitting diagonal [7]. There is also a change in MaxDiff where a lower maximum pelvic position is reached after push off when the rider is concurrently rising [6]. This occurs due to the downward momentum induced when the rider actively rises and counteracts the hindlimb push-off, mimicking a push-off lameness.

Head
Head movement is also affected in rising trot [6]. MaxDiff shows an increased maximum height after push-off from the forelimb during the stance the rider was sitting. MinDiff of the head is not affected in rising trot.

Circle effect

During circular motion, horses are naturally asymmetrical [8]due to a circle induced asymmetry, which is depended on the speed and circle diameter [9]. Most horses will show a head MinDIff on the inside limb of the circle. Most horses will show a MinDiff on the inside hind limb and a MaxDiff on the outside hind limb for the pelvic movement.

With the addition of the rider, rising trot and riding on a circle induce systematic changes in the movement symmetry of the horse [6]. When sitting on the correct diagonal (sitting during outside forelimb/inside hindlimb diagonal stance) counteracts the circle induced asymmetry. The opposite effect has also been observed when riders sit on the incorrect diagonal during circle. In this situation, all motion symmetry variables increase, amplifying the natural circle induced asymmetries.

Conclusion

The rider has a considerable influence on the biomechanics of the ridden horse.   When performing gait analysis of the ridden horse, it is a prerequisite to understand the expected effect of the rider, especially the impact of the trotting style and trotting direction, as this can either mask or augment lameness related motion asymmetry. Strict protocols for lameness assessment of the ridden horse need to be put in place to achieve standardization required to interpret gait analysis of the ridden horse correctly.

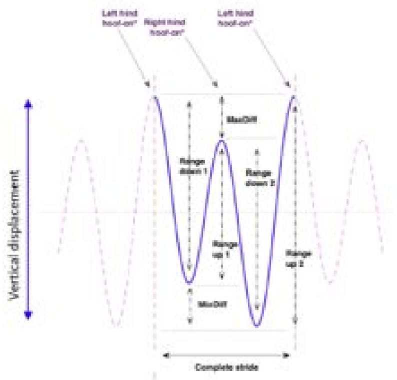

Figure 1: Graphical presentation of the vertical displacement of the pelvis during a complete stride at the trot. MinDiff: the difference in minimum position between two consecutive steps; MaxDiff: difference in maximum position between two consecutive steps.

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Shoeing for soft tissue conditions – how to affect the fetlock angulation and load on associated tendons and ligaments

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Introduction

Biomechanics principles of orthopedic shoeing to support the fetlock region
Therapeutic application of orthopedic horseshoes aims to change hoof orientation, and thereby the alignment of the phalanges and the digital joint angles to achieve less extension in the fetlock joint during stance phase. A change in toe angulation intends to relieve the suspensory apparatus of the fetlock joint. To reduce strain on the flexor tendons, the suspensory ligament or the sesamoid ligaments extension of the fetlock needs to be reduced. With this information in mind, the following biomechanics principle has been established by Denoix et al. as a basis for the use of orthopedic horseshoes (Figure 1) [1–3]: A steeper orientation of the hoof and the distal phalanx causes an increased flexion of the distal interphalangeal joint (DIPJ) (coffin joined) associated with a relief of the navicular region and less strain on the deep digital flexor tendon ***(DDFT)***. Simultaneously, a steeper palmar angle of the distal phalanx is stated to be connected with a lowering of the middle and proximal phalanx, causing a decreased dorsal fetlock joint angle, equivalent to increased extension in the fetlock joined. This means a higher load on the suspensory apparatus. According to this stated principle, relief of structures supporting the fetlock joint is achieved by lowering the hoof orientation causing a more upright orientation of the middle and proximal phalanx related to less extension in the fetlock joint. Superficial digital flexor tendon ***(SDFT)*** and suspensory ligament ***(SL)*** experience less strain. Based on this statement, use of wide toe shoes to treat SL and SDFT injuries has been promoted. Due to the wider toe of the shoe and the narrowed branches, sinking of the dorsal hoof region into penetrable ground should be reduces, while the palmar aspect penetrates soft surface easily, causing a flatter hoof orientation related to the intended relief of the announced structures.

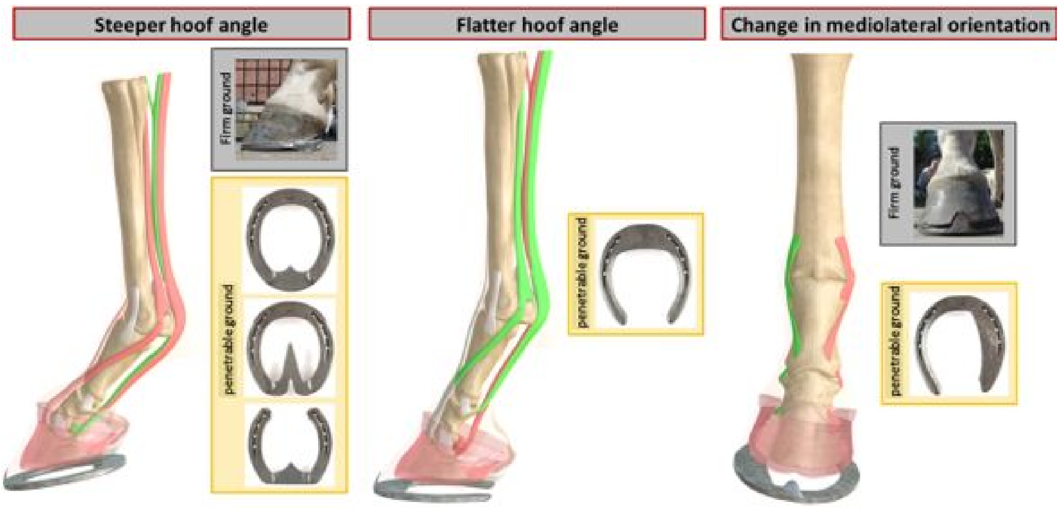

Figure 1: Interaction between a change in hoof angle and fetlock angulation associated with different load on associated tendons and ligaments

However, in daily practice this principle is not applicable for all horses affected by lesions at the SDFT, DDFT or SL. Practical observations showed that orthopaedic shoes recommended for specific injuries of tendons or ligaments do not function in all cases. Severe individual reactions related to orthopaedic shoeing to relief the DDFT, SDFT and SL disagree to the assumption of general solutions to treat specific orthopaedic disorders. Therefore, the author and her research group performed scientifically and clinically relevant studies to examine the effect of a change in hoof angulation on the orientation of the phalanges, the fetlock joint angle and the load on the flexor tendons. Next to fundamental research the influence of different orthopedic horseshoes on the stated factors was examined under practical conditions and on different types of ground in stance and walk. The aim was to gather practical relevant data to improve the management and treatment of orthopedic patients and to optimize the communication between veterinarians, farriers and owners.

The authors research aimed to examine what initial change in hoof angulation is necessary to have a significant effect on the fetlock joint angulation and the strain on the DDFT and SDFT in a larger population of live horses with different toe conformation under physiological conditions. Since examinations of the SL is difficult to perform with the chosen set up and study design, research related to the relief of the SL is still open. Nevertheless, clear findings with regard to the flexor tendons can be presented. In addition, the current research aimed to study the effect of modified horseshoes on the toe angulation at different grounds in stance and walk to draw conclusions on the strain of associated tendons and ligaments.

Current scientific studies and main findings

Fundamental research [4–6]
30 sound warmblood horses were used to examine the effect of a change in hoof angulation on the phalangeal alignment, the dorsal fetlock joint angle and the cross-sectional area (CSA) of the flexor tendons. Based on the statements of Rooney (1983) and Thompson et al. (1993) that the individual dorsal hoof wall angle and the ratio between toe and heel length interfere with the impact of heel or toe elevation on the digital joint angulation and strain affecting the flexor tendons, horses with different dorsal wall angles were included in this study (min: 44°, max. 68°). [7,8] The palmar angle of the distal phalanx varied between -1.66° and 15°. The dorsal wall angles of both front hooves were assessed with a Dallmer gauge. The forefeet of all horses were radiographed barefoot and consecutively equipped with 5°, 10°, and 20° plastic heel wedges and 5°, 10°, and 20° toe wedges. Two orthogonal radiographs of the toe were obtained by centering the radiation beam over the distal interphalangeal joint and fetlock joint. The dorsal wall angle, length and angle of the middle and proximal phalanx, palmar angle of the distal phalanx and fetlock joint angle were measured by using the software MetronPXHoof. Ultrasound examination was carried out using a portable ultrasound unit and a variable frequency linear transducer with a stand-off pad. Transverse images of both digital flexor tendons were assessed 8cm, 12cm and16 cm distal of the accessory carpal bone to calculate the cross-sectional area (CSA) at each zone using ImageJ.

Ultrasound examinations were performed according to the radiographic examination with 5°, 10° and 20° toe and heel wedges. Ultrasonographic examination of the flexor tendons to calculate the CSA of the tendons has been chosen because its non-invasive character. The method has been previously validated as very accurate and precise so that subtle changes of the CSA can be measured with this technique. The use of this method is based on the following physical principle: Hook’s law states that a change in length of an elastic structure is proportional to the applied forces. In addition, the applied force is anti-proportional to a change in the cross-sectional area (CSA) of this elastic structure. this means that the higher the acting force the longer an elastic structure becomes and the lower its CSA. Decrease of the CSA is equivalent to higher forces acting on the tendon and increase of the CSA is related to relief of the flexor tendons.

Results and Discussion
The current research showed that heel elevation induced a linear increase in extension of the fetlock joint and an increase of cross-sectional area of both flexor tendons, whereas a decreased hoof angle, induced by applying toe wedges, caused a decreased extension of the fetlock joint and a decrease of the cross-sectional area of both flexor tendons. In contrast to Crevier-Denoix et al. 2004, ***the superficial and deep flexor tendon reacted similar to heel and toe elevation. A steeper hoof orientation caused a relief of both flexor tendons*** (Figure 2)***.***

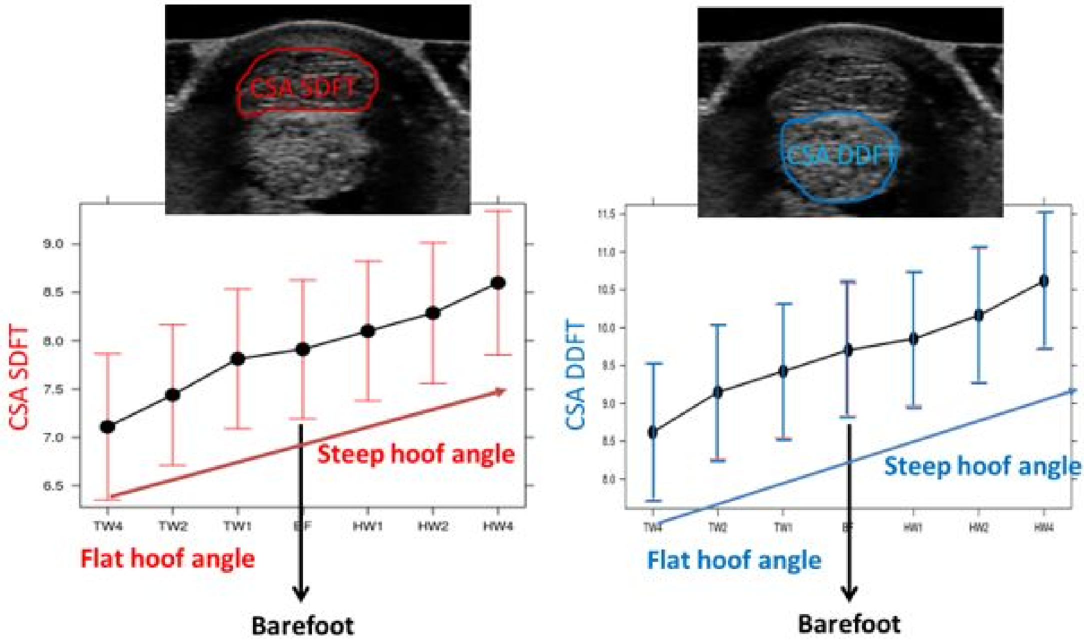

Figure 2: Size of the cross-sectional area of the **SDFT** and **DDFT** with 20°, 10° and 5° toe wedge , barefoot, 20°, 10° and 5° heel wedge

Still, a change in hoof angulation less than 10° does not have a relevant effect on the examined parameters. ***Significant changes of the fetlock joint angle and the cross-sectional area of both flexor tendons were initially demonstrated for a change of hoof angulation by using 10° and 20° heel wedges and 20° toe wedges.*** It is doubtful, if such severe changes of hoof orientation are of practical relevance and might cause strong side effects.

However, ***one third of the examined horses showed the intended reaction (less extension in the fetlock joint and less strain on both flexor tendons) with only a change of hoof angulation of 5°*** (Table 1).

Table 1: Reaction of the examined horses in percentage on application of a 20°, 10° and 5° Toe wedge

	20° lower hoof angle	**10° lower hoof angle**	**5° lower hoof angle**
Intended reaction (less extension in the fetlock joint)	**87%**	**61%**	**32%**
No reaction	**3%**	**17%**	**35%**
Opposite reaction	**10%**	**22%**	**33%**

This raises the question which factors might interfere with the effect of a change in hoof angulation on the dorsal fetlock joint angle and the CSA of the flexor tendons.

The influence of a change in hoof angulation on the fetlock joint angle and the cross-sectional area of both flexor tendons were significantly affected by angulation and length of the middle and proximal phalanx, the dorsal wall angle of the hoof and the palmar angle of the distal phalanx. In horses with long and low angled pastern a lowering of hoof angle does not reduce extension in the fetlock joint. The leverage of the long pastern seems to be too high to achieve elevation of the pastern by change in hoof orientation. Therefore, the individual toe conformation should be carefully judged before applying therapeutic horseshoes. In horses with long and low pastern a change in hoof angulation to support the flexor tendons and the suspensory ligament seems to be not the optimal solution. Increasing palmar support might be a better concept in such cases.

Clinical Research [9–11]
Since it has been examined that a change in hoof angulation of at least 10° is required to have a significant effect on the proximal toe orientation and fetlock joint, it is questionable about which degree application of different horseshoes can achieve this reorientation of the toe.

The influence of different horseshoes on the phalangeal alignment was examined on 25 warmblood horses. The horses were shod with a standard horseshoe and with different modified horseshoes.

Data were collected separately for the barefoot hoof, standard horseshoe and modified horseshoe at the left forelimb of each horse. The radiological examination was carried out with a portable x-ray unit and a digital detector system. 0° and 90° radiographs of the left toe were taken for each condition. The horses were positioned bearing equal weight in their most natural position with both forelimbs parallel at the same height. In order to perform quantitative radiological measurements, the hoof was marked permanently after trimming to allow the repeated centering of the x-ray beam on the same spot of the weight bearing margin. A standardized set-up was used for image acquisition. For subsequent analysis of the radiographs, the examined foot was placed on a podoblock with embedded reference points, allowing calibration of the x-ray images. ***Additionally, the podoblock was equipped with a wooden block changeable with a soft pad to simulate different ground properties (firm and penetrable ground).*** The radiographs were analyzed with the software Metron DVM®.

Results and Discussion
Primary focus is led on the effect of different horseshoes, such as bar shoes, or wide toe shoes, on ***the sagittal orientation of the hoof and the distal phalanx*** in relation to the ground.

Horseshoes are directly attached to the hooves and thereby, immediately affect the orientation of the hoof. However, the impact of shoeing on the sagittal orientation of the hoof and the palmar angle is related to the ground conditions on which the horse is kept during the period of rehabilitation. Orthopedic shoeing is mainly performed and judged on a firm, plane ground surface. However, the maximum effects of all horseshoes modified in their weight bearing surface (bar shoes, wide toe shoe, wide branch shoe…) are revealed on penetrable ground, which enables sinking in of specific parts of the hoof.

Before suggesting or applying a specific orthopedic horseshoe, environmental properties with regard to ground conditions have to be discussed with the owner of the horse.

In general, ***bar shoes cause a steeper alignment of the hoof and an increased palmar angle on penetrable ground***. This is caused by the palmar support reduces the sinking-in of the posterior hoof region while the tip of the hoof penetrates the ground easily.

However, the palmar angle changed not more than 1–2° (max. 5°), which might be insufficient to achieve a calculable and reproducible effect on the angulation of the fetlock joint in each case. On firm ground no effect on the stated parameters occurs. In comparison, the application of heel wedges causes a steeper orientation of the hoof independent of the ground properties, about almost the same degree on firm and penetrable ground. **A wide toe shoe causes the opposite effect** – the palmar angle of the distal phalanx becomes planer, since the toe support reduces the sinking-in of the tip of the hoof, while the narrowed branches penetrate the ground easily. The palmar angle of the distal phalanx decreases about 1°. The application of a wide branch shoe affects the mediolateral orientation of the hoof and the distal phalanx on penetrable ground. Due to the unilateral support, the aided side does not penetrate the ground, while the narrowed side sinks in easily.

Initially, the study showed that the change of the palmar angle of the distal phalanx by orthopedic shoeing can be calculable influenced. It is possible to directly relieve diseased structures such as the navicular region, the digital deep flexor tendon or the distal interphalangeal joint.

In the second step, the correlation between a changed palmar angle of the distal phalanx and the alignment of the middle and proximal phalanx as well as the dorsal fetlock joint angle is shown. Heterogeneous data for the alignment of the proximal phalanges and the dorsal fetlock joint angle caused by an altered hoof position occurred. ***No consistent or significant effects of the use of modified horseshoes on the orientation of the middle and proximal phalanx could be demonstrated. Moderate changes of the hoof angulation caused by orthopedic horseshoes are not generally affecting the fetlock joint angle in the intended way. In particular, the approach to decrease the hyperextension of the fetlock joint to relieve the suspensory apparatus is hard to achieve***. ***Findings showed severe individual differences between horses.***

It could be hypothesized that in motion strain affecting the distal limb increase, enhancing the effect of modified horseshoes on the fetlock joint angle. High-speed fluoroscopic kinematography was used to capture 2–6-s clips (500 fps) (70kV, 100 mAs) of the distal limb during stance in walk. For this study, 4 clinically sound ponies (1.00 – 1.20m) were available. All ponies underwent a computer tomography measurement to gather data for the subsequent creation of 3D models of each bone of the distal limb for subsequent calculation of 3D digital joint angle changes in motion. The ponies were held and led directly at the holster to ensure regular and standardized movement and calculable strides on the platform. Examinations on firm (wood) and penetrable ground (wood shavings) were carried out. However, examinations n motion showed no significant differences in digital joint angles between use of standard shoeing and orthopedic horseshoe in walk on different grounds. ***Results obtained in motion are similar to those described for static conditions.***

It might be that in trot or gallop the effect of modified horseshoes on the digital joint angulation might increase, but it has to be considered that rehabilitation from acute orthopedic injuries is usually related to box rest or controlled motion of the patient in walk, so that ***therapeutic shoeing should show the intended effect in stance and walk already.***

The author believes that additional factors may influence the impact of orthopedic shoeing on the alignment of phalanges and the fetlock joint angle. ***Individual body and limb conformation, length of the proximal phalanx, tendon stiffness, ground properties and shoe manufacturing interfere with the effect of orthopedic shoeing on the digital joint angles and strain affecting associated tendons and ligaments.***

Chosing the optimal shoeing for each horse, the performance of some pre-tests can be helpful to estimate the effect of a changed hoof position by the application of a modified horseshoe. Temporary attachment of wedges with tape at the hoof in stance and walk can give an idea on how the fetlock joint might react to a change in hoof orientation and on the tolerance of each individual horse. The tolerance of an altered orientation of the bones of the distal limb can be checked in advance by using the Extension Device ® (H. Castelijns) or a board for flexing or extending the limb.

With regard to shoeing to support the fetlock joint alternative approaches than a change in hoof angulation should be taken in account. A functionally very important parameter is the toe-support-ratio, which describes the length of the dorsal leverage affecting the distal interphalangeal joint and the size of the supporting area in the palmar aspect. By adding a bar which exceeds the heels, the palmar support is increased, so that during mid stance phase the palmar extension might aid the suspensory apparatus of the fetlock joint. ***Combining moderate heel elevation with increased palmar support might more calculable relieve diseased SDFT, DDFT and SL in the acute phase. During progress of rehabilitation length of palmar support and degree of heel elevation can be adapted and reduced to come back to a standard shoeing as soon as possible.***

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Mechanics of the equine spine: surgical implications

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The investigation of the biomechanics of the equine spine is hampered by the size of the animal as well as the relative stiffness of the area of the thoracolumbar spine in particular. Previous work utilized manual force, heavy weights, straps attached to vertebral segments or mechanical testing devices to assess the range of motion (ROM) of the equine thoracolumbar spine *in vitro* (Jeffcott and Dalin 1980; Townsend et al. 1983; Denoix 1999, Schlacher et al. 2004).

To test the hypothesis that back surgery may impact on the biomechanics of the equine spine the authors developed a device that facilitates an even distribution of the moment of force along the vertebral column and permits computed tomographic evaluation of equine thoracolumbar spine segments (T8 – L3) in motion.

Maximal dorsoventral flexion and extension, bilateral bending as well as rotational movement was assessed with a force of 60 Nm applied to spinal specimens (n = 6) during each motion cycle. Results confirmed previous observations where the lateral bending and rotational ROM of the equine spine in horses without evidence of back pathology is largest in the cranial thoracic spine (T10 - T12). Additionally, dorsoventral flexion and extension is larger in the cranial thoracic spine and reduces significantly towards the caudal thoracic and lumbar segments.

The biomechanics of the equine spine largely depends on the interplay of the epaxial musculature and associated fascial layers and ligaments that show a crossing fibre arrangement and provide core stability during locomotion (Stubbs et al. 2006; Ehrle et al. 2017). Whilst it has been shown that muscular pain results in altered back kinematics, little is known about the influence of osseous pathology on the ROM of the thoracolumbar spine in horses (Wennerstrand et al. 2004/2009). The evaluation of specimens with severe spinal pathology including spondylosis and fusion of dorsal spinous processes identified a reduction in the dorsoventral range of motion in the current study.

An investigation was performed into the influence of back surgery on the biomechanics of the equine thoracolumbar spine *in vitro* including cranial wedge ostectomy on two dorsal spinous processes (T15/16) and 5 dorsal spinous processes (T15 - L1) (Jacklin et al. 2014). Similarly, the desmotomy of the *interspinous ligament* as described by Coomer et al. (2012) was performed in the interspinous spaces between T15 - T17 and subsequently between T14 - L1 was also investigated. The dorsoventral flexion and extension as well as lateral bending and rotational movement were assessed pre- and post-operatively. Little change was identified in the lateral and rotatory ROM. Dorsiflexion of the thoracolumbar spine increased post-operatively, particularly in the area (T15 - L1) where surgery was performed. Post-operative dissection of specimens confirmed soft tissue transection of varying degree in the area of the *Mm. multifidus* and *longissimus* following desmotomy of the interspinous ligament.

In other species it has been demonstrated that the desmotomy of the *supraspinous* and *interspinous ligaments* results in altered biomechanics of the back with resulting increase in pressure within the intervertebral discs (Merter et al. 2019). The long-term consequence of spinal surgery and its influence on the kinematics of the equine thoracolumbar spine *in vivo* as well as on adjacent soft tissue structures warrants further investigation.

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Effect of Topical Oxygen Therapy on guttural pouch mycotic lesions: an experimental and clinical study in horses

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Introduction
Given positive experience of oxygen therapy in the resolution of human's fungal disease, its beneficial effect in numerous wound healing situations, a two-phase study was performed to validate if Topical Oxygen Therapy (TOT) is safe and feasible in horses with induced guttural pouch mycosis (GPM) (phase-1) and to report its efect in a phase-2 clinical study with naturally occuring disease.

Material and Methods
For oxygen delivery, the outside part of a spiraled catheter placed into the GP was secured to the halter and connected via his Luer lock extremity to an extender adapted to a bottle of medicinal oxygen at 200 bars. Eight horses in phase-1 had both GP inoculated with *Aspergillus fumigatus* and one was randomly assigned to receive one TOT session a day for 30 minutes, for 1 to 4 days at 9 L/min. Four individuals were included in phase-2 and TOT was performed, alone or in combination with transarterial coil embolisation (TACE). TOT sessions of 45 to 60 min, at 15L/min, 2 to 4 times a day, for 6 to 27 days were performed.

Results
In all horses TOT was easy to perform standing with no adverse effect and full recovery of GPM lesions was recorded. Clinical cases were treated with TOT alone (n=1) or with a TACE (n=3). Reduced neurological disorders (3 laryngeal hemiparesis, 2 dysphagia) was recorded.

Discussion/Conclusion
TOT was feasible and safe with a trend to reduce mycotic lesions. This treatment may be considered alone or as an adjunctive therapy to treat GPM.

Efficient Immunotherapy of Equine Sarcoids Using Live-Attenuated Recombinant Influenza Viruses Co-Expressing Shuffled Bovine Papillomavirus Type 1 Oncogenes

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Introduction
Bovine papillomaviruses types 1 and 2 (BPV1, BPV2) induce semi-malignant skin tumours termed sarcoids, which affect between 2 and 12% of horses worldwide and may be highly refractory to treatment.

Material and Methods
We have developed recombinant NS1-deleted influenza (Flu) A and B viruses that are live attenuated and co-express shuffled BPV1 E6 and E7 antigens as immunotherapeutic vaccines. Following a phase I- trial demonstrating the safety of the vaccines, 26 horses consecutively presenting at our clinic with multiple, partly recurrent sarcoids were intratumorally injected with recombinant influenza A virus (iNS1-FluA-BPV1-E6E7), and then boosted at least two times with the influenza B equivalent (iNS1-FluB-BPV1-E6E7). At least one sarcoid per horse was left untreated.

Results
Per December 2020, treatment led to significant tumour regression (11/26) or complete eradication (7/26) in 18/26 patients so far. In the most recent cases, monitoring is still ongoing. Eight patients bearing multiple recurrent verrucous sarcoids only poorly responded to therapy. Intriguingly, the vaccines also induced a systemic anti-tumour response as revealed by synchronous regression of injected and non-injected lesions located at different sites of the patients' integument.

Discussion and conclusions
To our knowledge, this is the first immunotherapeutic approach that proves effective in reducing the tumour burden in sarcoid patients irrespective of disease severity. Eight sarcoid patients with recurrent verrucous sarcoids failed to respond to therapy, suggesting that this clinical sarcoid type in conjunction with a history of previous, unsuccessful treatment attempts may negatively affect the responsiveness to the vaccine.

Session: **Large Animal General**
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Computer-Assisted Dental and Sinus Surgery in Horses

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Introduction
Surgical orientation on the equine head can be challenging due to the complex anatomy and the inherent limitations of conventional intraoperative imaging. Specific reports of clinical applications of computer-assisted surgery (CAS) in horses involving the head are lacking.

Materials and Methods
This retrospective study reports on clinical cases operated with the aid of CAS at the Vetsuisse-Faculty of Bern between 2015 and 2020. Navigated instruments were used to assist different dental and sinus surgeries in standing and anesthetized horses.

Results
Computer-assisted dental and sinus surgery was performed in 15 horses: In four, navigated minimally invasive transbuccal screw extraction (MITSE) or trephination and repulsion (MITR) were applied for exodontia. In one, a navigated alveolar ostectomy was performed through a lateral buccotomy approach prior to extraction of a malformed molar. In five, an ectopic tooth, residual dental fragments, or sequestrated alveolar bone were removed by means of CAS. In five horses, effective drainage into the nasal passages was established with CAS and via a direct percutaneous approach to the dorsal and/or ventral conchal bulla. In one horse, CAS facilitated intraoperative orientation in an anatomically distorted paranasal sinus.

Discussion
The use of CAS allows for the execution of precise surgical procedures like direct surgical access to the conchal bullae, or controlled MITSE/MITR techniques. The real-time 3D imaging provides excellent orientation and depth control for surgical procedures involving the horse’s head. Once familiar with CAS principles, the technique is readily applied and adapted for various applications.

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Laparoscopic configuration of the nephrosplenic space in horses and its influence on left dorsal large colon displacement

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Introduction
Left dorsal displacement of the large colon (LDDLC) or nephrosplenic entrapment is a common colic type in horses. The goal was to examine in a retrospective single-blinded case-control study whether the shape of the nephrosplenic space (NSS) amongst other possible risk factors has an influence on the development of LDDLC.

Methods
Laparoscopic images and/or videos of the NSS from 85 horses were evaluated: 29 cases treated with NSS closure due to (recurrent) LDDLC and 56 controls without history of LDDLC, undergoing left flank laparoscopy for other reasons. The shape and size of the NSS was evaluated blindly by three different evaluators using three self-developed techniques: NSS shape categorisation, angle measurement and depth estimation. Statistical analysis was performed on data from patient files and owner telephone interview.

Results
Mean age of the horses was 10.45 ± 5.82 years and 40/85 horses (47%) were warmbloods. The multivariable analysis revealed that cases had a larger nephrosplenic space angle ($p = 0.048$), significantly more cribbing behaviour ($p = 0.012$) and a higher training intensity ($p = 0.025$) compared to controls. In addition, taller horses had a significantly larger nephrosplenic space angle ($p = 0.005$).

Conclusion
This study demonstrates 3 new contributing factors to the development of LDDC, including the nephrosplenic space configuration and cribbing behaviour. Further analysis would benefit from a more random sample size as well as a distinction between recurrent and single colic episodes and response to medical or surgical treatment.

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Equine prosthetic laryngoplasty technique and case management: A survey of veterinary surgeons

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Introduction
Many different techniques have been reported for equine prosthetic laryngoplasty surgery, yet the popularity of these variations and other aspects of case management in practice is unknown. This study aimed to survey equine veterinary surgeons on surgical technique, antimicrobial therapy and simultaneous upper respiratory tract procedures for prosthetic laryngoplasty surgery in clinical practice.

Materials and Methods
An online questionnaire was distributed by email to equine surgeons performing laryngoplasty surgery (including ACVS and ECVS Diplomates). The questionnaire had four sections: respondent profile, surgical technique, antimicrobial therapy and simultaneous procedures. Descriptive statistical analysis was performed.

Results
There were 128 complete responses with 65.6% of respondents holding ACVS and 41.4% ECVS Diplomate status. Most laryngoplasty surgery is still being performed under general anaesthesia (57.0% of respondents) using 2 prostheses (82.8%) and using a single loop in both the cricoid (74.2%) and arytenoid (97.7%) cartilages. In most cases surgeons aimed to achieve Grade 2 intra-operative arytenoid abduction. Most surgeons used systemic antimicrobial therapy for 1-3 days post-operatively (44.5%) with 37.5% using local antimicrobial therapy. The structures most commonly operated on in combination with laryngoplasty were the left ventricle (92.2%) and the left vocal fold (85.2%).

Discussion/Conclusions
This study documents notable variations in laryngoplasty technique and provides perspective on their use in a clinical context. Many of the methods established relatively early in the development of the procedure remain popular.

Endoscopic Progression of Recurrent Laryngeal Neuropathy in an Uniform Population of Warmblood Horses

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Objective
To report the prevalence of progression of recurrent laryngeal neuropathy (RLN) in warmblood horses.

Study design
Retrospective study.

Samples
Uniform warmblood population (n= 70).

Methods
Between November 2016 and November 2019, 70 warmblood horses with an audible “metallic” inspiratory noise were scoped at rest. Age and sex were recorded. Endoscopic examination was performed without sedation and swallowing was induced. Horses were graded by one blinded veterinary surgeon according to the Robinson grading scale with subgrading: I – synchronous arytenoid movement; II – asynchronous arytenoid movement but full abduction can be achieved and maintained; III – asynchronous arytenoid movement without full abduction; IV – complete immobility of arytenoid cartilage. Every horse was scoped and blindedly graded again after one year. Progression of the RLN grade was recorded.

Results
Horses were aged between 2 and 4 years. Sixtysix were male and 4 were fe-male. Nineteen horses (27%) demonstrated no progression of RLN grade within one year. Thirty-seven horses (53%) deteriorated one Robinson grade within one year. Four-teen horses (20%) deteriorated two or more grades within one year.

Limitations
Only one surgeon performed the gradings.

Conclusion
In this uniform warmblood population, RLN progression rate was higher than reported previously.

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Surgical Management of Comminuted Fractures of the Proximal Phalanx using a Biological Bridge Plating Technique with an LCP Femoral Plate

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Introduction

Currently the recommended treatment for P1 comminuted fractures is the transfixation cast. The prognosis for survival is guarded and heavy complications are common. Biological bridge plating has been developed in human and small animal fracture repair: the complex fracture zone is virtually left untouched and is bridged by the plate. The objective was to demonstrate the usefulness of a human distal femoral locking compression plate (LCP DFP) for combined metacarpophalangeal and proximal interphalangeal arthrodesis to treat P1 comminuted fractures in horses.

Materials/Methods

Surgical procedure was assessed ex vivo on 6 cadaver legs. Then the whole procedure, combined with a minimally invasive cartilage removal technique was applied on 9 horses (February 2018- September 2020). After contouring, a 9 to 11-hole LCP DFP (DePuy Synthes-DPS), was tunneled under the digital extensor tendon and fixed by strategically positioning a combination of locking head screws and cortex screws via stab incisions.

Results

Of 9 horses that had a combined arthrodesis, 5 healed and were sound for breeding purposes or pasture activity 5 to 8 months post-operatively, 4 horses were euthanatized (one for colic during the short post-operative period, two others for surgical wound infection, one for implant failure and contralateral laminitis). Two horses presented mild and long-term postoperative complications (one had cutaneous infection and mild contralateral laminitis; another had broken screws and stayed casted for a longer period).

Conclusion

Biological bridge plating using the human LCP DFP constitutes a useful alternative to the transfixation cast for surgical management of highly comminuted P1 fractures.

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Maintenance of Arytenoid Cartilage Abduction With the Use of Metallic Suture Buttons on the Cricoid After Laryngoplasty in 78 Horses

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Objective
To report complications, in particular, the loss of abduction after application of metallic suture buttons on the cricoid in clinical cases of laryngoplasty.

Study design
In-vivo retrospective clinical case series.

Samples
Client-owned horses (n= 78)

Methods
From February 2014 to February 2018, 390 horses who underwent a laryngoplasty performed as recently described in the standing horse, were reviewed. Inclusion criteria for the horses in the study were: 1.) left-sided recurrent laryngeal neuropathy, 2.) the cricoid-suture construct was performed with a metallic button on the ventral aspect of the cricoid excluding its caudal border and, 3.) two prosthesis were placed in each horse, 4.) follow-up endoscopy images of the larynx were available 24 hours and 6-8 weeks after surgery, 5.) owners or trainers were contacted for a telephone questionnaire (wound healing complications, intermittent coughing, dysphagia, noise, exercise intolerance and overall satisfaction). In the included cases, the left arytenoid angle was calculated and compared between these two time points (24 hours/6-8 weeks) in a blinded fashion. Intra-operative, short and long-term post-operative complications were reviewed.

Results
78 horses met the inclusion criteria. Mean loss of abduction of the left arytenoid angle was 3,1° (+/- 0,97°) corresponding to ½ Dixon abduction grade. Complications were: complicated seroma (n=5), infection of the prosthesis (n=1), intermittent coughing (n=8), dysphagia (n=6) and remaining noise (n=5).

Conclusion
Application of a metallic button on the cricoid during equine laryngoplasty is clinically effective and provides post-operative stability of the left arytenoid.

Effect of Bio-Electro-Magnetic-Energy-Regulation (BEMER)-horse therapy on Cardiopulmonary Function and Recovery Quality after isofluran anesthesia in 100 horses subjected to pars-plana vitrectomy

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Objective
To evaluate equine cardiopulmonary function and recovery quality after Bio-Electro-Magnetic-Energy-Regulation (BEMER)-horse therapy during general anesthesia for pars-plana vitrectomy surgery

Study design
Placebo-controlled, double-blinded, randomized study

Samples
Horses suffering from equine recurrent uveitis (n= 100).

Methods
During general anesthesia for vitrectomy surgery, horses were subjected to a BEMER-blanket application for 15 min. Two batches of visually identical blankets were used, one with a functional BEMER module (B+ group) and the other with a placebo module (P- group). The two groups were blinded and the horses randomly assigned to one or other group. Arterial pressure, blood gas, blood lactate, and CK values were measured and compared between the groups. Recovery quality was scored with 10 being the best and 72 the worst and these values were compared between the groups.

Results
The P- group had a significantly lower recovery score (16.1 +/- 7.15) than the B+ group (22.4 +/- 13.0). Arterial blood pressure and blood lactate were lower in the B+ group but without statistical significance. CK values were similar in both groups.

Limitations
Only one blinded veterinary surgeon graded the recoveries

Conclusion
BEMER-Therapy has an effect on general anesthesia and the recovery quality of horses during vitrectomy surgery

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Hybrid natural orifice transluminal endoscopy surgery (NOTES) to perform bilateral ovariectomy in mares

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Introduction
Hybrid NOTES combines NOTES (Natural Orifice Transluminal Endoscopic Surgery) and traditional laparoscopic techniques, and it is considered an evolution of the minimal invasive abdominal surgery in humans. The objective of the study was to use a hybrid NOTES technique to minimize number and enlargement of paralumbar laparoscopic portals for bilateral ovariectomy in standing, sedated mares.

Materials and Methods
Six mares with normal ovaries were restrained in stocks were sedated and caudal epidural anesthesia performed. A 7.5 MHz ultrasound probe was used transvaginally to select placement of vaginotomy. Each ovary was grasped and exteriorized through the vaginotomy using a 70 cm long esophageal forceps, while visualized and transected via ipsilateral paralumbar fossa laparoscopic portals. Surgical time, intra-, and postoperative complications were recorded. Vaginoscopy was performed at days 0, 3, 7, and 14 postoperatively. After 14 days, mares were euthanized and necropsied.

Results
Hybrid NOTES was successful in all mares, with a mean surgical time of 71 minutes. In two mares, one ovary was dislodged from the forceps during vaginotomy extraction. Abdominal retrieval of the ovary was successful with reapplication of forceps or a surgeon’s hand via vaginotomy. At necropsy, 5 mares had no adhesions within the abdominal cavity or at the vaginotomy site. One mare in which hand retrieval of the ovary was necessary developed an adhesion between the bladder and the vaginotomy.

Discussion/Conclusions
This technique offers a safe alternative for bilateral ovariectomy with minimal postoperative complications. Avoiding the enlargement of paralumbar laparoscopic portals could decrease complications associated with exteriorization of ovaries through the flank.

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Peri-operative antimicrobial treatment and antimicrobial susceptibility in horses with surgical site infections in the United Kingdom

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Introduction
Surgical site infections (SSIs) are an important cause of morbidity and the bacterial isolates responsible are often multidrug resistant (MDR).

Materials and Methods
Results from diagnostic submissions from SSIs collected prospectively from five equine hospitals in the UK from November 2016 -March 2019 and associated horse data were included.

Results
72 submissions (142 bacterial isolates) were collected following exploratory laparotomy (86.1%) and others (13.9%). Penicillin/gentamicin were the most common peri-operative antimicrobials (used in 95.8% and 80.0% of horses, respectively). The dose rate of penicillin and gentamicin ranged from 12.0-20 and 5.5-9.4 mg/kg respectively. Median administration of antimicrobials was 15 min prior to induction (IQR 5-38 min) and median duration of antimicrobial treatment was 5 days (IQR 3-6 days). The median day SSI was first detected was 7 days (IQR 5-10.5). Polymicrobial cultures accounted for 69.4% of submissions. The most common bacterial isolates included *Staphylococcus* spp. (27.5%), *E. coli* (23.9%) and *Enterococcus* spp. (12.7%). The majority of isolates were MDR (57.0%), including 17 (12.0%) extended-spectrum β-lactamase-producers (ESBLs) and 7 (5.0%) methicillin resistant *S. aureus* (MRSA). Only 18.1% of bacterial isolates were susceptible to penicillin (penicillin had been administered peri-operatively in 96.0%) while 24.6% of bacterial isolates were susceptible to gentamicin (gentamicin had been administered peri-operatively in 45.2%). Susceptibility to trimethoprim-sulfamethoxazole and doxycycline in bacterial isolates was 38.9% and 39.3% respectively.

Discussion/Conclusions
SSIs can develop despite adequate peri-operative antimicrobial administration. Majority of bacterial isolates were resistant to antimicrobials which had been administered peri-operatively. Surgical aseptic technique is important to minimise SSIs.

Evaluation of the Airway Mechanics of Modified Toggle Laryngoplasty Constructs using a Vacuum Chamber Airflow Model

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Introduction

Progressive loss of arytenoid abduction after the laryngoplasty (LP) is a frequent postoperative complication. A LP technique that uses a suture button to secure the suture material to the base of the muscular process of the arytenoid cartilage eliminated suture pull-through from the muscular process in cadaveric equine larynges subjected to in-vitro cyclic loading. Prior to clinical use of the modified toggle LP technique it is necessary to evaluate its performance under airflow and inspiratory pressures comparable to those recorded in horses during maximal exertion.

Materials and Methods

Bilateral LP constructs were performed using a modified toggle or a standard LP technique. Constructs were tested in an airflow model before and after in-vitro cyclic loading which was designed to mimic postoperative swallowing. The cross-sectional area (CSA), peak translaryngeal airflow (L/s), and translaryngeal impedance (cmH20/L/s) were compared between LP constructs before and after cyclic loading.

Results

The mean CSA of the rima glottidis slightly decreased in all LP constructs following cyclic loading. However, the translaryngeal impedance remained constant before and after cyclic loading of the modified LP (median =0.22 cmH20/L/s) and standard LP (median =0.21 cmH20/L/s) constructs.

Discussion/Conclusions

The modified toggle and standard LP constructs results in similar airway mechanics, which suggests both LP techniques are equally effective to restore normal airway function in horses affected by recurrent laryngeal neuropathy.

Lamellar neutrophil myeloperoxydase infiltration in hyperinsulinemic-induced laminitis

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Introduction
Laminitis is a pathology of the equine digit resulting in failure of the dermo-epidermal interface. Inflammation is a central player in its pathophysiology. Neutrophil activation and the presence of myeloperoxidase have been observed in the black walnut heartwood extract model. However less is known about their role in the hyperinsulinemia model.

Materials and methods
Archived samples from a previous experiment approved by the ethics committee were used. This experiment included five horses randomly assigned to a control group (n = 2) and a prolonged euglycemic hyperinsulinemic clamp (pEHC) group (n = 3). Histological sections of lamellar tissue from all horses were immunohistochemically stained for myeloperoxidase as well as counterstained with hematoxylin-eosin. The sections were examined for histopathological evidence of laminitis and myeloperoxidase.

Results
Histopathological changes that characterize insulin-induced laminitis and increased presence of myeloperoxidase, especially in the dermal lamellae, were observed in histologic sections of pEHC-treated horses compared to control horses.

Conclusion
Neutrophil activation with myeloperoxidase release may play a role in the pathophysiology of endocrinopathic laminitis. Their exact implications warrant further investigation.

Probability of and factors influencing horse owner's decision to consent to exploratory laparotomy

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Introduction
Horses owners are asked to give consent for exploratory laparotomies (EL) in time pressured situations, where the alternative is frequently euthanasia. The objectives of this study were to 1) determine the proportion of Australian and New Zealand horse owners who would consent to EL and 2) identify motivators and barriers for consent.

Methods
Ethics approval was obtained (2020/445). A questionnaire, consisting of 20 questions, was developed and distributed online.

Descriptive statistics were calculated by tabulating the respondents by their answer to whether they would consent to EL. Univariate analysis were used to determine which factors were associated with consenting to EL.

Results
2200 horse owners participated with a 68.3% survey completion rate. The majority of participants were female (95.6%, n=1443/1510).

18.7% (n = 400/2138) of respondents indicated they would consent to EL, 55.2% (n = 1181/2138) indicated it depended on which horse required surgery and 26.1% (n = 557/2138) indicated they would not consent to EL.

Financial comfort of respondents was not associated with consenting to EL ($P = 0.309$). Respondents anticipating higher veterinary costs ($P < 0.001$, OR 2.2, 95% CI: 1.9 – 2.6), lower likelihood of survival ($P < 0.001$, OR 0.5, 95% CI: 0.5 – 0.6) and poorer athletic outcomes ($P < 0.001$, OR 1.4, 95% CI: 1.3 – 1.6) were less likely to consent to EL.

Discussion/Conclusion
Perceived outcomes of EL significantly influenced the likelihood of horse owners consenting to surgery. Ensuring clients are correctly educated about EL may influence their decision to consent.

Laparoscopic partial suturing of the vaginal ring in 10 mature stallions

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Introduction
Acquired inguinal herniation in stallions is a devastating disease that may lead to small intestinal necrosis. Laparoscopic techniques are routinely elected to prevent reherniation once the stallions have survived initial treatments. These techniques may also be performed if vaginal rings are thought to be too large and/or flaccid. We hypothesized that partial suturing of the cranial part of the vaginal rings would be an effective method to prevent inguinal herniation and would not lead to short- and long-term complications.

Material and methods
All animals were mature warmblood stallions initially presented due to inguinal herniation (6/10), or enlarged/ flaccid vaginal rings (4/10). Ventral midline laparotomy was performed in two horses without small intestinal resection. Laparoscopic intervention consisted of partial suturing of the cranial part of the vaginal ring using poliglecaprone (8/10) or polydioxanone (2/10) sutures.

Results
Follow up ranged from 3 to 72 months (median 24.5). All horses were used as intended. Eight horses never showed colic signs in the short- and long-term period. One horse needed a relaparotomy 3 years after inguinal hernia due to a right dorsal displacement of the ascending colon. One horse (sutured with poliglecaprone) had a recurrence of inguinal herniation 12 month after laparoscopic closure and was castrated.

Conclusion
The described technique is a valid method to prevent inguinal herniation in stallions. Polydioxanone sutures may be preferred due to their longer resorption time to close vaginal rings.

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Benefits of superglue mesh closure following exploratory laparotomy in horses

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Introduction
Skin closure of laparotomy wounds using topical cyanoacrylate mesh (Prineo®) provides a secure bactericidal barrier whilst obviating subsequent stitch/staple removal, benefitting veterinarian safety and cost. The effect on wound complications and cost has not been previously compared to established closure methods. We aimed to assess the incidence of wound suppuration and incisional hernia when using either Prineo®(DP), metallic staples(MS) or polypropylene suture(ST) for skin closure following laparotomy.

Materials & Methods
From 2009-2020 one of the above three methods of skin closure were used following laparotomy for acute colic. Method was not randomised. Owners were contacted ≥3 months postoperatively to identify complications. Rate of suppuration and herniation were calculated with binomial 95% confidence intervals. Surgery time, complication rates and costs were compared using chi-squared tests, with the confounding effect of surgeon assessed via multivariable logistic regression.

Results
110 horses met the selection criteria: 17(15.5%) developed wound suppuration, of which 4/45(8.9%) DP, 9/49(18.4%) MS and 4/16(25%) ST, P=0.23. Twenty-four horses developed incisional hernias, 21.8%: 4/45(8.9%) DP, 17/49(34.7%) MS and 3/16(18.8%) ST, P=0.009. Results were not confounded by surgeon choice. Median hospitalisation cost was higher for DP, but overall cost was no different between groups.

Discussion/Conclusions
No difference in rate of wound suppuration or cost was demonstrated, though MS was associated with a higher rate of hernia formation. Despite increased capital cost, Prineo® proved safer and was no more expensive, when cost to remove sutures/staples was factored in.

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Back movement and muscle activity changes in horses with induced fore- and hindlimb lameness at trot

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Introduction
Adaptive changes in back movement and muscle activity during equine lameness have been described separately. This study aimed to simultaneously compare back range of motion (ROM) and Longissimus Dorsi (LD) activity in horses with induced lameness.

Material and Methods
Surface electromyography (sEMG), at T14, and 3D-kinematic data were collected in clinically non-lame horses (n=7) during in-hand trot. Forelimb (iFL) and hindlimb (iHL) lameness induction occurred, with baseline data collected before induction. MinDiff quantified iFL and iHL lameness (2-3/5 AAEP), using poll (HDMin) and pelvis (PDMin), respectively. Back ROM was calculated using the planar angle between T6 to T13 and T13 to Tuber Sacrale segments for flexion/extension (FL/EX) and lateral bending (LB). Average rectified value (ARV) was calculated from sEMG and normalised to the maximum value from individual horse/muscle location during baseline. Data were grouped as lame (LS) and non-lame side (NLS) according to the side of lameness induction. Statistical comparison between conditions (baseline, iFL and iHL) was performed using linear mixed models with significance set at $p<0.05$.

Results
Compared to baseline, bilateral (NLS and LS) ARVs significantly decreased during iFL and increased during iHL ($p<0.0001$). FL/EX and left and right LB significantly decreased during iFL and iHL ($p<0.0001$), with smaller decreases in LB consistently observed on the LS.

Discussion/Conclusions
Adaptive movement strategies during iFL and iHL include spinal stiffening during the lame step expressed in FL/EX and LB, the latter is more pronounced on the LS, and this stiffening coexists with higher LD activity during iHL.

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Outcome and Racing Performance of 194 horses undergoing standing fracture repair (2007-2018)

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Introduction
Standing repair of sagittal proximal phalanx (P1) and parasagittal metacarpal/metatarsal III (MC/MTIII) fractures has developed from a salvage procedure to reduce cost, to a recognised treatment option. To date it has not been evaluated for large cohorts. The aims of this study were to determine short and long-term outcomes of horses undergoing standing fracture repair, and compare pre and post-surgical racing performance.

Materials and methods
A retrospective clinical record review of all horses >2 years old, admitted to a UK equine hospital, January 2007-December 2018, for standing repair of P1 or MC/MTIII fractures. Signalment, fracture configuration, surgical procedure and complications were recorded. The Racing Post database (www.racingpost.com) was used to obtain race records for all racehorses and data analysed using Mann Whitney U, Chi-squared and Wilcoxon signed rank tests to determine differences between variables, $P \leq 0.05$.

Results
Overall 194 cases met the inclusion criteria, with 98% (95%CI:96-100%) surviving to discharge. Of the 186 Thoroughbred/Arab racehorses included in the study, 64% (95%CI:57-71%) raced post-surgery, a median of 266 days later, with no significant difference in proportion of MC/MTIII and P1 fractures racing post-surgery ($p=0.397$). Horses that raced after surgery had a significantly shorter duration of hospitalisation ($p=0.036$), suffered fewer complications ($p=0.003$) and were more likely to have raced pre-surgery ($p=0.020$) than those that failed to race again. There was no significant difference in race earnings pre- and post-surgery ($p=0.519$).

Discussion/Conclusions
Standing fracture repair is a valid surgical procedure: capable of returning horses to the racetrack within an acceptable time frame.

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Bone edema in equine stifles – A real threat?

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Introduction

Bone edema (BE) is a rarely described MRI-based diagnosis. Thus, we report on incidence/location of BE and delineate therapeutic consequences after stifle-MRI. We hypothesized, that BE are (1) less frequently observed, (2) mainly detected in acute/subacute injuries and (3) associated with concurrent pathology and thus, MRI will assist in management of BE-associated lameness.

Materials and Methods

Medical records of 164 confirmed stifle lameness, that underwent MRI were reviewed for breed/age/gender/clinical findings, degree/duration of lameness, MRI-anesthesia time/-findings and treatment/management. MRI was performed in dorsal recumbency and different sequences/several planes were acquired. Horses with accessible, concurrent pathology underwent subsequent arthroscopic exploration.

Results

MR-examinations were completed in average time of 67min without problems. BE were less frequently observed as compared to soft tissue lesions. Proximal tibiae and patella were affected in 14% of horses predominantly after acute/subacute injuries. Although BE were mostly recorded as sole pathology, concurrent joint effusion and cruciate desmopathy was frequently noted. Degree/duration of lameness and time to presentation varied among horses. Logically, BE remained undetected arthroscopically, but all concurrent/accessible/superficial soft tissue lesions were revised successfully. In contrast, intralesional soft tissue degenerations were unreliably detected in arthroscopy as compared to MRI. Although meniscal and cruciate ligament flexibility appeared reduced while probing, consistent prognostic staging was impossible arthroscopically.

Discussion/Conclusion

BE are less frequently observed as compared to other stifle lesions, are mainly observed in acute/subacute injuries and can occur with concurrent pathology. Combination of MRI with subsequent arthroscopy is a save/promising approach for global understanding of stifle pathology/management/treatment and prognosis.

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Outcome following traumatic pelvic fracture involving the acetabulum in Thoroughbred racehorses trained in Newmarket, UK

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Introduction
Traumatic pelvic fracture involving the acetabulum is an uncommon injury. Limited published data exists to aid clinical decision making. Clinical and athletic outcomes after acetabular fracture in Thoroughbred racehorses are described.

Materials and methods
Retrospective case-series review (2004-2019) of Thoroughbreds with pelvic fracture involving the acetabulum where their history implied traumatic aetiology. Diagnosis was based on clinical suspicion and confirmed with imaging. Post-injury racing and breeding outcomes were assessed.

Results
Twenty horses were identified; 19 female and 1 (castrated) male, aged 1-7 (median 2) years at presentation. Injured leg was the right in (11/20, 55%; 95% CI:33-77%) and left (9/20, 45%; 95% CI:23-67%) with no bilateral cases. Clinical suspicion was confirmed by: ultrasound 19/20 (95%; 95% CI: 85-100%), radiographs 4/20 (20%; 95% CI:2.5-38%) and nuclear scintigraphy 4/20 (20%; 95% CI: 2.5-38%). Seven (35%; 95% CI:14-56%) horses survived; 5 (71%; 95% CI:38-100%) were retired to stud and 2 (29%; 95% CI:0-62%) returned to race training (1 raced and 1 retired from training due to contralateral limb orthopaedic injury). Follow-up time for survivors was 362-3981 (median 1258) days, post-injury dystocia was not observed. Thirteen (65%; 95% CI:44-86%) horses were euthanased due to injury, 1-138 (median 21) days later; 3 became recumbent and 10 lame.

Conclusion
These data may assist clinical decision making and encourage attempts at salvage. While cases were selected due to a traumatic aetiology, pre-existing prodromal stress fracture pathology cannot be definitively excluded. Nuanced non-clinical decisions may have impacted retirement/euthanasia. Greater number of females than males warrants further research.

Computer-assisted orthopaedic surgery in horses

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Introduction
Computer-assisted orthopaedic surgery (CAOS) enhances surgical precision compared to conventional intra-operative imaging techniques. In equine surgery, potential applications of CAOS have been described in experimental studies.

Materials and Methods
This retrospective study reports on clinical cases managed with the aid of CAOS at the Vetsuisse-Faculty Bern between 2016 and 2020, including different indications and clinical applications.

Results
CAOS was performed in 23 cases: In 14, cortex screws were placed for fracture repair of the proximal phalangeal bone, third metatarsal bone, accessory carpal bone, ulna and tibia, respectively. In two, minimally-invasive arthrodeses were performed. In two horses, trans-lesional screws were placed through a subchondral bone cyst of the medial femoral condyle and distal third metacarpal bone, respectively. In five cases, computer-guidance was used for trans-articular drilling, osteochondral fragment removal, curettage of an osteolytic lesion, or for implant removal. In 12 out of the 23 cases, CAOS was facilitated by the use of a purpose-built frame.

Discussion
CAOS can be an integral part of minimally invasive equine surgery, allowing real-time, precise orientation and implant placement at various anatomical localizations, while avoiding radiation exposure to the surgical team. The learning curve for operating surgeons and support staff is steep. To optimize workflow and time-efficiency, a team-approach is recommend, with one team designating to operative planning and another to the execution of the surgical plan. Specialized equipment, like the presented purpose-built frame, will further improve CAOS applications in equine surgery.

Tenoscopic desmotomy of the accessory ligament of the superficial digital flexor tendon (AL-SDFT) to treat superficial digital flexor tendonitis (SDFTs) in 19 FEI event horses

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Background
SDFTs is a common finding in performance horses, well documented in racehorse populations (Pinchbeck et al., 2004; Lam et al., 2007; Ely et al., 2010). Previous multi-discipline population studies are reported, with an ascending recurrent injury risk, from show-jumpers, to eventers and racehorses; overall recurrent injury rates for eventersare reported of 43% (Dyson 2004). In event horses the incidence of injury is highest in horses competing at advanced or international level (Murray 2006, Dyson 2011), in the authors' experience horses often present when they have been successfully trained to an elite level.

Bramlage was first to apply the open technique AL-SDFT desmotomy to cases of SDF tendinitis and in racehorses (Bramlage, 1986), resulting in 69% returning to racing. Tenoscopic AL-SDFT has been described (Cauldwell et al. 2011).
We hypothesise that bilateral tenoscopic AL-SDFT desmotomy protects against recurrence of SDFTs, in event horses.

Methods
Nineteen FEI event horses, that had competed at least three times, with acute SDF Tendonitis were treated by a bilateral, modified tenoscopic AL-SDFT desmotomy technique. Age range: 8-13 years, 12 geldings and 7 mares, follow up mean period was 48 months (20-80 months).

Results
Seventy-nine per cent of treated horses competed 5 or more times without re-injury, 63% at the same level or higher, 26% at 5* level. Sixteen per cent of cases suffered further SDFT injury.

Conclusions
Bilateral endoscopic AL-SDFT desmotomy can improve the prognosis of SDF Tendonitis in event horses.

Meniscal Disruption in 3 Neonatal Foals Associated with Septic Arthritis

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Introduction
The stifle is commonly involved in septic arthritis in foals. Although disruption of the meniscus has been reported due to trauma, tears secondary to septic arthritis in foals have not been described. This report documents 3 cases of meniscal disruption in foals associated with septic arthritis.

Cases
Three neonatal Arabian foals with septic arthritis of the lateral femorotibial joint (LFTJ), were diagnosed with lateral meniscal tears, based on persistent lameness despite improving synovial parameters, suspicious ultrasound (US) findings (protrusion of meniscal tissue beyond the level of the condyles, with hypoechoic disrupted regions), and confirmed with Computed Tomography arthrogram and arthroscopy. Treatment included arthroscopic lavage of the joint and debridement of the meniscal tear. Postoperative care included systemic and intra-articular antimicrobials, based on culture and sensitivity results. Two foals also received intra-articular injections of autologous mesenchymal stem cells.

Results
Grade III meniscal tears were observed in the LFTJ of the affected stifle joints of all foals, involving the meniscal body (n=2) and the caudal horn (n=1). Purulent material, noted within the torn tissue, was debrided with a synovial resector. All other soft tissue structures were intact. Foal 1 was lame-free as a yearling. Foals 2 & 3 improved one lameness grade at 9 & 4 weeks post-operatively with meniscal disruption still visible on US at these time-points.

Conclusion
Meniscal disruption and infection should be considered as a differential in neonatal foals with persistent femorotibial septic arthritis. In such cases, the lateral meniscus could be the primary nidus of infection.

Arthroscopic removal of palmar intermediate carpal bone fracture fragments in four horses using a transthecal approach through the carpal sheath of the flexor tendons

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Introduction
Fractures of the palmar carpal bones are recognised injuries with a poor prognosis following non-surgical treatment. Traditional arthroscopic access to the palmar intermediate carpal bone is difficult. We describe an alternative tenoscopic approach.

Materials and Methods
Retrospective study of horses undergoing palmar intermediate carpal bone fracture fragment removal using a transthecal tenoscopic approach through the carpal sheath. Data on signalment, clinical presentation, imaging findings, complications and outcome was collected.

Results
Four horses were identified, two were injured when falling and two during anaesthetic recovery. Two horses underwent magnetic resonance imaging in addition to conventional imaging. Three horses had concurrent fractures of the radial and/or accessory carpal bones. One horse underwent concurrent antebrachiocarpal and one concurrent antebrachio and middle carpal arthroscopy. A conventional proximolateral carpal sheath arthroscope portal was used with a medial instrument portal. The palmar intermediate carpal fragments were retrieved through the carpal sheath in all horses. Surgery time was 85 to 142 minutes. One horse experienced a post-anaesthetic myopathy. All four horses were discharged 3 to 8 days post-operatively. Two horses returned to athletic work 9 months post-operatively, one is 6 weeks from surgery and one was euthanased due to persistent lameness.

Discussion/Conclusion
A tenoscopic transthecal carpal flexor tendon sheath approach provides good access for removal of palmar intermediate carpal bone fracture fragments.

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Indications, Technical Aspects and Pitfalls with the Use of Absorbable Bone Screws in Equine Surgery

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Introduction
Although used for a wide variety of applications in humans, limited reports of absorbable screw use exist in equine literature. Lack of popularity in horses may be due to concerns regarding inadequate strength for long bone fracture repair and financial constraints compared to stainless steel screws. However, their bioabsorbable properties mean that additional surgeries for removal can be avoided, thereby offering an attractive alternative in some circumstances. Here, we describe our clinical experience with the use of poly lactic-co-glycolic acid (PLGA), absorbable, ActivaScrew™.

Case Descriptions
Cases including non-healing Type 2 fragmentation of the proximo-plantar wing of P1, medial femoral condyle subchondral bone cyst, distal P1 subchondral bone cyst, unicortical distal condyle MC3/MT3 fracture, and angular limb deformity were treated using absorbable screws placed in lag fashion under general anesthesia using standard AO instrumentation under radiographic or CT-guidance.

Results
Some challenges with screw placement were encountered, such as increased friction during screw insertion, torque gauging, breakage of screw head, and suboptimal screw length. Technical tricks were developed to overcome these issues over time: inserting/removing a regular AO screw first to clean threads and to ensure appropriate screw length selection; saline lubrication; strict adhesion to 2-finger screw insertion technique.
No adverse effects were noted in any of the cases postoperatively. Results obtained with the absorbable ActivaScrews were comparable to stainless steel screws.

Discussion/Conclusions
Absorbable screws should be considered a safe and effective alternative to stainless steel screws for certain orthopedic applications in horses. Important technical tricks can help avoiding intraoperative problems.

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Efficacy of tiludronate: retrospective study on 343 horses

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Introduction
Tiludronate is a bisphosphonate used to treat numerous bone conditions in horses, especially navicular syndrome and bone spavin. Multiple controlled studies prove its efficacy but no large-scale retrospective study has been conducted yet.

Objective
To evaluate efficacy of a single slow IV administration of 1mg/kg tiludronate in horses over a year.

Material and methods
Each horse that received at least one tiludronate-based treatment between 2006 and 2019 at Virginia Equine Imaging or Fairfield Equine and for which follow-up is available over a year was included in the study.
For each horse, lameness grade before tiludronate administration and at follow-up examinations was recorded.
When available, performance data were recorded from 6 months prior to treatment and up to a year after.

Results
A total of 1804 horses received at least one tiludronate administration and 343 of them had more than one year follow-up. Most horses (>80%) presented an initial lameness score over 1.5/5. Over 47% were sound by 30 days and 52% after a year. Lameness score improved by 1.1 grade 30 days after treatment and by 1.2 grade a year after. Performance data were available for 131 horses. One year after tiludronate administration, 49.5% of horses returned to the same level of activity and 29.9% to a higher level.

Discussion
Collected data on both lameness scores and performance suggest good efficacy of tiludronate treatment over a year after administration. Despite limitations inherent to any field study, this is the first retrospective study combining a large group with long-term follow-ups.

Temporary Pan-carpal Arthrodesis as a Treatment of Distal Radial Fracture in a Pony

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Introduction
Radial fractures carry a poor prognosis in adult horses. In foals and ponies, fracture repair may have good outcome following open reduction and internal fixation. Distal radial fractures are difficult to stabilize due to limited bony purchase in the distal fragment. Therefore, carpal arthrodesis may provide a viable option for salvaging the horse. In this report, we describe pan-carpal arthrodesis as a treatment for distal radial fracture in an adult pony.

Case Description
Twelve years old, 180kg, pony gelding was presented due to left front non-weight bearing lameness with distal radial instability. Diagnosis of a closed, comminuted, displaced distal radial fracture, with radio-carpal joint involvement was made radiographically. The fracture was repaired and pan-carpal arthodesis was performed, by placing 14 and 15-hole broad 5.5mm LCPs on the dorso-lateral and dorso-medial aspects of the radius, respectively. Joint cartilage curettage was minimal. Recovery was uneventful and the pony was discharged from the hospital. Four months after discharge the horse was re-admitted due to surgical site infection. The implants were removed in a minimally invasive standing procedure, in two separate occasions, with one month interval in-between. Eighteen months following surgery, the horse is not lame at the walk and can flex the affected carpus. Radiographs revealed complete healing of the fracture and failure of the arthrodesis.

Conclusion
In essence, we performed temporary arthrodesis by repairing a distal radial comminuted fracture fixation while preserving the carpal range of motion. This technique may be further modified and applied on other distal/proximal long bone fractures.

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Ex vivo CT diagnosed degenerative articular changes in the equine thoracic spine.

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Introduction
A descriptive study concerning joint pathology in thoracic articular facet (AF), costo-vertebral (CV) and costo-transverse (COT) joints.

Materials and Methods
Dissected, thoracic spines of 10, randomly chosen Warmblood horses with unknown history (mean age: 10 yrs, mean body mass: 572 kg) were examined with computed tomography. A total of 1080 joints and costovertebral ligaments were examined. Changes related to joint degeneration and ligament mineralization were scored as mild, moderate to severe.

Results
A total of 23 COT joints in 7 horses showed pathological changes. Seven were classified as mild, 8 as moderate and 8 as severe. Of these 23 joints, 78% were present between T1-T6. Four CV joints in 3 horses were pathological, 1 was classified as mild, 1 as moderate, and 2 as severe, all between C7-T5. AF joint pathology was encountered in 14 locations in 5 horses, with 71% between T14-T18. The number of mild, moderate and severe degenerated joint were 2, 6 and 6, respectively. In 40 locations ligamentous changes were present, 88% of these were localized between T1-T8. Twenty-one were classified as mild, 15 as moderate and 4 as severe.

Discussion/Conclusion
The prevalence of COT and CV joint pathology in the thoracic equine spine was not expected and has not been reported earlier. In humans it is a known cause of back pain. Further research is needed to assess the clinical significance of these findings.

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When and how to use intestinal bypass techniques

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Intestinal bypass procedures are less frequently indicated compared to resection and anastomosis in the equine gastrointestinal tract. However, these procedures may be the only option where preservation of key structures is critical, where resection is technically challenging and / or may require a second surgical procedure. The long-term effects are not fully known for many of these procedures and various different syndromes identified in people undergoing bypass surgery are likely to be relevant to the horse also. Critical aspects of intestinal bypass procedures include maintenance of normal anatomic orientation wherever possible, avoiding blind loop-syndrome and preventing potential spaces being created through which bowel may herniate.

Gastric bypass
These are the most frequent intestinal bypass procedures performed in foals and are most commonly indicated in the management of gastric outflow obstruction that does not respond to medical therapy. Rarely, these may be indicated in adult horses but surgical access to the stomach is more challenging. A variety of procedures are described dependent on the location of the obstruction[1], which in foals is usually stricture of the pylorus and / or duodenum secondary to gastroduodenal ulceration. Gastroduodenostomy is indicated in the management of pyloric obstructions[1,2] but pyloroplasty may be an easier, viable alternative[3]. Gastrojejunostomy is indicated in bypass of duodenal obstructions, enabling the duodenal papillae and associated hepatic and pancreatic ducts to be preserved. Key aspects of surgery include the orientation of the jejunum with some authors proposing that left to right orientation reduces the likelihood of complications[2] and orientation of stapling instruments oral – aboral to avoid aboral stricture formation[4]. Concurrent Jejeuno-jejunostomy avoids the risk of blind loop syndrome and potential intestinal rupture but is not always performed[1,2,4].

Jejunal bypass techniques
Jejunal bypass is rarely indicated but has been described for the management of abscesses and adhesions causing small intestinal obstruction that cannot be resected or where bypass would minimise the risk of further adhesion formation [5,6].

Ileal / ileocaecal valve bypass
Ileocaecal bypass may be indicated in some cases of ileal muscular hypertrophy, irreducible ileocaecal intussusception and has been proposed as an option for management of ileal pathology which is recurrent or where the inciting cause is unknown or in some ileal obstructions where resection is not required[7]. Complete and incomplete bypass techniques have been described.

Caecal bypass
This is one of the most common bypass procedures performed in adult horses and is most frequently indicated in the management of caecal impactions that are recurrent / likely to be recurrent or in some cases of irreducible caecocolic intussusception[8,9]. Complete and incomplete bypass procedures are described, with risk of caecal filling where incomplete bypass is performed[10]. A modified technique with occlusion but without transection of the ileum avoids the risk of recurrent caecal impaction and is quicker and easier to perform[11].

Right dorsal colon and small colon bypass
Bypass of the right dorsal colon is infrequently described in the literature in the management of focal right dorsal colitis where medical management is unsuccessful / persistent signs of abdominal pain develop. Various techniques have been described with a combination of bypass and surgical resection considered currently to be the most optimal approach[12]. Small colon bypass is infrequently indicated, as resection is a more common

alternative option, but could be considered as a surgical option in specific cases to bypass areas of stenotic small colon[13].

Rectal bypass
Temporary diverting colostomy is an option for management of Grade III / IV rectal tears and as an alternative to use of an indwelling rectal liner. Atrophy of the distal segment can complicate reversal of the colostomy so maintenance of health of the distal segment is important to minimise longer term complications following colostomy reversal[14].

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Does laparoscopy have a place in the management of horses with colic?

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Despite the progress in diagnosis, surgery and intensive care colic remains a major cause of mortality and morbidity in horses. Therefore, a timely decision of either medical or surgical treatment is critical. Some cases may not respond to medical treatment but present insufficient signs of obstruction or indication for surgical intervention and can therefore be candidate for laparoscopic evaluation (1). Due to the large abdomen in horses, a complete evaluation by one access is not possible. In the standing sedated horse, laparoscopy allows to visualize the complete dorsal part of the abdominal viscera but a left and right flank approach are necessary (2). In order to visualize the ventral part of the abdomen an approach in dorsal recumbency under general anaesthesia is performed, with Trendelenburg position for the examination of the pelvic and caudal viscera or reverse Trendelenburg position for the cranial part of the abdomen (3).

In cases of acute colic, important abdominal discomfort may not allow laparoscopy in the standing patient for the exploration of the dorsal part of the abdomen. Furthermore, distension of viscera by gaz, fluid or impaction reduce considerably the working space and the visualization of the abdominal cavity and make the introduction of the cannula at risk for organ puncture. Good case selection for potential candidates for laparoscopy is essential. Nevertheless, in many cases ventral midline coeliotomy will still be needed e.g. for intestinal resection or massage of small intestine and repositioning of colon. Communication to horse owners is essential that laparoscopy may not allow the complete treatment. Furthermore, laparoscopy is technically more challenging in set-up and needs an experienced surgeon and assistant, so that the technique may not be feasible in many clinics as an emergency procedure.

The most documented application of laparosocopy in the management of colic cases is preventive closure of the nephro-splenic (NS) space to avoid entrapment of the left colon. Several techniques are described in experimental settings as well as in clinical cases (4) (5) (6). The most used technique proving efficient with a low complication rate is a continuous suture pattern (7). Good apposition of the most dorsal border of the spleen with the ligament all through the NS space is essential. Otherwise recurrent entrapment can occur. Cranially, near to the stomach courses the splenic artery and vein that should be avoided, at the risk of seeing profuse haemorrhage to occur. Too deep biting in the NS ligament should also be avoided as the kidney can be hurt, especially in very thin horses. In order to obtain good apposition of the most caudal part of the NS space, the last suture bite can be in the ligament from medial to lateral and then finished by an extracorporeal knot. More recently, a barbed suture that does not need knotting at the end of the suture shows a secure closure of the NS space (5) (8). The use of a polypropylen mesh is also reported (9) (6) but has not gained popularity due to the possible adhesion formation, the less secure closure and the higher costs (10). In case of nearly permanent LDDLC, suturing the NS space may be hindered by the displaced intestine. One study shows that a mini-laparotomy in the flank can permit reduction of the displacement and subsequent NS closure (11). Also, the distension with CO2, normally not necessary for the NS space closure, can be sufficient to reduce the displacement keeping the minimal invasive nature of laparoscopy and allowing closure in the same procedure.

For acquired inguinal hernia in mature stallions laparoscopic technique is mainly preventive for recurrence as this pathology has a high recurrence rate of nearly 80 %. Laparoscopy in dorsal recumbency for reduction of incarceration, allowing evaluation of the viability of the intestine, is also performed by some authors followed by immediate closure of the internal inguinal ring (1). Others prefer in acute cases, external manipulation and massage under general anaesthesia to reduce the hernia (12). Most frequently, the reduction of the vaginal inguinal ring is performed in the sedated standing horse and should better be performed as a non-emergency procedure. Different techniques are described: One inserting a cylindrical mesh of polypropylene (13), the peritoneal flap (14) and cyanoacrylate glue (15) as well as suturing with barbed suture material (16). A polypropylene mesh apposed around the testicular cord is a more secure closure and may be performed in cases with a very large vaginal or inguinal ring (17). A compromise between secure closure of the inguinal/vaginal ring and sufficient vascularization of the testicle is important to keep fertility of the stallion. Several studies evaluating testicular perfusion and semen quality did not find deleterious effect of the peritoneal flap herniorraphy (18) (19) (20) whereas close contact of a mesh to the spermatic cord was associated with deleterious effects on the testicle in other species and should be avoided (21).

Most congenital inguinal hernias in foals are not strangulated and are self-resolving so that there is less need for surgery. Reduction of herniation and subsequent closure (testicle sparing or not) is necessary in case of enlarging hernia. In foals this is performed in dorsal recumbency under general anaesthesia with suture closure of the vaginal ring (1).

After a previous incarceration, laparoscopic evaluation of the epiploic foramen accompanied by mesh closure is a more recently reported technique and well documented in experimental horses and in clinical cases (22) (23). A special custom-made introduction cannula is used for this mesh closure. The technique allows a secure closure and is more straightforward than the closure of the EF securing the gastropancreatic fold and the right lobe of the pancreas to the caudate hepatic lobe using helical titanium coils (24). A mesh obliterating the EF can also be posed during the ventral midline coeliotomy (25) (26).

Diagnostic exploration for chronic / recurrent colic in the standing horse permits to take biopsies of liver (27), spleen, kidney (28) or small intestine, head of caecum or descending colon. Taking small intestinal biopsies is tricky with strict laparoscopic intra-abdominal technique (29) (30). Therefore, after laparoscopic exploration, enlarging an instrument portal allows extra-abdominal biopsy taking of good quality and of the region of interest (31) (32). For focal lesions, small intestinal resection can also be performed by the standing flank incision (especially for horses with poor general condition) (32). Intra-abdominal masses can have complementary diagnosis to trans-parietal or trans-rectal abdominal ultrasound. Large pedunculated lipomas with a short stalk can cause non-strangulating obstruction and their removal is possible after sectioning the stalk (1).

Laparoscopy in the standing horse allows good visualization of the distal part of the small colon, the uterus and the pelvic region and post-foaling injuries can be assessed (33) (1).

Adhesiolysis is described in experimental cases in pony foals associated or not to instillation with hyaluronate to reduce the risk of reforming adhesions (34) (35) as well as in case reports (36) (1). Monopolar/bipolar laparoscopic dissection probes are used for adhesiolysis to reduce bleeding (37). The lower peritoneal inflammation following laparoscopy compared to laparotomy may reduce the risk of *de novo* adhesion formation. Studies in human medicine show a high recurrence rate of adhesions after adhesiolysis (38). Only scarce information is available in equine cases based on case reports (36).

The repair of mesenteric or diaphragmatic rents causing small intestinal incarceration, is essential for long-term survival after initial correction performed by laparotomy. Very dorsal mesenteric rents may not be reached with ventral midline coeliotomy and successful repair by laparoscopy or hand-assisted laparoscopy is reported (39) (40) as well as for diaphragmatic rents (1).

One experimental study also reports suture of rectal lacerations in horses under general anaesthesia in sternal recumbency (41) and one clinical case is reported with a hand-assisted technique in a standing sedated mare (42).

Due to the large abdomen in horses, specific instruments have to be developed in order to allow more laparoscopic procedures to be performed in horses with colic (special trocars, long instruments) (43). The huge volume and weight of equine viscera does not permit as many procedures as described in human medicine (appendectomy with loop suture !).

In conclusion, laparoscopy has a place in the management of horses with colic, especially for preventive procedures like NS closure and inguinal herniorraphy as well as diagnosis of chronic, recurrent colic. The use of barbed suture may also enhance the feasibility of several techniques.

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Inguinal herniation in stallions: pre-, intra- and post-op decision making

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Indirect inguinal herniation (IIH) is a common cause of colic in adult stallions. The diagnosis is routinely made based on the finding of a hard, cold swelling of the testicle on the affected side. The most commonly performed surgical technique consists of surgical exploration of the inguinal area and reduction of herniated viscera with or without ventral median laparotomy (VML) combined or not with uni- or bilateral castration.

In 2007 Wilderjans et al. described a manual reduction (MR) technique under general anaesthesia to reduce the herniated viscera.[1] Recently we published a retrospective study with the results of this technique in 89 stallions.[2] By manual reducing the intestines, laparotomy and castration can be avoided in selected cases. Avoiding laparotomy allows for a relatively short convalescence period and an early return to previous use. However, recovering a horse from anaesthesia without exploration of the abdomen carries certain risks and when a horse is not castrated immediately other preventive measures need to be taken to prevent recurrence. A good outcome will depend strongly on the pre-, intra- and postoperative decision-making.

In our hospitals nonsurgical reduction of an IIH using external manipulation is always attempted. In a population of mainly Warmblood horses 90% of IIH are successfully manually reduced. The reasons for an unsuccessful MR are rupture of the vaginal tunic during manual reduction and very tight constrictions where the IIH cannot be reduced within the set time of 15 minutes. It is possible that in other breeds like Thoroughbreds MR is more difficult because of a different conformation of the vaginal ring. In horses with a very tight hernia, alternating the position of the hind limbs can be beneficial. When the time for the MR attempt is set at maximum 15 minutes not too much time is lost in case a classic surgical approach is needed and spending more time will probably not lead to significantly more success.

In our retrospective study, 56% of the horses were treated with MR only and without exploratory laparotomy, 33% underwent immediate (IVML) and 11% delayed ventral midline laparotomy (DVML). In recent years, the percentage of horses treated with MR only increased to 80%. Horses undergoing DVML following a successful MR had the highest mortality rates during hospitalisation and thus a delay in VML should be avoided as in any other surgical colic. This requires a thorough pre-operative exam and clinical experience. The most common surgical findings during DVML are small intestinal volvulus and a non-viable previously entrapped intestinal segment necessitating resection. The pre-operative exam should focus on identifying these patients by abdominal and inguinal ultrasound and peritoneal fluid lactate measurement. In case of doubt an IVML should always be performed following a successful MR.

When an IIH is manually reduced and there is no need for an IVML it needs to be decided whether or not to castrate the horse. This decision will largely depend on the discussion with the owner pre-operatively. When there is no need to keep the horse as a breeding stallion, castration along with ligation of the spermatic cord and vaginal tunic as proximal as possible is probably the most safe and effective technique to prevent recurrence. In case of an active breeding stallion the horse can be castrated unilaterally or the size of the vaginal rings can be reduced laparoscopically after surgery. Hemicastration is often not desired by the owner of breeding stallions although it does not seem to impair fertility. [3] Furthermore, in Warmbloods there seems to be no clinical need to castrate the affected testicle. In our retrospective study, owners of active breeding stallions did not report testicular atrophy nor reduced fertility. However, the effect of the herniation on the affected testicle is difficult to interprete as the contralateral testicle may compensate for impaired spermatogenesis.

Various techniques have been described to reduce the size of the vaginal rings by laparoscopy. The most commonly used techniques are direct suturing with or without barbed wire suture, the application of cyanoacrylate glue and a peritoneal flap hernioplasty. A 9 year follow-up of the PFH technique in the standing horse revealed a recurrence rate of 3/37 (8%) (unpublished data). When laparoscopically re-examining stallions that suffered from a repeat episode of IIH, it was noted that the peritoneal flap had shrunk to a narrow string not covering the vaginal ring. It is possible that there is a size limitation for a successful closure of the vaginal ring using a peritoneal flap or other described laparoscopic closure techniques. For these cases we developed a tacked intraperitoneal slitted mesh techique (TISM).[4] The surgical procedure is performed on the standing horse through a flank approach using 4 laparoscopic portals. The vaginal ring is covered with a mesh of 15 by 10 cm. An asymmetric cut of 10 cm is made in the mesh parallel to its longest side dividing the mesh into 2 flaps of different width: the dorsal flap is passed under the spermatic cord and ductus deferens and the ventral flap above. The mesh is then secured in place with laparoscopic tacks. Two types of mesh were used in this study: a polypropylene mesh (ProleneÒ) and a composite mesh made of polyester with a collagen film on one side to minimize visceral attachment (Symbotex™ Composite Mesh). Although the Prolene mesh is inexpensive, our preference goes out to the Symbotex mesh. This mesh is stiffer which makes intra-abdominal handling easier and it is more transparent improving anatomical visualization through the mesh.

Transient mild post-operative discomfort and limitation in activity was noted for 3 stallions in this study and is an important concern. The owners reported a stiff and shortened gait and loss of strength behind which gradually resolved after 6 months. It is possible that the fixations devices are the source of pain as they penetrate the body wall and harm nerves and vessels. The endohernia roticulator staples used in the PFH technique were not able to penetrate deep enough through the mesh and into the abdominal wall and were replaced by Protack™ tacks. These tacks provide a far stronger fixation of the mesh compared to staples but are also associated with a significant morbidity in man. For those reasons, the Protack™ tackers were abandoned and now we use absorbable Securestrap® tackers. A more detailed surgical anatomic knowledge of the neurovascular anatomy around the vaginal ring may reduce post-operative pain by avoiding perineural fibrosis and bleeding caused by tacks.

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Prevention and management of abdominal midline incisional complications

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Equine midline abdominal incisions often result in complications, including mainly edema, infection, dehiscence, and hernia.

Edema
Some edema is part of the normal body response to the trauma of surgery but excessive edema can interfere with healing and can be an indication of pending or existing infection. Also, shorter incision results in less edema and a longer incision is more likely to result in SSI. Edema can be both prevented and treated by pressure bandage and CM™ hernia belt applies more pressure than other types of bandages.

Infection
The most commonly reported and dealt with complication is surgical site infection (SSI) (~20%, Range: 0-40%). By the commonly used strict definition, any surgical abdominal wound, draining over 24h and more after surgery, is considered infected. I believe that there is a marked underestimation of the rate of SSI after colic surgery and the main reason is that in the majority of the cases, the drainage actually commences at home, several days after the horse was discharged from the clinic. Also, most of the SSI are mild and transient and the site of the infection is ventral, somewhat concealed. That, combined with the limited veterinary follow up at home, contribute to the underestimation of SSI prevalence. Infection of the incision can add expenses, extend hospitalization and may lead to further complications including dehiscence and hernia formation. In certain cases, SSI may even have a negative effect on survival. The severity of SSI is defined by the depth of the infection, the degree of wound gaping and the level of dehiscence.

Obviously, preventing SSI is preferable to treating them and in order to prevent, one must recognize the risk factors leading to SSI. Over the years, many studies have investigated the subject and revealed certain risk factors for SSI. Regarding many factors there is a significant controversy as to their impact on SSI. Many of these factors cannot be controlled such as the signalment of the horse and the severity of the colic while others, such the method of closing the incision or whether or not to shield the incision from the environment and by what method, are chosen. Increased PCV, an indication of cardiovascular compromise, is associated with higher SSI rate. Increased body weight is associated with higher rate of SSI, and pregnant mares also have higher rate of SSI. Longer anesthesia times are associated with higher SSI rate. Decreased partial pressure of oxygen during anesthesia was found to be detrimental in one study while a more recent study negated such association. Repeat celiotomy dramatically increase the rate of. According to some studies performing large colon enterotomy or small intestinal resection increase SSI rate, while other studies demonstrated no such effect.

Closure Technique
Suturing a stent on the incision was found protective by some and detrimental by others. Also, suturing the incision in 2 layers, instead of the traditional 3, did not affect the results according to one study, markedly reduced SSI according to a second study, while a third study found that the traditional 3-layer closure results in less SSI than the innovative 2 layered closure. While these studies attempted to reduce the number of layers to reduce foreign material in the incision, other studies found that adding a 4th layer, the peritoneum, actually reduced the incidence of SSI. Using intradermal sutures resulted in no SSI at all in one study. Skin closure with staples was shown to increase SSI in one study, but showed no such effect in an unpublished randomized prospective study we performed. Use of absorbable skin staples did not have an effect on healing of the incision, when compared to regular metal staples. Use of an antibiotic impregnated suture did not reduce the

occurrence of SSI. Lavage of the incision with saline and use of local antibiotics was found to be protective against SSI and it is supported by extensive studies in people.

Incision Protection

Using a bandage postoperatively markedly (12 times!) reduced SSI in one study while in our clinic, we found post-operative bandages can actually increase the rate of SSI but that may be weather related. The CM® hernia belt was found to apply more effective pressure on the abdomen than other types of bandages. A more basic and effective incision protection is an adhesive iodine impregnated nylon drape (Iobane®). Suturing a stent bandage on the closed incision was found effective by some studies but ineffective or even detrimental by others. Recently, in a controlled, randomized study we found that using intra incisional medical grade honey, markedly decreased SSI rate.

Treatment of SSI

initial treatment involves removing skin sutures/staples, cleaning and may include prescribing antibiotics and using a bandage, if the infection is worsening. In severe SSI we found vacuum treatment to be effective.

Incisional Hernia

Infection of the incision predispose to hernia formation, early, effective therapy such as using a pressure bandage (CM Hernia Belt) may prevent hernia formation. While hernia can reduce return to athletic activity, its repair, may even be fatal in large horses. However, many hernias may just be a blemish without interfering with the horse’s function at all, only large; pendulous or thin walled hernias actually require repair, to prevent accident, resulting in fatal evisceration. There are multiple methods of hernia repair but closing the hernia ring followed by subcutaneous polypropylene mesh implantation is a straightforward reliable, effective technique.

Incisional Dehiscence

Superficial dehiscence results in gaping of the wound and delays healing, but complete dehiscence may lead to fatal evisceration. Once complete dehiscence is looming, immediate supportive bandaging is essential, followed by urgent, secondary body wall closure. The repair is performed using cerclase wires (18g) in an interrupted mattress pattern with rubber bolsters.

Ophthalmic Surgery in the Standing, Sedated Horse

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Introduction
Surgical intervention plays an ever-increasing role in the management of many ocular diseases in the horse, and many surgical procedures can be safely and effectively performed by providing local anesthesia with the horse under sedation. The most obvious advantage of performing standing ophthalmic surgery in the horse is the avoidance of risks associated with general anesthesia and the post-operative recovery period. However, ophthalmic surgical procedures also become more accessible which leads to earlier surgical intervention during the disease process. Owners are mor likely to consent to surgery when the risks associated with general surgery can be avoided.

We are very fortunate to have a multitude of surgical techniques available which allow us to treat a variety of individual ophthalmic diseases and disorders. But, in order to be successful, an ophthalmic surgeon must not only possess the necessary surgical/microsurgical skills, they must also understand the individual nuances of each procedure well enough to select the appropriate surgical technique for a specific situation. This will prepare them to counteract any anticipated or unforeseen complications that may arise.

Analgesia and Sedation
Analgesia is provided using systemic nonsteroidal anti-inflammatory medications (NSAIDs) systemically in addition to local analgesia facilitated by regional nerve blocks (see next section). Sedation is achieved with one, or more frequently, a combination of medications. While opioids, such as butorphanol have historically been avoided for standing ophthalmic procedures due to subsequent head-bobbing, there are several indications for its use. Minimizing the amount of butorphanol administered intravenously (i.v., 0.01-0.02 mg/kg) and giving an intramuscular (i.m., 0.02-0.04 mg/kg) bolus injection can positively influence the effects of sedation. Characteristic “head-bobbing” is commonly only significant during the first 5-10 minutes following i.v. administration and subsides thereafter. Generally, administering local eyelid and retrobulbar blocks, obtaining ophthalmic photographs and prepping the eye and surrounding site appropriately for sterile surgery will take at least 15 minutes, at which time any residual head-bobbing will be minimal and is unlikely to negatively influence the surgery.

Alpha-2 agonists provide good short-term analgesia and reliably consistent sedation. In general, alpha-2 agonists (e.g., detomidine 0.01-0.02 mg/kg) are administered i.v. to facilitate rapid onset of effect and to provide consistent and predictable results. Additionally, we have found the use of subcutaneous (s.c.) administration of detomidine (0.03 mg/kg) to be beneficial in providing more profound sedation while also extending the duration of effect, especially when combined with i.v. administration. Although constant rate infusions are not utilized in our practice, their use for standing surgery in the horse is quite widespread.

Regional Nerve Blocks
The most common local blocks utilized for ophthalmic diagnostic and surgical procedures are the palpebral (auriculopalpebral) and supraorbital (frontal) nerve blocks. For many surgical procedures additional analgesia and regional anesthesia can be achieved using a retrobulbar block and topical corneal and conjunctival anesthesia. Lidocaine is a commonly utilized local anesthetic that is valued for it’s quick onset of action (5-15 min) as well as its duration of action (60-120 min). However, lidocaine can be locally irritating and may cause hypersensitive tissue reactions resulting in significant chemosis. These negative effects can be all but eliminated with the use of mepivacaine. Mepivacaine also has a relatively short onset of action (5-30 min) and an extended duration of action (90-180 min) compared with lidocaine. Longer acting local anesthetics with a prolonged onset of action, such as bupivacaine, are not routinely utilized but may be indicated following enucleation, where prolonged analgesia is desired. Additional local eyelid blocks, such as eyelid line blocks and lacrimal, zygomatic and infratrochlear nerve blocks can be strategically utilized, should further regional anesthesia be desired or required.

Head Support and Sterile Preparation
Head support is provided by positioning the horse's head on stack of custom made pads placed on top of a mobile cart. We utilize custom-made pads with a thermosensitive central core to facilitate prolonged comfort and stabilization (Neumaier Upholstery, Erding, Germany). With the head supported in this fashion, the horse is generally calmer than if the head were being supported by a person or instable stand (i.e., dental stand), which is important to facilitate microsurgery. Following local eyelid blocks (+/- retrobulbar block, depending on the procedure) and clipping of the periocular hair, aseptic preparation is carried out via a three-step surgical site preparation sequentially using dilute baby shampoo followed by a 1%-5% povidone-iodine scrub, and completed with a sterile saline solution. The conjunctival fornix is prepared similarly and the head is draped with a self-adhesive aperture drape. For many procedures an eyelid speculum is placed within the palpebral fissure to facilitate exposure of the surgical site. In some instances, e.g., intravitreal injections or aqueocentesis, a Demarres eyelid holder is sufficient to facilitate access to the desired part of the globe.

Magnification
Magnification is the first aspect of microsurgery that is compromised when performing standing ophthalmic surgery in the horse. Even if a head-mounted microscope is utilized, there is a dramatic reduction in magnification compared with a floor or ceiling mounted ophthalmic microscope. Generally, head loupes (Galilean, 2.3x to 2.5x or prismatic 3.5x to 6.0x surgical loupes) are utilized for equine ophthalmic surgery performed under sedation. Both types of loupes have both advantages and disadvantages, with surgeon preference playing an extremely important role. Galilean surgical loupes are smaller, lighter, and have a larger field of view than prismatic surgical loupes. Although the degree of magnification is less with Galilean surgical loupes, the ability to visualize or perceive the surgeon's surroundings while wearing the loupes is much greater than with prismatic surgical loupes. This is a huge advantage when performing delicate surgery on a large and sometimes unpredictable animal. While a light-weight surgical head-mounted microscope would be very advantageous with regards to surgical precision there are currently no models available.

Categories Of Equine Ophthalmic Surgery
The following four categories represent the scope of ophthalmic surgery routinely peformed at Auburn University using skills learned and honed over the past 15 years. Don't let the category names mislead you; even minimally invasive (Category I) and simple (Category II) procedures require a significant amount of training and experience to perform consistently well. Procedures are categorized based on the need for special instrumentation and if sutures are required.

Category I: MINIMALLY INVASIVE
These procedures are quickly performed, often not requiring retrobulbar blocks, and utilize modified but profound sedation and local anesthesia. Examples: ***aqueous paracentesis, intravitreal injections, episcleral cyclosporine implant placement, diamond burr keratotomy***.

Category II: SIMPLE
More advanced instrumentation is required and these procedures take more time to complete than Category I procedures. Examples: ***enucleation, nictitans excision, eyelid neoplasia, laser ablation of iris/uveal cysts, transscleral cyclophotocoagulation (TSCP).***

***Category III:* ADVANCED**
These procedures often require suturing and precise surgical excision within very thin and delicate ocular tissue. Examples: ***superficial lamellar keratectomy, grafting procedures (conjunctiva, amniotic membrane, BioSiSt, A-cell), intrastromal injections, glaucoma shunt bleb deroofing.***

Category IV: COMPLICATED
Highly specialized surgical procedures requiring a significant level of experience and microsurgical expertise, patience and intuition. Examples: ***Suprachoroidal cyclosporine implant placement, lamellar keratoplasties (deep lamellar endothelial keratoplasty, DLEK; posterior lamellar keratoplasty, PLK; corneoconjunctival transposition, CCT), gonio-shunt placement.***

Standing Ophthalmic Surgery in the Horse
Horses are ideal candidates for standing ophthalmic surgery, which can be safely and efficiently performed, as long as certain precautions are taken. Profound sedation and adequate local anesthesia (e.g., eyelid and retrobulbar blocks) coupled with stable and supportive (e.g., pads and cart system) restraint, and a quiet environment, will allow the trained ophthalmologist to perform a wide variety of surgical procedures. The majority of these procedures, if performed correctly, drastically reduces the risk for postoperative life-threatening complications.

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Reconstructive surgery of the eye

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Introduction
Ophthalmic disease affecting the eyelids/adnexa is quite common in horses, with eyelid lacerations and neoplasia being two of the most common diagnoses (1).

In case of eyelid lacerations, or after surgical excision of ocular neoplasia, it is important to properly reconstruct the equine eyelid to preserve normal anatomy and function (1,2).

The treatment of eyelid lacerations and selected blepharoplasty procedures will be discussed in the lecture.

Eyelid lacerations
The lateral position of the eyes of a horse, together with the environment in which many of these fright-and-flight animals are kept, makes the horse susceptible to ocular and periocular trauma (1,3,4). Therefore, eyelid lacerations often occur and prompt repair is necessary to maintain ocular health.

It is important to perform a complete and thorough ophthalmic examination, to determine the severity of the injury and to conceive an appropriate treatment plan (1).

For example, lack of pupillary light responses, presence of corneal lacerations, the presence of fibrin in the anterior chamber or orbital fractures should not be missed, as these may necessitate a different approach or additional treatments (1,4).

Suturing of an eyelid laceration can often be done in the standing sedated horse with local blocks but there are cases that require general anaesthesia (5). Due to the excellent blood supply to the eyelids, most lacerations heal very well after suturing, even when a laceration is several days old (1,2).

If a horse presents with much swelling of the eyelids, use of a wet ocular bandage or of cold packs before starting the repair is often helpful.

Lacerations should be flushed with a diluted (1:50) povidone iodine solution (10%), followed by rinsing with sterile saline (2). A two-layer closure is warranted for all eyelid lacerations to prevent excessive granulation tissue and scar formation (1,2). Minimal debridement is required, as the eyelid margin must be preserved as much as possible (1,2).

If tissue loss is less than one third of the eyelid margin, direct apposition is possible. If more than one third of the eyelid margin is lost, or in case the defect is situated close to the medial or lateral canthus, a blepharoplasty procedure might be required (1,2).

It is important to align the eyelid margin, as otherwise chronic keratitis due to scar tissue or trichiasis can occur causing ocular discomfort. To align the eyelid margin, a figure-of-eight suture is used to prevent suture material from abrading the corneal surface (6). In general, the prognosis of the repair of eyelid lacerations is very good.

Adnexal/Ocular neoplasia
Squamous cell carcinoma (SCC) is the most common neoplasia involving the equine eye and adnexa (7,8). Other periocular tumours are sarcoids, melanomas, fibromas/fibrosarcomas and lymphosarcomas (7,8).

Surgical excision alone carries a high risk of recurrence. Tumour free margins of two centimetres have been recommended when excising SCC, but this is often impossible in the periocular region. Many adjunctive therapies have been described in literature, like chemotherapy, cryotherapy, hyperthermia, radiation, carbon dioxide laser ablation or photodynamic therapy (1,2,8,9). It is advised to combine surgical excision or a blepharoplasty technique with one of the adjunctive therapies to reduce the risk of recurrence (1,8,9).

To close large eyelid defects in horses several blepharoplasty techniques have been described, including the sliding skin graft or H-graft, tarsoconjunctival advancement graft, full-thickness eyelid graft (Cutler-Beard procedure), the rhomboid graft, the sliding “Z”-graft and various combinations (2,10,11). In all these techniques it is important to restore a functional eyelid margin.

Extensive blepharoplasty techniques, as performed in other species, are difficult in horses as the periocular skin is firmly attached and poorly mobile and the superficial blood supply to the skin is poor (10). Following a blepharoplasty procedure in a horse, retraction of the scar, dehiscence and necrosis of part of the flap are common complications (1,10).

Unfortunately, instead of a blepharoplasty, enucleation or exenteration may often be required, even though the eye of the horse is not visually impaired (10).

In all techniques, a part of the eyelid margin is replaced by haired skin and this can cause trichiasis. Some modifications have been described like a free labial mucocutaneous graft (or lip to lid graft) and sliding canthoplasties to prevent trichiasis from happening and to create a mucocutaneous junction at the eyelid margin (12-14).

Other techniques that are more commonly used in other species and have occasionally been described in horses are the Tenzel Rotational Flap, Mustardé technique, Modified Kuhnt-Szymanowski surgical procedure and the use of a soft tissue expansion device (15-18).

The most used blepharoplasty techniques in horses (the sliding skin graft and rhomboid graft), as well as selected modifications, will be discussed in the lecture.

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An Update on Equine Intraocular Surgery

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Introduction
Intraocular surgery actually constitutes are very large portion of the equine ophthalmic surgery spectrum. I have chosen to talk specifically about non-corneal intraocular surgery, as corneal reconstructive surgery will be covered in another presentation. On the surface, it may seem as though equine intraocular surgery is rather simplistic, however, due to the large size of the equine globe and various anatomical differences between other common veterinary species (cats and dogs) and humans, there are many challenges associated with these procedures in horses. Some of these challenges have been overcome by the introduction of equine-specific surgical instruments. Not only are these instruments larger, but they have often been modified to ensure optimal tissue-handling in the horse.

As is the case with many equine ophthalmic surgical procedures, several intraocular surgeries can be performed under standing sedation by an ophthalmologist with appropriate microsurgical training. However, due to the potential for globe-threatening complications from the long surgical instruments with minimal movement from the horse, surgeries of the lens (e.g., phacoemulsification, irrigation and aspiration) and vitreous (e.g., pars plana vitrectomy) are still performed under general anesthesia.

Glaucoma Surgery
Surgical intervention for glaucoma in horses is often performed as a salvage procedure very late in the disease process, despite the fact that horses generally maintain functional vision very late into the disease process. As a result, surgical intervention for glaucoma continues to be associated with poor surgical outcomes in the horse. In these situations the eyes have usually undergone significant and substantial tissue damage and may not represent the best candidates for surgical intervention. Although we cannot currently prevent glaucoma from occurring, we may be able to preserve vision in more horses by performing surgical intervention such as transscleral cyclophotocoagulation (TSCP) or gonio shunt placement earlier in the disease process. A great deal of research remains to be performed regarding the most appropriate time point and ideal candidate for surgical intervention.

The use of gonio shunts in horses represents a feasible treatment option in horses with glaucoma, especially those not responding favorably to intraocular pressure (IOP) reduction via topical carbonic anhydrase inhibitors (CAI). Gonio shunt placement requires meticulous attention to detail and careful planning to avoid complications. Postoperative hyphema, a relatively common complication associated with the postoperative recovery from general anesthesia, may be dramatically reduced by performing the surgical procedure under sedation and local anesthesia. Placing the gonio shunt under sedation minimizes the risk of traumatic injury to the eye during the immediate postoperative period.

Additionally, it is important to determine if a TSCP and gonio shunt placement procedure should be performed simultaneously or independently. With the ability to perform these procedures under sedation, we will likely be able to better address this question in the future. Although occlusion has been anecdotally blamed for most gonio shunt failures in the past, more recent experience suggests that simple management interventions, such as intracameral tissue plasminogen activator (TPA) can successfully overcome such occlusions. A more substantial problem associated with shunt failure appears to be the fibrous bleb that forms over the shunt base at irregular postoperative intervals. Anecdotal evidence suggests that routine bleb revision (e.g., "deroofing") may ensure postoperative gonio shunt patency in horses undergoing this procedure. There remains a great deal of additional research that needs to be conducted to uncover some solutions to these challenges.

Lens Surgery
Phacoemulsification and irrigation/aspiration with or without an intraocular lens (IOL) implantion is performed much less frequent than in small animals (i.e., dogs), but remains a relatively routine intraocular surgery in the horse. Although there are many similarities between species, there are several differences that make the procedure different, and unique, in the horse.

Following a traditional 2-step clear corneal incision, the corpora nigra is consistently pulled towards the incision as the aqueous humor drains from the anterior chamber. In order to minimize this risk, a 3-step clear corneal incision can be utilized, thus creating a hinged, self-sealing corneal entry into the anterior chamber. There are several methods to perform the anterior capsulotomy, including high-frequency diathermy, which can be useful in creating consistently sized openings in the anterior lens capsule in the horse. More traditional manual approaches are also feasible and the choice of technique selected is mainly due to surgeon preference. Despite the use of foldable IOLs an introducer does not exist. In the horse the large 21-24mm diameter IOL must be manually inserted into the capsular bag following corneal incision extension. This is achieved by folding the IOL in half and grasping it with IOL introduction forceps.

It is also quite useful to implement a two-handed surgical technique when performing phacoemulsification and irrigation/aspiration in the horse. The use of an IOL dialer or nucleus rotator, which is inserted through a peripheral stab incision and guided using the surgeon's non-dominant hand can be very useful in positioning the IOL during introduction. By utilizing a second instrument to control IOL placement within the capsular bag the surgeon can dramatically reduce the risk of unexpected radial tears or posterior capsule penetration by providing stabilization of the IOL during insertion.

Surgical Intervention for Uveitis

Suprachoroidal cyclosporine implants (SCI) provide medical suppression of active inflammation for a duration of approximately 30-33 months. Patient selection is key to ensuring a favorable outcome. Horses that are well controlled with topical and systemic anti-inflammatories are generally great candidates for this surgical implant. Horses that demonstrate a positive response to systemic and topical anti-inflammatory therapy may still respond positively following implantation of the sustained duration cyclosporine devices, however, these horses must be monitored closely for signs of recurrent or persistent inflammation in order to administer additional adjunctive or alternative therapy to control the uveitis. Proper placement of the SCI is imperative to ensuring a positive postsurgical outcome. It is possible to place these implants under standing sedation

Another surgical procedure that has been shown to minimize recurrent bouts of inflammation in specific horses diagnosed with ERU is the pars plana vitrectomy (PPV). This is a more invasive, intraocular procedure that enjoys widespread use in Europe, especially in Germany, where the procedure was first introduced. Traditionally, successful suppression active uveitis and prevention of recurrences was based on the presumption that the ERU was caused by *Leptopira interrogans spp.*, and that the PPV allowed for removal of the intraocular (e.g., vitreal) reservoir of leptospiral antigens. This school of thought presumes that all cases of ERU are caused by leptospiral organisms, which is likely not the case. A study performed at the University of Zürich (Tómórdy) concluded that horses with c-values (Goldman-Widmer coefficient) greater than three were more likely to positively benefit from a PPV, whereas those horses with a c-value of 3 or less were more likely to suffer from recurrent bouts of inflammation. As a result of this study, along with much of the available postoperative anecdotal information available pertaining to the PPV, horses with a high c-values (indicating intraocular production of leptospiral antibodies) for *Leptospira*, are the most suitable candidates for a PPV. These cases are also most likely to manifest as posterior uveitis with a significant degree of hyalitis or inflammatory vitreal membrane formation, but also exhibiting moderate to marked aqueous flare, miosis, and ocular discomfort. Due to the recent success of low-dose intravitreal gentamicin injections (4mg) to suppress inflammation associated with ERU and to prevent recurrences, the numbers of PPVs being performed outside of Germany has dramatically declined.

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Comparison of the ability of two different ultrasound transducers to identify abdominal organs in clinically healthy horses

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Introduction
Traditionally equine abdominal ultrasound scans are performed using 2-5 MHz curvilinear array or sector transducers ("abdominal probes"), which generally restricts usage to veterinary referral centers that are equipped with these transducers. First-opinion veterinarians commonly possess 5-10 MHz linear array transducers ("rectal probe"), yet no data exists to show whether this probe has comparable efficacy to the abdominal probe in abdominal ultrasonography.
The objective of this study is to compare organ identification using a rectal probe and abdominal probe for transcutaneous abdominal scans of healthy horses.

Material and Methods
Twelve clinically normal adult horses owned by the University of Calgary were enrolled in the study. Abdominal ultrasonography was performed by 4 practitioners, each randomly assigned to an alternating rotation of rectal or abdominal probe and left or right side of a horse. Using a Chi square test or Fisher's exact test, the frequency of identification for each organ was compared between both probes

Results and Discussion
There was no significant difference in organ identification on the right side of the abdomen. On the left side the stomach, liver and kidney were less likely to be detected with the rectal probe. No correlation between body condition score and organ identification could be established.
Compared with a low-frequency abdominal probe, a high-frequency linear rectal probe delivers diagnostic images in transcutaneous ultrasonography of the equine abdomen except for the left kidney, left liver and stomach

Concurrent cecocolic intussusception and large colon displacement associated with a heavy jejunal ascarid burden in a foal

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Introduction
Concomitant surgical lesions of the small and/or the large intestine, apparently unrelated, can develop in the same horse.

Case Description
A 3-month-old male QH was referred with a history of severe acute colic for 3 h, unresponsive to treatment with flunixin meglumine. The foal had also a history of 1-week profuse watery diarrhea and had been treated 2 week earlier with fenbendazole paste. On admission, relevant physical examination findings and limited laboratory data included: moderate clinical signs of acute abdominal pain; depressed mentation/attitude; heart rate 68 beat/min; pale pink oral mucous membranes; capillary refill time 3 seconds; reduced intestinal borborygmi in all abdominal quadrants; respiratory rate 20 breaths/min; rectal temperature 38.1°C; PCV 31%, TPP 5 g/dl. Diagnostic FLASH findings were: bowel within bowel of the large intestine (“target-like” or “bull’s eye” sign) and displaced/distended mesenteric vessels in the right side of abdomen; hyperechoic lines (“train tracks”) or circular structures within the small intestine lumen in the ventral window. Concurrent counterclockwise right dorsal displacement of the large colon and cecocolic intussusception were identified during exploratory celiotomy, which were manually correct and reduced, also careful manual milking of the jejunal intraluminal ascarid worms was attempt. The foal had no postoperative complication and was discharged 9 days post admission.

Results
At 16 weeks post-surgery foal had recovered without complication.

Discussion and Conclusion
In this uncommon case immediate surgical correction and gentle intraoperative technique avoided performing a partial typhlectomy with or without right ventral colotomy and/or a cecal bypass procedure.

Diverse treatment strategies for horses with ‘Kissing spines’ – international survey of equine orthopaedic specialists

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Introduction
‘Kissing spines’ are the most common cause of back pain in horses. Treatment options range from manual therapy to local injection or surgery. The aim of this study is to investigate which treatment is preferred by equine orthopaedic specialists (EOS) with different qualifications and to assess which techniques are most commonly used for local injection of the equine thoracolumbar spine.

Materials and Methods
An online survey was distributed amongst members of the European/American College of Veterinary Surgeons (ECVS/ACVS), the European/American College of Veterinary Sports Medicine and Rehabilitation (ECVSMR/ACVSMR), the International Society of Equine Locomotor Pathology and nationally recognized specialists. Data were recorded and analysed using SPSS. Ethical approval was obtained.

Results
The survey was completed by 353 EOS (response 24%). Local injection is performed regularly by 276/353 EOS. The injection techniques most commonly utilized are: placing one spinal needle (20G 3½”; P=0.020) in midline (35%) between two dorsal spinous processes (DSPs) or: placing two needles abaxial to the DSPs (43%) under ultrasonographic guidance (31%). Manual therapy is considered by 46% of ECVS/ACVS and 54% of ECVSMR/ACVSMR members. Surgical intervention is the preferred first line treatment option for 17% of ACVS members whilst among ECVS surgeons (84%) recommend surgery only in horses that do not respond to medical management (P=<0.001).

Discussion/Conclusions
Despite a growing body of evidence the therapeutic approach to ‘Kissing spines’ in horses is strongly influenced by professional specialisation and regional preferences. Variations in injection techniques and differing criteria for surgical intervention warrant further investigation.

Effect of allogeneic mesenchymal stromal oral mucosa cells on equine wound repair

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Introduction

This study evaluates application of equine allogeneic mesenchymal stromal oral mucosa cells (OM-MSC) or their secretome (OM-secretome) on induced thoracic and distal limb wounds in horses. We hypothesized that these treatments improve clinical outcome when compared with hyaluronic acid (HA), the vehicle treatment and with untreated controls.

Material and Methods

Eight adult horses, free of front limb lameness and of any scars were included in a unicentric, double blind sudy. All wounds were submitted to the application of one out of four treatment option: untreated wound (T1), OM-MSC embedded in HA-gel (T2), OM-secretome embedded in HA-gel (T3), and HA-gel (T4) alone. Daily clinical evaluation was performed combined with gross visual evaluation and digital photography. Histology of full-thickness biopsy sample was obtained during wound creation and two months later.

Results

All wounds healed completely by the end of the study (90 days) without adverse effects. Gross wound-healing variations were observed within the first month after wound creation and no significant differences were collected after this period. Distal limb wounds were slower to heal than body wounds. OM-MSC and its secreome had a positive impact on thoracic wound contraction, and OM-MSC had a positive impact on contraction and epithelialisation of distal limb wound. No significant differences were noted at histological examination between wound sites, before and after treatment.

Discussion/Conclusion

HA-gel is a good transport medium. This study also suggests the existence of a therapeutic benefit of OM-MSC on skin wounds with a time window for topical administration.

Effect of reducing bone to cast distance in equine transfixation pin casts: ex vivo biomechanical study

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Introduction
We aimed to evaluate the effect of reducing the bone to cast distance on the resistance of the pin to cyclic loading in equine transfixation pin casts.

Materials and Methods
Eleven pairs of cadaver equine third metacarpal bones were prepared and a 6.3/8.0 mm transfixation pin placed in standard fashion 1 cm proximal to the distal physeal scar into each bone. One metacarpus of each pair was tested with a distance of 10 mm (10 mm group) and the contralateral metacarpus with a distance of 20 mm (20 mm group) between the outer cortex of the bone and the fixation of the pin. Eight pairs were tested using a simplified test setup in which the pins were fastened at both ends to polyoxymethylene-copolymer sleeves. The pins of the remaining three pairs of bones were incorporated into a fiberglass cast. All specimens were tested under cyclic loading until failure in axial compression of the metacarpus.

Results
All pins failed uni- or bilaterally at clinically relevant load levels. Pins of the 10 mm group endured significantly ($p < 0.05$) higher load levels and total number of cycles until failure than pins of the 20 mm group.

Conclusions
The distance between the bone surface and the cast at the site of pin insertion has a significant effect on the resistance of pins to cyclic loading. Therefore, the amount of padding applied underneath an equine transfixation pin cast can have an influence on the overall stability and durability of the construct.

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Establishing a Metabolic Performance Profile for Endurance Race Horses

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Introduction
Equine performance in endurance competitions depends on the interplay between physiological and metabolic processes. Although participating animals are frequently eliminated from the race, due to various health conditions, there is currently no parameter estimating the animal readiness for competition. Our objectives were to provide an in-depth characterization of metabolic consequences of endurance racing as well as to establish a metabolic performance profile for those animals.

Materials and Methods
Performance of 47 Arabian and half-Arabian horses in endurance races at a distance ranging from 80 km to 120 km was recorded. Blood plasma samples were collected before and after the competition and analyzed using a broad non-targeted metabolomics platform.

Results
792 metabolites were measured, out of which 417 showed significant alterations between before and after the race. The race triggered alterations in molecules involved in branch chain amino acid (BCAA), histidine, lysine and taurine metabolism, as well as α-, β- and ω-oxidation of fatty acids. We further identified metabolic differences between the animals who completed the race and those who didn't, in particular in molecules related to BCAA and omega-6 fatty acid metabolism. Using lasso regression with stability selection, we identified a set of metabolite predictors of animal performance in endurance competition. The resulting model included six metabolites and had an AUC of 0.92.

Discussion/Conclusions
This study provides an in-depth characterization of metabolic alterations induced in horses participating in endurance races. Furthermore, we showed the feasibility of identifying potential metabolic signatures as predictors of race completion and animal performance.

Features of the Equine Small Intestinal Mesenteric Attachment Predisposing to Leakage

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Introduction
Rupture of equine small intestine with formation of a pouch of ingesta within the mesentery has been reported in clinical colic cases. Multiple ex-vivo studies using anastomosed jejunum also observed rupture into the mesentery, distant to the anastomosis. Both scenarios suggest the jejunum is predisposed to rupture at the mesenteric attachment.

This study aims to 1) demonstrate equine jejunal segments repeatedly rupture at the mesenteric attachment when subjected to high intraluminal pressures and 2) use histology and high field magnetic resonance imaging to document predisposing anatomical features of the mesenteric attachment.

Materials and Methods
Permission to use cadaver materials for research was obtained from an Ethics committee. Twenty-two jejunal segments from four equine cadavers were subjected to intraluminal infusion of water until rupture occurred. Sections of the ruptured jejunum (RJ) and unruptured controls (C) were evaluated histologically.
Unruptured jejunum (UJ) from a fifth equine cadaver was imaged using 11.7T MRI.

Results
Four jejunal segments disconnected from irrigation pump construct instead of bursting, all other segments ruptured at the mesenteric attachment. Disruption through the fenestration at the site of mesenteric attachment was seen histologically in RJ sections.
MRI of UJ and histology of C sections revealed repeatable fenestration in the muscularis externa at the site of mesenteric attachment, associated with mesenteric-jejunal vasculature.

Discussion/Conclusion
The mesenteric attachment is the point where mesenteric vasculature enters the jejunal wall, reaching the jejunal submucosa through fenestrations in the muscularis externa. This manifests as a structural weakness which may have clinical implications during abdominal surgery.

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Foreign body in the linea alba as a cause of chronic problem in the horse

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Introduction
A 15 year old gelding was admitted due to a chronic swelling and abscess located in the linea alba area. First symptoms had been seen about 1,5 years before when an expansive swelling of the entire linea alba was detected. After antibiotic and anti-inflammatory therapy, there was an improvement for about one month, after which the abscess opened. The situation repeated several times. The results of two swab tests showed an E.Coli infection. Antibiotic treatment was given for a total of 10 months.

Case description
The ultrasound of the abdomen was performed and three abscesses with fistulas were identified. There was a suspicion of a foreign body. Decision about surgery under general anesthesia was made. During debridement of the abscesses a metal wire was found in sheath of rectus abdominis muscle. A 7 cm long item was located horizontally between muscles covered by soft tissue. It was impalpable during clinical examination. After debridement, the three-layer closure of wound was done and it was covered by protective gauze.

Results and discussion
After the surgery the horse spent 13 days in the clinic and then recovered at home. He returned to work under the saddle 3 months later. Currently, 14 months after the surgery there is no trace of the past problems and the horse is doing well.

Conclusion
This case is an excellent proof that nothing happens without a reason. The surgery was necessary to find and remove the primary cause.

In Vivo and In Vitro Ageing of a 3D-printed Resorbable Device for Ligation of Tissue in Equines

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Introduction
A resorbable polydioxanone (PDO) device was 3D printed to aid ligation during surgical procedures in equines. The degradation and mechanical performance of the device were evaluated after in vivo and in vitro aging.

Materials and Methods
Filament of PDO was used to 3D print a perforated flexible band with a locking case in one end, facilitating a self-locking loop. For in vivo ageing, the device was inserted subcutaneously on the trunk in six horses and two ponies. The devices were excised at 10 and 28 days. In vitro degradation of the device was carried out under static conditions at 37 °C in PBS buffer. In vitro and in vivo degradation profiles and mechanical performance were tested.

Results
The device was degraded in vivo and in vitro, with release of cyclic and linear water-soluble products. There was a major loss of mechanical performance after only 10 days in vivo where Young´s modulus and tensile strength at break decreased with 28% and 54% respectively. In contrast, these values were stable for the same period in vitro. Furthermore, scanning electron microscopy revealed complete disruption of the PDO matrices at 28 days of in vivo ageing, this was not observed in vitro.

Discussion/Conclusion
3D-printed PDO device degraded into water-soluble products in accordance with previous studies. However, in vivo ageing resulted in a completely different mechanical behaviour of the devices than after ageing in vitro. This highlights the importance of understanding the differences between in vivo and in vitro ageing when testing medical devices.

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Injury of the sustentaculum tali associated with tenosynovitis of the tarsal sheath: clinical presentation, surgical management and outcome of 5 cases

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Introduction
The sustentaculum tali (ST) is a prominent osseous projection at the medial side of the calcaneal bone. Due to its sparse soft tissue coverage, external trauma may easily lead to injury and fracture. The lateral digital flexor tendon (LDFT) and the tarsal sheath (TS) are often involved in the disease. This study aims to describe the clinical presentation, diagnosis, surgical management, and outcome of five horses with septic and non-septic ST injuries.

Materials and Methods
A retrospective case report of 5 cases.

Results
Three of the five cases presented ST injury with accompanying septic TS synovitis. Two of the five cases showed bone remodelling and exostosis formation at the ST and non-septic tenosynovitis of the TS. Surgical treatment included tenovagiscopy of the TS, debridement of intrathecal LDFT lesions, ST fragment removal, and bone curettage. All horses were followed-up. Long-term, three horses were ridden at the previous level. One horse performed at a lower exercise level. One horse with an ST exostosis of unknown cause and an LDFT lesion was euthanized because of recidivism.

Discussion
Horses with ST fracture and septic TS due to traumatic and penetrating injury have a good prognosis with surgical treatment including wound debridement, fragment removal, and TS lavage. The prognosis is considered poor when recidivism of ST exostosis occurs.

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Intramural jejunal haematoma in an Arabian mare– Clinical presentation, diagnosis, treatment and results.

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Introduction
Intramural haematoma of the small intestines as a cause for colic in horses is a rare condition scarcely described in the literature. Intramural or submucosal hematomas of the small colon were described previously. Complete surgical resection and anastomosis is required and carries a favorable prognosis. In humans it most commonly affects the jejunum, but may involve various gastrointestinal segments. Common causes include blunt abdominal trauma, coagulopathy, pancreatic disease, malignancy, inflammatory and immune-mediated disease.

Case description
An 11 years old Arabian mare, three months pregnant, was presented to the VTH for colic. Upon arrival the mare was painful, and didn't respond to analgesia and medical treatment. She underwent exploratory laparotomy, which revealed 70cm jejunum segment with haematoma and necrotic appearance of its antimesenteric aspect. A hand sawn end-to-end jejunojejunostomy was performed. The segment was sent for histopathology- locally extensive acute haemorrhage and necrosis between the inner and outer muscle layers were found.

Results
The mare recovered well, aside from two mild colic episodes. One-year post surgery the mare is healthy, and gave birth to a healthy foal.

Discussion
The present case report describes the successful outcome of resecting portion of the SI due to intramural haematoma. Intestinal intramural hematoma is an uncommon condition in horses, and most cases involve the small colon rather than the small intestine. The etiology of the condition is yet to be determined. The case emphasizes the importance of sending intestinal samples from abdominal surgery for histopathology. Additional descriptions will contribute to better understand the pathology.

Pastern joint arthrodesis in a filly with subchondral bone cyst in the proximal phalanx

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Introduction
In the horse, the phalanges are the second most common location for the occurrence subchondral bone cyst after the medial femoral condyle of the stifle.

Case description
A one-year-old Czech-warmblood filly was presented with chronic left hind lameness due to subchondral bone cyst (SBC) localized in distal aspect of the proximal phalanx. The defect was managed surgically through inverted “V” skin and tendon incision with transection of collateral ligaments. Surgical treatment of the SBC involved removal of the cyst content, curettage and filling the cavity with a biocement substance. Subsequently, arthrodesis was performed using three 4,5 mm transarticular cortical screw. An axially screw was placed as a first in lag fashion from dorsoproximal aspect of P2 in the distoplantar aspect of P1. Second and third screw were placed parallel, 1 cm abaxial to the axial plane in proximodistal direction. A half-limb cast was placed and maintained the distal limb in neutral position.

Results
The filly was confined in the box for 3 months and maintained in the bandage cast for an additional 6 weeks. Control radiographs after 3 months confirmed almost complete bony fusion of the PIPJ and mild osseous periarticular reaction.

Discussion/Conclusions
This case report describes the successful return to athletic function of a filly following treatment of a SBC in the distal aspect of P1 using an arthrodesis of pastern joint with three cortical bone screws placed in crossed lag fashion in combination with intralesional application of biocement powder.

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Safety of tiludronate : retrospective study on 1804 horses

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Introduction
Tiludronate is a bisphosphonate used to treat numerous bone conditions in horses, especially navicular syndrome and bone spavin. Scientific literature suggests good tolerance but recent practitioners' reports of potential side effects motivated a large-scale retrospective study.

Objective
To assess tolerance of a single slow IV administration of 1mg/kg tiludronate (TILDREN ND) in horses.

Material and methods
Each horse that received at least one tiludronate-based treatment between 2006 and August 2019 at Virginia Equine Imaging or Fairfield Equine was included in the study.
Concomitant medical treatments, preliminary NSAID injection and potential side effects (signs of colic, renal failure, fractures, any potentially related clinical abnormality) were recorded after each administration.

Results
Tiludronate treatments were administered to 1804 horses over the study period. Out of the 2497 injections, 2390 were preceded by an intravenous flunixine injection.
Twenty-three horses displayed potential side effects. The most frequent one was colic signs (18 horses), that remained mild to moderate. Most were resolved within hours after medical treatment. One horse presented polyuria/polydipsia (resolved in less than a week) and two horses presented a traumatic fracture (proximal sesamoid bone, tuber coxae) several months after treatment.

Discussion
Collected data suggests excellent tolerance to tiludronate in both practices. The proportion of reported side effects (<1%) was lower than published data. This can be due to flunixin injection, which would limit signs of colic after Tildren administration. Despite use of a NSAID, no case of renal failure was reported. The two fracture cases were deemed independent of Tildren administration.

Surgery and rehabilitation in a case of multiple fractures of the thoracolumbar dorsal spinous processes in a horse

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Introduction
Fractures of the thoracolumbar vertebrae in the horse are usually a traumatic in origin. The prognosis is strongly associated with the occurrence of damage to the central nervous system.

Case Description
An 11-year-old (580 kg) stallion presented with a 3-week history of severe ataxia. The owner reported that neurological signs had acute onset due to trauma and improved with corticosteroids and NSAIDs. Clinical presentation deteriorated without anti-inflammatory drugs. On examination, the horse showed ataxia grade 4 (Mayhew's score). Radiography and ultrasonography revealed fractures of dorsal spinous processes (T16-L1). The T16 fracture was comminuted, with a large fragment displaced cranially overriding T15. The T17 to L1 fractures were transverse; T17 was displaced cranially; T18 and L1 were aligned. Displaced fragments were surgically removed with the horse standing and sedated. A gradual rehabilitation program increasing proprioceptive challenges was carried out. The horse was undergoing ridden exercise 3 months after surgery.

Discussion/Conclusions
A thorough radiographic examination of the thoracolumbar spine of an adult horse is difficult, and in this case, it was not possible to determine if the vertebral canal was damaged. However, the horse improved with anti-inflammatory drugs at first, suggesting that neurological signs were more likely associated with local inflammation. The purpose of surgery was to remove displaced fragments and control pain and inflammation, removing malalignment healing leading to impingement. This case suggests the relation of severe trauma with proprioception deficits associated with muscular inhibition, which results in inappropriate neuromuscular afferent output for the accurate execution of movement.

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Surgical repair of congenital lateral luxation of the patella using a polypropylene mesh in two Arabian foals

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Introduction
Congenital luxation of the patella is most commonly reported in miniature horses and ponies but can occur in all breeds. Surgical repair of lateral patellar luxation through lateral release and medial imbrication has reportedly produced good results in ponies, but in larger breeds post-operative reoccurrence of the luxation is common.

Case Description
Two Arabian foals were diagnosed with congenital lateral luxation of the patella by palpation and radiography. No additional congenital abnormalities were noted. The two foals were surgically treated by transecting the lateral parapatellar fascia (tendon of gluteofemoralis muscle, lateral femoropatellar ligament, lateral patellar ligament, parts of tensor fascia lata muscle) and imbricating the medial parapatellar fascia (femoropatellar joint capsule, sartorius muscle, medial patellar ligament) with seven interrupted vertical-mattress sutures using USP 0 polydioxanone. The imbrication was reinforced with an onlay polypropylene mesh.

Results
Post-operative complications included incisional dehiscence and infection in both foals and septic arthritis of the femoropatellar joint in one foal. On follow-up 6-12 months after surgery both horses showed no lameness, the patellae were in the correct position and no radiographic abnormalities of the stifles were visible.

Discussion
Surgical repair of congenital lateral patellar luxation by transection of the lateral parapatellar fascia and imbrication of the medial parapatellar fascia can be reinforced by suturing an onlay polypropylene mesh to the imbricated fascia. This modification of the surgical technique can improve the success rate of this surgery in large breed horses. Several post-operative complications were encountered and should be considered before undertaking this procedure.

Surgical treatment of a postoperative iatrogenic synovial hernia of the carpal tendon sheath in a horse

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Introduction

Iatrogenic articular or tendon sheath synovial hernias after arthroscopic or tenoscopic procedures are rare and outcome after surgical management is barely reported.

Case description

A 6 years old Warmblood mare underwent diagnostic tenoscopy of the right carpal tendon sheath followed by standard skin closure and postoperative bandaging. Sutures were removed 2 weeks after surgery. In the postoperative period a progressive fluctuant non painful swelling appeared on the palmarolateral side of the antebrachum, just proximal to the antebrachiocarpal joint. Ultrasonography and contrast tenography confirmed two distinct synovial hernias at the location of the previous arthroscopic and instrument portal. Reconstructive herniorrhaphy was performed 6 weeks after the initial surgery. The hernial rings were identified by tenoscopy and subsequently an open approach was used to dissect and remove both hernial sacks (3x3 cm). Both hernial rings were closed with a double layer USP 2/0 continuous suture pattern (polyglactin 910). The dissection plane was sutured in 2 continuous intradermal pattern (poliglecaprone). Bandage was applied for 2 weeks and the horse received antimicrobials and NSAIDs for 5 days postoperatively.

Results

Six weeks postoperatively no lameness was observed and a good cosmetic result was obtained.

Discussion

Synovial hernia is a rare complication after arthroscopy and has never been reported after carpal tenoscopy. Ultrasonography and contrast radiography are valuable diagnostic tools and arthroscopy/tenoscopy helps the surgeon planning dissection and herniorrhaphy. Appropriate surgical correction can provide good functional and cosmetic result.

Large Animals

Canine/Equine Regenerative Medicine

Saturday 10 July, 2021

Veterinary Regenerative Medicine: What we know – a canine perspective.

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Background
The concept of regenerative medicine goes back to the Ancient Greeks who observed the ability of the liver to regenerate, hence naming it hepar, after hepaomai meaning 'repair oneself'. This idea is further reflected in the Greek myth of Prometheus, punished by Zeus for introducing fire and knowledge to human beings. In this myth, Prometheus is tied to a rock and everyday an eagle eats part of his liver which then regenerates. In the late 1800s, there was an awareness of a need for a source of cells 'stem cells' to allow certain tissues, such as blood, skin, bone, to renew continuously over a lifetime. Stem cells are undifferentiated cells that can self-renew by cellular division, and depending on from where and when they are isolated, are variably able to differentiate terminally down a variety of cell lineages. Totipotent stem cells can form an entire organism from a single cell and this ability is restricted to the stem cells of the embryo 'embryonic stem cells', prior to the eight cell morula stage. Pluripotent stem cells can form all the embryonic germ layers tissues (endo-, meso-, ectoderm) and finally multipotent stem cells are further lineage restricted. Stem cells are considered as either embryonic or adult, with adult being defined as those found in the postnatal animal. Finally, there is a category of artificial adult stem cell, created in the laboratory from an adult terminally differentiated cells; the induced pluripotent stem cell. The term "regenerative medicine" is widely considered to be coined by William Haseltine during a 1999 conference on Lake Como. But what do we mean by regenerative medicine, tissue engineering and cell therapy? These terms are frequently used interchangeably, but there are differences (Cossu et al 2018).

- *Regenerative medicine* is a medical endeavour to regenerate tissues/organs and thus restore function. It could be achieved by cells, medical devices, gene therapy or small molecules
- *Tissue engineering* relates to the implantation of artificial tissues or organs and may or may not use cells.
- *Cell therapy* involves the delivery of cells as a medicine. It may not be regenerative, and most reported veterinary work in regenerative medicine is actually cell therapy.

In the 1960s, adult stem cells were extensively researched from experiments examining the potential of bone marrow to recapitulate the blood system, and researchers started to becoming aware if its osteogenic potential. Alexander Friedenstein identified the responsible osteogenic sub population of bone marrow stromal cells as fibroblastic-like cells, isolated by their adherence to tissue culture plastic and ability to form colonies. These bone marrow stromal cells, or skeletal stem cells, or mesenchymal stem cells (MSCs) - a term coined by Caplan in the 1990s (Caplan 1991), have unique defining properties namely, tissue culture plastic adherence, self-renewal, and *in vitro* tri-lineage differentiation (bone, cartilage and fat). Notably, when bone marrow stromal cells are transplanted *in vivo*, they can develop into a fully fledged 'bone organ' (Bianco et al. 2013). The *in vitro* definition of MSCs adopted by Caplan began to be applicable to adult derived cells in many tissues, most notably adipose, leading to a theory of a universal mesenchymal stem cell found in all mesenchyme derived tissues. The MSC from one any adult mesenchyme tissue source was envisaged to be able to regenerate all mesenchymal tissues (bone, fat, cartilage, muscle, nerve, tendon/ligament) irrespective of its adult tissue source, and hence an explosion of research applications of MSCs for in particular musculoskeletal regeneration. After initial experiments it was evident that *in vivo* outcomes were unpredictable, and their status as a stem cell was ultimately questioned, leading to rebadging as a mesenchymal *stromal* cell. What also become apparent was that MSCs had significant paracrine signalling potential (Ucelli et al. 2008)

Application
A PubMed search in May 2021 for "mesenchymal stem cells" returned 70,846 results, whereas "dog mesenchymal stem cells" yielded 833 results, which includes experimental studies. When considering veterinary studies involving clinical patients the number of studies dwindle (Kang & Park 2020). There were a handful of clinical studies on dermatological (wounds, atopic dermatitis) and cardiovascular applications (dilated

cardiomyopathy), 11 neurological studies, mostly focused on spinal cord injury. Of these 7/11 had showed a beneficial effect but only three of those had a control population.

The most prevalent application of ‘regenerative medicine’ in clinical dogs is for osteoarthritis treatment. The rationale for MSCs in canine osteoarthritis has a good basis in experimental research. A landmark caprine study (Murphy et al 2003) demonstrated cartilage healing a meniscal regeneration with a single intra-synovial injection of mesenchymal stem cells. Numerous experimental studies in a range of animals including dogs have also shown that MSCs improve or facilitate the healing of cartilage defects (Sasaki et al 2019), although there are mechanistic contradictions; for example, labelled canine MSCs have been traced in dog studies to contribute to direct cartilage healing by chondrocyte differentiation (Mokbel 2011), whereas some rodent studies only show a stimulation of healing and not direct tissue formation (Satue et al 2019). Basic science MSC research also quite clearly demonstrates anti-inflammatory, immunomodulatory paracrine effects of these cells (Iyer & Rojas 2008). There is therefore a significant potential for MSCs to interact and have a positive impact in clinical disease through immunomodulation rather than all or any effects being by tissue regeneration.

The table below highlights a few canine osteoarthritis studies which were interesting for a variety of reasons including study design (placebo controlled), the number of patients, or use of objective outcome measures. Broadly, there is evidence for some beneficial impact of MSCs to treat the clinical osteoarthritic dog, but the variation between these studies make it hard to clarify the clinical indication and expected response. When asked what is happening in the dogs that respond to stem cell therapy, the answer is we do not know. Clinical veterinary studies are not able to routinely apply advanced MRI techniques, or second look arthroscopy, although one case of second-look arthroscopy showed promising results (Kriston-Pál et al 2017).

Location	Numbers	Cells	Assessments	Author
Hip	18 dogs divided to stem cell and control group (injection of placebo material)	Autologous AD-MSCs; intraarticular injection; 4.2–5 × 10^6 cells	At 30, 60, and 90 days; the results showed significantly improved scores for lameness and the compiled scores for lameness, pain, and range of motion.	Black 2007
Hip	9 dogs in stem cell group; 5 healthy dogs in control group	Autologous AD-MSCs; intraarticular injection; 30 × 110^6 cells	At 30, 90, 180 days; improvement of limb function in dogs with hip OA was objectively seen	Vilar 2014
Hip	8 dogs in stem cell group; 5 healthy dogs in control group	Autologous AD-MSCs; intraarticular injection; 30 × 10^6 cells	At 30, 90, 180 days; reduced lameness due to OA was observed after stem cell therapy.	Vilar 2013
Hip	18 dogs in stem cell group; 17 dogs in PRGF group	Autologous AD-MSCs; intraarticular injection; 30 × 106 cells	At 1, 3, 6 months; Both groups showed safe and effective outcome and compared to PRGF, cell group showed better results at 6 months.	Cuervo 2014
Hip	10 dogs in stem cell group; 5 healthy dogs in control group	Autologous AD-MSCs; intraarticular injection; 30 × 10^6 cells	At 30, 90, 180 days; MSC therapy significantly improved limb function in dogs with hip OA.	Vilar 2016
Hip, Elbow, Shoulder, combinations	74 dogs Prospective, randomised, placebo (saline injection) controlled	Allogenic AD-MSCs 12x10^6	Significant improvement treated CSOM scores, vet pain score, vet global score, owner global score vs control 60 days.	Harman 2016
Elbow	68 dogs, double blinded, placebo controlled (saline injection)	Allogenic Umbilical cord derived MSCs; intraarticular	No change on Force plate Improvements in CBPI 6months	Kim 2019
Elbow	13 dogs, no controls	3 intravenous allogenic AD-MSCs, 1-2 x10^6/kg, q 2 weeks	CROMS showed significant improvement (CBPI, LOAD, CSOM). Force plate & accelerometers no change, synovial biomarkers no change	Olsen 2019

How do we value different studies?

Studies utilising client reported outcome measures (CROMS), if validated such as CBPR or LOAD are valuable if they are applied to a randomised controlled trial. If not, they can be prone to caregiver placebo effect. Objective measures (force plate, pressure mat, accelerometers) are generally unaffected by the placebo effect, and hence have greater reliability in studies which do not include controls or placebos, but are most powerful when they do. The contradiction seen in some studies between objective measures and CROMs does not necessarily mean the CROM result is spurious. It is entirely possible for a benefit of stem cell therapy to be identified using CROMs and not identified using objective data measures of movement, particularly in a multi-joint diseased dog, whereby their options for weight-redistribution are limited. Likewise, more qualitative aspects of a more comfortable joint, which are relevant to the patient may not be identified in gait analysis but show-up when using a CROM. It is worth noting that the FDA and EMA now accept CROMs as a key outcome measure. With due consideration of the study set-up both CROMs and objective outcome measures can be useful, and probably they are best when combined, but it should not be expected that they will give allied results. Beyond study design, are there other reasons why clinical studies are so variable? Consider the following:

1. Is the therapy regime correct? The analogy is prescribing a pharmaceutical such as an antibiotic.
    a. Correct dose & duration = cell number, frequency application, duration application?
    b. Correct indication = early vs late disease? Which joint?
    c. Correct drug = Correct stem cell type? Correct vehicle – saline, PRP etc?
    d. Correct route = intravenous, intraarticular?
2. Is the MSC source appropriate – “apples and oranges”.
    a. Source tissue, allogenic, autogenic, cellular subtypes – may be determined by functional assays or cell surface markers. Individuals may have MSCs with different potency, which we cannot account for.
3. Do experimental models accurately represent clinical osteoarthritis?
    a. Acute damage leads to upregulation of chemical stem cell attractants such as SDF1 (Penn et al 2010). This may facilitate the administered stem cells binding to sites where healing needs to occur. Chronically diseased osteoarthritis joints do not significantly express these homing signals.
    b. Chronic OA environment may be detrimental to stem cells (Kiefer et al 2015).

What next - Is it reasonable to use stem cell therapy for OA in dogs?

Management of osteoarthritis in dogs is clinically significant problem for which we are still relatively limited in our treatment options, particularly in late-stage disease. MSC therapy does not have any reported complications (Kriston-Pál et al 2020), and there are indications of benefit. Clearly, more veterinary clinical trials are needed but they need to make consideration and improved reporting of bio-composition (cell source, culture techniques, and any validation studies – surface marker expression, live:dead etc). In the currently unregulated landscape of stem cell therapy for dogs, this could be improved by imposed regulation from appropriate bodies (VMD, EMA). Studies also require greater consideration of their design including n-number, inclusion criteria, baseline evaluations, what outcome measures should be used. CROMs are accessible and should be layered onto studies which have the luxury of objective measures. A control group, and better still, a placebo-controlled group will clarify the potential and help us to determine the correct 'prescription' of regenerative medicine in veterinary medicine.

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What's up: Regenerative medicine strategies for canine and equine patients – Orthogen

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Orthogen is a biotech company producing the medical devices Orthokine®vet irap (10ml and 60mL) and Osteokine®ProGen. The devices are used to produce Autologous Conditioned Serum (ACS) / Blood Cell Secretome (BCS) and Platelet Rich Plasma (PRP) respectively. Veterinarians as well as human doctors may process these Autologous Blood Products (ABPs) in their own practice for use on their own patients.

To define a strategy to treat certain indications it is pivotal to understand the differences between the ABPs used in practice. They differ strongly in means of content and composition after being processed. We see ACS / BCS as an anti-inflammatory and regenerative therapeutic for synovial structures and inflamed soft tissue while PRP is rather used for pathologies with substantial tissue loss in tendons and ligaments to support regeneration and restauration of function.

New insights on the mode of action of ACS/BCS can be drawn from a human knee OA study examining biochemical changes of synovial fluid. Changes in parameters like Nitrate, Dienes and synovial fluid viscosity show that clinical effect of ACS/BCS may not only be attributed to IL-1Ra blockage. The complex composition of the Blood Cell Secretome may have an effect on immune cells probably stimulating a shift in macrophage polarization.

Neonatal Cell Therapy In Two Animal Species For Osteoarthritis Management

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Several Mesenchymal Stromal Cells (MSC) types are currently being investigated in veterinary medicine for different purposes in different animal species, initially for horses then dogs and now cats. Conditions which are investigated the most frequently are those affecting locomotor system. The initial assumption was to take advantage of the in vitro potential of those cells to differentiate in a desired cell type specific of a tissue under laboratory condition, to recreate in vivo a new tissue as functional as the native one injured in a regenerative attempt. This objective is not met yet and the related assumption is not yet verified today. However, MSC display a strong immunomodulatory and anti-inflammatory activity through cell-to-cell contact and bioactive molecules secretion which can be harnessed in vivo to control and modulate chronic inflammation and promote harmonious healing of injured tissue. This is the rational for investigating their use in the medical management of osteoarthritis (OA) in an attempt to slow down cartilage degradation and eventually promote its healing.

Allogeneic use of MSC (patient is treated with cells from a healthy donor) is very attractive to democratise this approach compared to autologous approach (patient is the donor) and is gained more and more interest by pharmaceutical companies to develop them as a standard veterinary medicine. However allogeneic setting raises questions, such as cell immunogenicity, transmission of an extraneous agents from the donor to the patient...

Compared to their adult counterparts from adipose tissue, peripheral blood or bone marrow, neonatal MSC retrieved from neonatal tissues such as umbilical cord connective tissue, placenta, amniotic membrane, have special features that make them very attractive for such approach of OA management: i) their recovery is “easy” and harmless for the healthy animal donor - ii) they are less prone to carry extraneous agents than adult tissues (Denys et al. Biopreserv & Biobank. 2020) - iii) they display more potent immunomodulatory activity (Saulnier et al. Vet Immunol Immunopathol 2015) - and iv) they retain a low immunogenicity under inflammatory conditions (Cabon et al. Front Vet Sci. 2019).

In a preclinical model of rabbit mild OA induced by meniscotomy (Saulnier et al. Osteoarthritis and Cartilage 2015) we showed that neonatal MSC injected in the knee during the inflammation peak were more proficient than if injected after, to decrease inflammation (IL1b), catabolic markers (MMPs), cartilage fibrillation and degradation (Col2A marker).

Considering the recognised short half-life of MSC when injected intraarticularly, we investigated in a randomised and double blinded clinical study with client-owned horses with moderate to severe OA, if a second injection of neonatal MSC one month after could improve the clinical benefit observed with a single administration (Magri et al. Front Vet Sci 2020). Data show that despite the positive clinical improvement observed after first injection, second injection did not bring additional benefit.

Interestingly, in a second study (Cabon et al. Front Vet Sci 2019) in client-owned dogs suffering from moderate to severe OA and refractory to other treatments, a second injection at 6 months was able to prolong for 6 additional months the clinical benefit observed during the initial 6 months period in all dogs. 75% of owners reported a two-year health benefit and mobility improvement. In this study we investigated a potential humoral response against allogeneic MSCs but was hardly detectable in only one dog after a second injection.

In both dog and horse setting, there was a reasonable number of occurrences of minor to mild proinflammatory adverse events appearing shortly after injection and resolving in most cases in a few days without pharmacological intervention. Only in exceptional cases a moderate to severe inflammatory events were observed regressing under anti-inflammatory pharmacological intervention, but with surprisingly good clinical and sportive evolution. No long-term safety concerns were recorded over the two years follow up period for dogs.

Those studies, despite their inherent biases, bring further evidence that MSC and in particular neonatal MSC are a promising therapeutical tool to manage for the long-term management of OA, without compliance and mid-long tolerance problems, representing a significant advance over current pharmacological treatments. Vetbiobank is committed to bringing this innovation to the market for the benefit of animals' wellbeing.

Boehringer Ingelheim's regenerative medicine strategies for canine and equine patients

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Musculoskeletal diseases in horses and dogs often results in an early retirement from an athletic career or in reduced mobility and pain resulting in diminished quality of life. Most available treatment modalities aim to reduce the pain and improve the animal's comfort. However, these therapies usually do not prevent further tissue degeneration and may even result in a progression of the disease. Regenerative medicine strategies are being explored in order to create sustainable treatments with long-term beneficial effects breaking the degenerative cycle and improving longevity and quality of life of both athletes and family members (including pets).

Peripheral blood is being used as a source of mesenchymal stem cells (MSCs) because of its ease of collection, large availability, and low immunogenic nature. In this regard, chondrogenic induced equine peripheral blood-derived MSCs in an excipient of equine allogeneic plasma (EAP) was the first stem cell product obtaining marketing authorization by the European Commission[1,2].

The regenerative strategy for horses is a local injection into a diseased joint or tendon. In order to give the cells the correct signals to target a certain disease, predifferentiation towards cartilage or tendon cells is induced *in vitro* and confirmed on a gene and protein level. This approach results in promising clinical outcomes[3-9].

The regenerative strategy for small animals, such as dogs is a systemic application for the ease of use, general application and multimodal approach. In this presentation the immunomodulatory potential and biodistribution pattern of MSCs after intravenous application of technetium-labelled MSCs in dogs is further being elaborated on.

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Adjunct regenerative Therapy in spinal Surgery

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Introduction
Intervertebral disc disease (IVDD) is a multifactorial disease process influenced by age, genetics, mechanics, overweight, malnutrition and trauma. All of these causes result in reduction of disc cells and an increase in catabolic remodelling of extracellular matrix (ECM). Additionally, molecular changes induced by the degenerative cascade including upregulation of matrix-degrading enyzmes and altered collagen synthesis by nucleus pulposus cells result in dehydration, loss of mechanical properties and reduction in the ability of the IVD to withstand load. The disase is also associated with inflammatory processes and pro-inflammatory markers and macrophages have been detected in canine degenerated discs. A degenerated disc is prone for pain and dysfunction mainly by mechanical or inflammatory stimulation of neurological or spinal structures.

Intervertebral disc disease can be treated conservatively and surgically but all procedures are directed to alleviate pain or resolve dyfunction by decompression/stabilisation without addressing the underlying degenerative disease process, which is incurable to date.

For this reason, cell-based therapies for treating intervertebral disc degeneration have gathered increasing attention in the past decade in human and veterinary medicine. Because canine IVDD shares many similarities with the human counterpart of the disease, dogs represent a valid large animal model for experimental studies but also for application of new technologies in patients with clinical disease. Results of these translational investigations are about to be introduced in clinical veterinary practice.

Among appropriate cell sources including nucleus pulposus cells (NP), disc chondrocytes, notochordal cells, mesenchymal stem cells (derived from bone-marrow or adipose tissue) have been used most frequently owing to their ease of preparation, self-renewal properties, multilineage potential, safety and immunosuppressive properties. Elegant in vitro studies have demonstrated their efficacy in rescuing and reactivating nucleus pulposus cells isolated from degenerative discs by enhancing ECM synthesis and by promoting upregulation of NP phenotypic markers. Bone-marrow derived MSC (BM-MSC) have been shown to regenerate IVD of dogs with experimentally induced degeneration measured by MRI, disc-height index and demonstration of increased content of proteoglycans/ECM and disc cells. In humans with clinical IVDD intradiscal application of MSC has demonstrated to improve disability in most patients. However, disc height indexes and disc regeneration based upon T2-hyperintensity (mostly expressed as improvement in the Pfirrmann score) have been found sporadically only. According to a recent systematic review, randomized clinical studies in people are lacking thus far and true effectiveness of disc regeneration using MSC is only based upon pilot studies and clinical trials.

Investigations in dogs with naturally occurring IVDD
We have investigated the potential of intradiscally delivered autologous BM-MSC in a total of 25 dogs (including 6 animals used as controls) with degenerative lumbosacral stenosis due to IVDD followed propectively. Different forms of delivery (MSC in saline, MSC bound to microcarriers, MSC bound to microcarriers crosslinked to growth factor TGF-beta 1) were used as adjunct therapy to decompressive surgery. Outcome was measured using a clinical scoring system for function and the Pfirrmann grading system for assessment of the disc status. Overall, results yielded an improvement in the clinical score in all dogs. Regeneration of the lumbosacral disc expressed as a decrease in the Pfirrmann score, could not be demonstrated in any of the treatment groups. Formation of Schmorl's nodes was an undesired side effect in dogs treated with a larger volume of injected microcarrier scaffolds. However, this complication did not affect the clinical outcome at the end of the study.

Based upon our results, intradiscal delivery of BM-MSC in naturally degenerated IVD does not result in regeneration that can be demonstrated with MRI. In this context it is important to note that assessment of disc health and hydration by T2-weighted MRI is an incomplete tool to assess disc function. Conversely, disc hydration most likely correlates with with increased ECM production yet increased ECM is not a definitive proof of successful regeneration. Based upon improved clinical score in humans treated with intradiscal MSC without improved disc hydration other benefits of MSC including activation of endogenous repair mechanisms through a variety of bioactive substances and suppression of the inflammatory environment produced by degenerated IVD have been suggested

Outlook

Dogs from our investigations were followed outside the study period and with two exceptions (control dogs) were not reported with recurrent signs of DLSS during 5-8 years after treatment. Although this information was based on owner information and absence of imaging in most cases it suggests that the effects of MSC treatment may have long lasting benefits and further study to investigate effectiveness of regenerative treatments for IVDD seem justified. A great deal needs to be done (in dogs and people) before cell-based therapies can become an effective new medicine for the treatment of IVDD. Major challenges include the design of robust clinical studies, the introduction of outcome measures in clincal patients that distinguish between symptom-modifying and disease-modifying effects and translation of promising cutting-edge technologies into clinical applications.

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Regenerative therapy for tendon disorders: equine and human

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Tendons can be injured through over-strain at a number of different sites. When injured outside a synovial cavity (extra-thecal), injuries frequently repair by fibrosis but this tissue is functionally deficient compared to normal tendon. Regenerative therapy offers the prospect of improving this repair to restore function and enable a successful restoration of activity while minimising the risk of re-injury. Regenerative therapies are probably best termed 'orthobiologic' therapy as there is currently minimal evidence that any of these therapies can induce true regeneration although many appear to beneficially modify the healing process. These therapies can be subdivided based on their main mechanisms of action into growth factor therapies (PRP and IRAP) and immunomodulatory therapies (stem cells and IRAP).

Naturally-occurring equine superficial digital flexor tendon (SDFT) overstrain injuries in the horse usually have a contained lesion, thereby enabling simple intra-tendinous injection. The equine injury has many similarities to human tendon disease although the correlates are matched more by function than by anatomy due to the differences in tendon loading between bipeds and quadrupeds. This makes the horse a useful model for human tendon disease.

Assessment of efficacy of the orthobiologics has been evaluated both experimentally and in small clinical case series[1-4]. Both PRP and IRAP have shown some benefit in these studies but conclusive evidence for efficacy in clinical cases is limited. The evidence within the human field is divided but a recent large multicenter clinical trial for the treatment of Achilles tendon rupture showed no benefit of PRP.

Mesenchymal stem cells have been in use clinically since the first reported use in 2003[5]. There are multiple sources for the cells but products differ more by their method of preparation – 'minimally manipulated' through direct extraction of a cellular component through enzymatic treatment of the tissue (eg fat) versus ex vivo culture. The latter provides a better defined and more homogeneous cell population and can be combined with bone marrow supernatant to provide an additional growth factor stimulus but necessitates a two-stage process (eg bone marrow extraction and subsequent implantation 2-3 weeks later). To test the hypothesis that stem cells will enhance tendon healing, a controlled experimental study of naturally-occurring SDFT injuries (n=12) has been performed[6]. MSC treatment appeared to 'normalise' many of the relevant tissue parameters so that they were closer to the contralateral, relatively normal, and untreated tendons than saline-injected controls, in spite of labelling experiments showing the majority of cells being lost within 24 hours[7; 8]. A second adequately powered and independently analysed study evaluated the clinical outcome of naturally occurring SDFT injuries treated using this technique (n=113) which showed a significantly reduced re-injury rate[9]. MSCs have also been used to treat a wider variety of other tendon and ligament injuries. The treatment is tolerated well but numbers are too small and injuries too variable to make any firm conclusions on efficacy. This same technique has been translated into the human medical field and a Phase 11a clinical study for Achilles tendinopathy has shown it to be safe and resulted in significant improvement in 8/10 patients.

Intrasynovial (intra-thecal) tendon tears usually communicate with the synovial cavity where the synovial environment is particularly challenging for successful repair because off the lack of a paratenon and adverse effects of synovial fluid on tenocytes within the tendon[10]. However, experimental assessment of MSCs administered intra-synovially have failed to improve healing in either equine (naturally-occurring) and ovine (induced) deep digital flexor tendon (DDFT) tears[11]. Labelling of the implanted cells showed them to lodge within the synovium with no cells present in the tendon defect. Hence, currently, the use of stem cells administered intra-synovially into tendon sheaths are not indicated and scaffolds are likely to offer better advantages for enhancing repair of intra-thecal tendon tears[12].

In conclusion, all orthobiologics are proving popular for the treatment of equine (and human) tendon and ligament injuries although conclusive proof of efficacy is lacking. Care should therefore be taken when using these products and select the most appropriate cases and orthobiologics to use.

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MSC based therapy for severe osteoarthritis of the knee

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Among the degenerative diseases associated with aging, osteoarthritis is the most common pathology and affects 16% of the female population over 65 years. The ADIPOA project started in January 2010 with the goal to develop a new cell based strategy for patients suffering from knee osteoarthritis (OA). Up to now, no therapeutic option exists to obtain a sustainable improvement of joint function beside knee arthroplasty. This prompted us to propose adipose derived stem cells as a possible cell therapy.

Adipose derived mesenchymal stromal cells (ASC) are adult stem cells exhibiting functional properties that have open the way for cell-based clinical therapies. Primarily, their capacity of multilineage differentiation has been explored in a number of strategies for skeletal tissue regeneration. More recently, MSCs have been reported to exhibit immunosuppressive as well as healing capacities, to improve angiogenesis and prevent apoptosis or fibrosis through the secretion of paracrine mediators. We performed 2 pre-clinical models of osteoarthritis, and showed that a local injection of ASC showed a reduction of synovitis, reduction of osteophytes, joint stabilization, reducing the score of cartilage lesions. This work was completed by toxicology data showing the excellent tolerance of the local injection of ADSC and biodistribution showing the persistence of cells after 6 months in murine models. In addition, quality control and tolerability of the injection of adipose derived mesenchymal cells led to the approval by AFSSAPS in France and in Germany by the PEI to conduct the clinical trial.

The ADIPOA research teams performed successfully the phase 1/2 clinical trial is in France and Germany. A phase 2B controlled trial is ongoing to confirm the clinical benefit of this strategy.

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Computed tomography of the neck

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Introduction
A variety of important clinical conditions are attributed to pathology of the equine cervical vertebrae and spinal cord that can result in reduced performance and morbidity. In sport horses, the cervical articular processes joints (APJs) are of particular interest. The clinical manifestations of disorders of the cervical spinal cord and vertebral column include neck stiffness, abnormal posture, reluctance to work, neurologic deficits, and lameness [1]. Abnormalities of the APJs can be caused by developmental defects, trauma and degenerative joint disease, which may contribute to cervical vertebral malformation (CVM) and result in nerve root compression and cervical stenotic myelopathy [1].

Diagnostic imaging of the cervical vertebral column is challenging; some cervical vertebral lesions can be diagnosed with radiography, ultrasonography or scintigraphy [1]. Myelography is used to detect spinal cord compression, however, only dorsal and ventral compression in the sagittal plane will be detected and the sensitivity and specificity of myelography may be site dependent [2].

Equine post mortem studies have shown that CT can image the cervical vertebral bodies, APJs, vertebral canal, soft tissues and compression of nerve roots and the spinal cord [3,4].

In recent years CT techniques for evaluating the cervical spine in live horses have been developed and reported [5-8].

Modern helical CT scanners provide both bone and soft tissue detail. Studies can be reconstructed and assessed as cross-sectional images in any plane, thus avoiding superimposition of anatomical structures seen in other imaging techniques.

Technique
The technique is described in detail by Lindgren *et al* [6]. The horse is anaesthetised and placed in lateral recumbency with the neck in extension. The front legs are tied in a caudal direction with maximal flexion of the shoulder joints, extension of the elbow joints and about 90 degrees flexion of the carpi. When positioned correctly the limiting factor will be the antebrachium colliding with the gantry. If the horse is placed off center the sternum, withers or point of shoulder will collide with the gantry limiting the examination of the caudal cervical and cranial thoracic vertebrae. Anaesthesia is maintained with an intravenous continuous rate infusion [6].

A standard CT study of the cranial neck followed by a study of the caudal neck is obtained. A CT myelogram is then performed if it is deemed safe for the horse or a necessary component for the evaluation of the horse. The CT myelogram is performed with the neck in extension.

Depending on the horse it will have either a free or rope assisted recovery with the vast majority (>90%) having a free recovery. Anaesthesia time from induction to placement in recovery ranges from 45-60 minutes for the full examination including standard CT and CT myelography.

CT findings
Osteochondral fragments: with true 3D imaging and no superimposition CT is superior to any other imaging technique in detecting and correctly determining the position of osteochondral fragments. Fragments have been seen in relation to APJs (cranial, caudal, axial, abaxial), the transverse processes and the ventral processes.

Fractures: CT is superior in identifying obscure fractures like fissure lines and non-displaced fractures compared to conventional radiography. Healed chronic fractures may be detected as periosteal proliferation and callus formation. The complex anatomy of the equine cervical bodies and the superimposition of structures on conventional radiography make misinterpretation a high risk especially in fractures in the sagittal plane.

Soft tissue lesions: modern helical CT scanners have very good soft tissue detail, enabling identification of soft tissue masses in or surrounding the spinal cord. Lesions of the neck muscles can be detected including partial rupture and abscess formation.

APJ osteoarthritis (OA): OA of the APJs is a major cause of decreased performance in sport horses. CT can visualise the 3D anatomy of the APJs. The correct anatomical location (axial/abaxial) of proliferative and osteoarthritic changes can be determined. Axial deviation of the joint capsule and distension of the APJs can be detected using myelography.

Intervertebral disc: CT visualises intervertebral disc degeneration, protrusion, calcification and collapse.

Spinal cord compression: CT myelography can accurately detect spinal cord impingement and compression. Lateral and dorsolateral compression which will not be identified in conventional myelography can be diagnosed. CT myelography with the neck in extreme positions is not feasible in larger horses, thus dynamic lesions may not be detected.

Conclusion

CT of the neck and CT myelography offer many advantages over other imaging techniques. Pathologic disorders that were not possible to diagnose reliably before can readily be diagnosed with CT. More studies are needed to correlate CT and clinical findings. CT should be considered the current golden standard for imaging of the neck.

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Repair of cervical subluxations and fractures

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Vertebral fractures in horses tend to involve the cervical or thoracolumbar regions. Foals are more susceptible to vertebral fractures than adults and cervical vertebrae are more likely to be affected. The causes of spinal trauma vary according to the age of the horse. The most common injuries in young horses (less than 6 months old) involve luxations, subluxations, and physeal separations of the most rostral cervical vertebrae, especially the axial dens or odontoid process. Depending on the degree of spinal cord compression and the neurological deficits, such fractures can be stabilized by internal fixation.

Adults are more commonly injured in high speed or race accidents and fractures can involve both the cervical and thoracolumbar regions. The fractures of the cervical vertebrae most frequently diagnosed are compression fractures of the vertebral body, followed by articular process fractures. High energy impact usually results in catastrophic fracture displacement, leading to major neurological signs and recumbency. For this reason, few attempts have been made to surgically repair such injuries. In some cases of cervical vertebral fracture, spinal compression may be minimal despite the obvious bone disruption. In this situation, spontaneous bone healing can occur but common complications include neurologic sequela and recurrent pain due to exuberant callus or domino-effect instability. Internal fixation can be used to stabilize the unstable fragments and thus prevent increased compression due to further displacement, and to prevent delayed compression by the callus, especially at the ventral border of the canal.

Cervical vertebral fractures (C3 to C7)
One common fracture configuration, associated with moderate to mild neurological signs that can be treated surgically, is an oblique displaced fracture of the caudal aspect of the body of the vertebra. Due to the strength of the strong fibrous intervertebral disk, displacement at the disk is minimal but often considerable at the mid-vertebra (Fig 1). In other situations, the fracture follows a transverse plane, across the vertebral body with slight displacement, or involves the base of the cranial articular process or the dorsal arch. Falls in which the neck is severely hyperextended can result in a severely displaced fracture with ventral rotation and displacement of the caudal vertebra through the ventral half of the caudal end plate of the body of the adjacent cranial vertebra. If trauma is severe, the dorsal lamina and pedicles of the caudal articular process fracture and rise up, effectively deroofing the spinal canal (Fig 2). Although such fractures can produce severe angulation of the spine, this deroofing reduces the neurologic effects. Cervical vertebral body fractures can also occur after ventral interbody fusion using a Kerf-Cut cylinder (KCC), particularly at C5-6 and C6-7. A complete neurological exam should be performed and repeated after starting the medical treatment. Fracture configuration, mainly for the rostral vertebrae, can be assessed radiographically, using the latero-medial and dorso-ventral views. Computed Tomography imaging is extremely helpful to determine the three-dimensional configuration of the fracture and to detect latero-medial displacement and compression.

Case selection for surgery
Deterioration of the neurologic deficit is a clear indication for surgical stabilization. In some horses with displaced fracture of the ventral part of the cervical body, the fracture line does not extend to the canal and ataxia may be due to direct injury to the cord during the fall, or to possible mobilization of the disk towards the canal, as described in humans or dogs. In such displaced fractures, internal fixation is elected. Displacement of the fragment during neck movements and possible further deterioration of the disk may lead to chronic pain and instability of the adjacent cervical joints.

Some horses with articular process fractures develop cervical osteoarthritis with neck stiffness and limited lateral flexion. In this situation, ventral cervical fusion may be used preventively, in the acute stage, to stabilize these articular fractures and improve the prognosis. When the fracture has already healed and the callus has already developed and is compressing the spinal cord, ventral cervical fusion is less indicated, especially if myelography or CT examination reveals permanent compression, whatever the position of the neck (static compression). In this situation, dorsal laminectomy should be preferred. The availability of sufficient bone in the vertebral body for implant fixation is an obvious necessity. Due to the difficulty to stabilize displaced fragments and frequent involvement of the intervertebral disk, fixation is almost always combined with cervical arthrodesis using ventral plating

Cervical fusion in vertebral subluxation

Cervical fusion is also indicated for surgical management of vertebral luxation and subluxation. The latter is one of the components of the cervical vertebral stenotic myelopathy (CVSM) syndrome and is more frequently observed at C3-C4 or C4-C5 intervertebral space. The most widely used technique with long term and large retrospective studies, is the KCC technique. It is an adaptation of the Bagby basket and uses threaded or partially threaded Kerf cut cylinders. The procedure leaves a core of bone, the isthmus, to encourage growth of bone through the implant and the remaining space is filled with autogenous bone graft. The success rate, meaning return to expected use, varies from 43 to 60%. All authors highlight the importance of case selection in the success rate.

A very solid biomechanical study compared ventral plating using LCP and KCC for cervical fusion at C4-C5 level in single tests to failure. LCP was superior in flexion, extension and lateral bending. Ventral flexion represents the weakest configuration for LCP constructs as the plate is then placed on the compression side. KCC failed with fractures of the caudal vertebral body, between the caudal aspect of the cylinder and the vertebral canal. This situation can be encountered in clinical situations. This experimental data and clinical observations have led us to design new cervical implants similar to the ones used in the human field for similar purposes, such as the anterior Cervical Diskectomy and Fusion (ACDF). The equine cervical implants are designed from CT images, printed in titanium, and reinforced with HIP treatment. The system includes an aiming device and a spacer similar to equine disks in shape. It has an internal pattern with micro holes allowing fast osteointegration. Once the spacer is fixed to the vertebra, a cervical plate with wider ends is placed over the disk and fixed with self-tapping cancellous screws locked in the plate.

Surgical technique

The approach is similar for surgical management of fractures or subluxation, and whatever the implants used. The horse is placed in dorsal recumbency under general anesthesia with the head extended. We use custom-made V-shaped blocks to stabilize the neck in a strictly vertical position. After routine aseptic preparation and placing an impermeable drape, a 30 cm midline ventral skin incision is made at the level of the fractured vertebra. The trachea is drawn to the left and the ventral vertebral surface is exposed by blunt dissection. The esophagus and carotids are also identified and retracted using two strong self-retaining Inge retractors while protecting the jaws of the retractor with wet abdominal gauze swabs to prevent slipping and damage to the recurrent nerves and esophagus, especially at the rostral vertebrae.

After sharply dividing and separating the longus colli muscle, using strong mayo scissors and a periosteal elevator, the muscles are retracted, and the ventral spine of the involved vertebra and the inter-vertebral disk are exposed. The fracture site is debrided and the hematoma evacuated down to the fracture bed. The ventral spine of the body of the vertebra is flattened by using a curved osteotome to allow plate application. The fracture is reduced by manipulation with bone forceps and strong digital pressure.

Use of LCP

LCP have advantageous mechanical properties in terms of stability and strength and are preferably used for cervical arthrodesis associated with fracture fixation. Locking head screws can be combined with cortical or cancellous screws applied in lag fashion across the fracture line to compress the fragment. When cervical fusion is performed, cancellous bone grafts, sampled from the sternebrae, or calcium phosphate are placed inside the intervertebral disk space to stimulate their fusion within this space.

Use of 3D printed Titanium Plate and Spacer (3DTPS)

For subluxation, we preferably use the 3D printed cervical plate and spacer, as this implant combines the advantages of a KCC and an LCP plate, providing stability in flexion, extension, and rotation. The aiming device is positioned using radiographic or fluoroscopic guidance. About $2/3^{rd}$ of the disk material are removed with three parallel axial drillings. The spacer is introduced in the disk space through the aiming device using a handle and a hammer. This provides slight distraction. After radiographic control, the spacer is secured with two screws. Then the cervical plate is positioned over the spacer and fixed using 6.5 self-tapping cancellous screws locked in the plate and secured with screw lockers.

Alternatively, KCC can be used according to the surgeon’s preference.

Follow up

Recovery and postoperative management are similar to other techniques. After a period of rest and paddock activity, the activity resumes at 5 to 7 months according to clinical signs and X rays.

In the presentation, the author will briefly describe the results and potential biomechanical advantages and limits of the available implants.

Figures

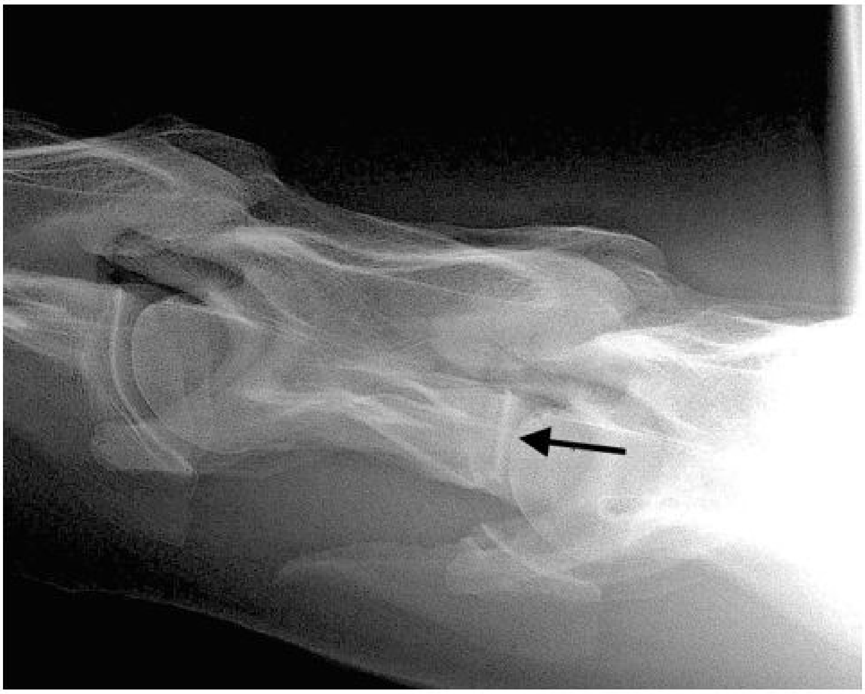

Fig 1: Oblique displaced fracture of the caudal aspect of the body of the fourth cervical vertebra. Due to the strength of the strong fibrous intervertebral disk, displacement at the disk is minimal but severe at the mid vertebra. Note the narrowing of the intervertebral disk space

Fig 2: Custom-made V-shaped blocks used to stabilize the neck in a strictly vertical position (white arrow). These blocks also facilitate placement of the radiographic cassettes. The X ray machine (large white arrow) is fixed to a support arm. The vertebra involved and surgical site are indicated with skin staples (black arrows)

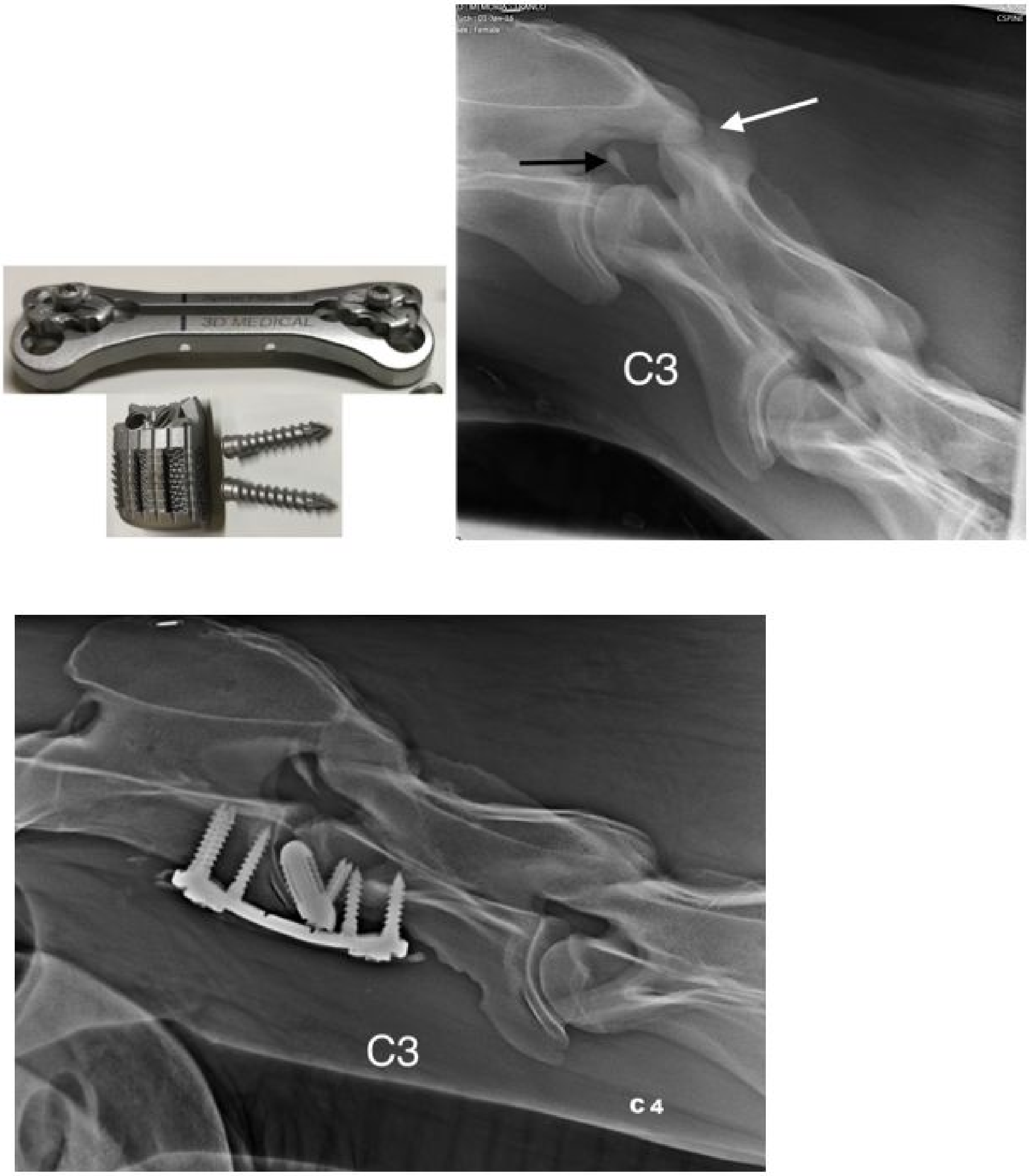

Fig 3: Ventral cervical fusion to stabilize a subluxation and disjunction of the articular facets of C2 and C3 with avulsion fracture. The vertebrae were realigned and fused using a combination of a titanium cage and cervical plate fixed with locking cancellous screws.

A: Titanium cervical cage and plate system

B: Preoperative Xray: subluxation of the articular facets (white arrow); avulsion fragment (black arrow)

C: 2 weeks postoperative Xray: note the good realignment of C2 and C3 and the cancellous locking screws used to stabilize the cervical plate.

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Arthroscopy of the cervical intervertebral facet (articular process) joints

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Background
Arthroscopy of the cervical articular process joints (APJs) was first proposed by Pepe et al (2014) who described a technique for entry into the APJs and the arthroscopic anatomy of the joints. Although the technique may be used to explore the APJ, at Liphook Equine Hospital we have modified the approach and used it to allow the removal of osteochondral loose bodies (OLBs) from the APJs.

Technique
Anaesthesia is induced routinely, and the horse is positioned in lateral recumbency with the affected side of the neck upper most. Where necessary, a fluid bag is placed under the neck to elevate the surgical site, particularly where the cranial recess is to operated on. The location of the APJ is found with ultrasound using a curvilinear transducer and marked with skin staples.

Approach to the cranial recess
A 6cm long incision is made through the skin with a no.10 scalpel blade in a cranioventral to caudodorsal direction. It is continued through the muscle layers of *m. brachiocephalicus, m. omotransversarius* and *m. serratus ventralis cervicis* by division of the muscle fibres where possible. The deeper muscles are left intact. A 19g needle is inserted into the joint pouch and 5ml sterile polyionic fluid injected. A stab incision is made with a no.11 scalpel blade through *m. longissimus atlantis* and *m. longissimus capitis* and the joint capsule 10mm cranial and 5mm dorsal to the cranial margin or the caudal articular process. An arthroscopic sleeve and obturator are introduced in a craniodorsal to caudoventral direction and the obturator is replaced with a 4mm 30^{o} forward facing endoscope. Instrument portal placement is guided by needles.

Approach to the caudal recess
A 5cm long incision is made through the skin with a no.10 scalpel blade in a craniodorsal to caudoventral direction. It is continued through the same muscle layers as the technique for the cranial recess. Again, the joint is distended with 5ml of sterile fluid before a stab incision is made through the deeper muscles and joint capsule. To enter the caudal recess, an arthroscopic sleeve and obturator are introduced in a caudodorsal to cranioventral direction before the obturator is replaced with a 4mm 30^{o} forward facing endoscope. Instrument portal placement is again guided by needles.

Outcome at Liphook Equine Hospital
Between April 2016 and March 2020, 57 horses underwent CT of the neck. OLBs were identified in 14 horses, 5 of which met the criteria for surgery. Horses that underwent surgery presented for poor performance including reduced range of motion of the cervical spine (n=4), pain on palpation of the neck (n=2) and bilateral shortened cranial phase of the stride in front without gradable lameness (n=2).

OLBs were removed from C6/7 in 2 horses, C5/6 in 2 horses and C4/5 and C5/6 in 1 horse. OLBs were removed from the caudal recess of 3 joints, the cranial recess of 2 joints and both recesses in 1 joint. The mean length of surgery was 114 minutes.

A complete resolution of signs of cervical pain was seen in 4 of 5 horses. All owners were satisfied by the outcome of the surgery.

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Cervical Intervertebral Fusion for Treatment of CVM – an Update

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Introduction
Cervical intervertebral fusion is indicated for horses with cervical compressive myelopathy, recalcitrant neck pain, and horses with lameness due to compressive radiculopathy, associated with inflammation of the synovial structures and pressure on the neural outflow at C5-6, C6-7, and C7-T1.

Technique
The technique for intervertebral fusion is similar for midcervical or caudal cervical junctions. Positioning of the horse in dorsal recumbency is required with a fulcrum under the affected midcervical junction, or for fusion of C5-6, C6-7 or C7-T1, complete extension of the caudal cervical vertebrae with support provided at the withers. A ventral midline approach, trachea to the left, and careful retraction of the right carotid and vagosympathetic trunk allow exposure of the longus colli muscles along the ventral aspects of the vertebral bodies. Use of Finochietto and Myerding lamina spreader retractors is essential for exposure. Intraoperative radiographs are used to verify the appropriate level before resection of the ventral crest of the cranial vertebrae of an affected junction. A midline 25mm hole is then made using a drill guide affixed to the bone of the resected ventral crest, after intraoperative lateral radiographs establish that the drill is centered on the most cranial extent of the intervertebral disc as it curves cranially. The drill should penetrate only 15mm, and is then exchanged for a kerf cutter style core saw (Fig 1), which advances until 25 to 30mm deep. This is then followed with a 25mm diameter tap which cuts threads in the deeper portion of the hole. A partially or fully threaded perforated stainless steel implant (Bagby or Seattle Slew implant) is then threaded into the prepared site, packed with drillings, and seated below surrounding ventral cortical bone of the vertebrae (Fig 2). The closure of the repair is routine, and a suction drain is always placed to evacuate serum accumulation.

Fig 1. Typical instruments for fusions.

Fig 2. Well seated partially threaded implant at C3-4.

Recovery From Anesthesia
Horses having single or double-level cervical fusion are generally moderately-to-severely ataxic prior to surgery, and assistance in the recovery box is important. Most horses will respond favorably to tail rope with several people assisting at the head and shoulder. Use of head ropes is not advised due to the nature of the surgery. Yearlings occasionally resist efforts to assist at the head; however, judicious use of assistance at the tail can be quite helpful in allowing these horses to regain their stability. All horses have a suction drain inserted at the time of surgery, and this is kept covered with a neck bandage for recovery. Recovery can frequently take one-to-two hours. Use of perioperative and postoperative steroids is rarely advised. However, if the horse has been

recalcitrant to attempts to assist it to stand, a large dose of dexamethasone, deep bedding, and reduced lighting may allow an improved attitude for recovery.

Aftercare
All horses have a suction drain applied at the time of surgery, and this needs hourly evacuation initially and every four hours thereafter. As much as 60 mls of serosanguinous fluid can be evacuated per hour initially. A syringe apparatus works well to provide suction. The danger of disconnection of the sterile line and syringe necessitates careful monitoring, attaching the syringe to the mane, and occasionally covering with portions of the neck bandage. Three rolls of four inch Elasticon cover the neck and minimize seroma formation. Additionally, the stapled skin wounds are covered with a stent bandage. Suction drainage apparatus are usually removed on day 3 to 5 postoperative. This usually also signals the endpoint for perioperative antibiotic therapy. Most horses receive prophylactic crystalline penicillin and Gentocin due to the severe consequences of infection at the surgery site.

Horses are confined to strict box stall rest, with careful handling the initial 8 weeks after surgery. Occasionally, less ataxic horses can commence limited walking exercise four to six weeks postoperatively, however, this is depends on the case.

Owners of horses undergoing surgical fusion are forewarned that most improvements in the degree of ataxia are gradual. Exercise is often dictated by the neurological deficit. Horses that are making steady progress, are allowed out for increasing periods of walking exercise from the 6 to 8 week point. Most horses are not allowed free pasture activity until radiographs 3 months postoperatively indicate advancing cervical fusion. If there is a delay in the formation of bridging callus through the implant and ventral to the implant, pasture exercise may be delayed until 4 months postoperatively.

Radiographs monitor the progression of fusion. The 3 month radiograph is followed by a 6 month evaluation, where a decision is made whether to continue pasture activity or attempt some training exercises. Neurological improvement will continue for as long as 14-months postoperatively, and most horses respond to forced training protocols during the 6-to-12 month period. Yearlings can generally be broken-in 9-12 months after surgery, and often show final improvement to normal during this process. Careful neurological examination 12 months after surgery is mandatory before pursuing more intensive training and riding. The exercise program, while important to continued neurologic improvement, cannot be advanced unless the horse has a final normal neurological examination 15 months after repair. Further improvements beyond this point are rarely recognized.

Overall, the prognosis following cervical fusion in horses is dictated by the degree and duration of neurological deficits initially, but also by surgeon's ability to recognize and treat all of the levels of compression. The most common reason for failure is not fusing all compressed intervertebral junctions. This may increase the need for double-level fusions, and occasionally a horse is a candidate for a triple-level fusion, which the is biomechanically stressful and not recommended.

Midcervical Compressive Disorders
Surgical fusion of the midcervical vertebrae is technically more simple than the caudal cervical vertebrae. The ideal candidate for surgery is a single-level compression, recent onset, and a grade 2 or less in severity. Myelographic examination is important to define clear single-level cases. Controversy and impact on results come with additional compressed sites. Retrospective analysis of the guidelines for myelographic compression compared to histological evaluation at necropsy, indicate a tendency to false positives, based on the fifty percent reduction of dorsal contrast column criterion. However, it is more appropriate to fuse all affected levels, than to leave a questionable intervertebral junction, which may develop more severe compression after fusion of the adjacent intervertebral junction. Fifty-five percent of horses having intervertebral fusion go on to neurologic normalcy. Recovery following surgery can take as long as 14 months, and results are improved by early training exercises, which in many cases includes breaking to ride and the use of reining exercises.

Caudal Cervical Fusion
Intervertebral fusion of the lower cervical junctions is more technically demanding, especially at C7-T1. Fusion at C6-7 is the most common site, although fusion of both C5-6 and C6-7 is frequent (Fig 3). The longer threaded SS implants (4 hole) are preferred for C6-7, while the standard 3 hole implant is adequate for C5-6 (Fig 4).

Fig 3. TB 3yr old, with C5-6 and C6-7 compression. **Fig 4.** Same case after double level fusion.

Neurologic recovery is generally slow, however, the regression and bony arthritic change, including osteophytes and lamina thickenings at the C6-7 and C5-6 junctions is often complete. Sixty-five percent of horses with cervical fusion in the lower vertebra have recovered normal neurological status. Improved recovery is often related to the more definitive diagnosis at this level, compared to midcervical vertebra, where there are often several suspicious sites. Two horses out of 17 C6-7 intervertebral fusions fractured a small portion of the caudal perimeter of C6, and this resulted in increased neck pain, but eventual fusion and recovery of neurological capabilities in both. Fusion for cervical radiculopathy has been done in six horses, four of which recovered from the lameness. Two horses were improved but lameness did not completely resolve.

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Diagnosis & Management of occupational neck pain in human athletes

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Neck pain is not only common in the general population, but also in athletes. The major causes for neck pain are trauma and degeneration. But sometimes the underlying cause is not clear, despite advanced radiological imaging.

The human neck is more vulnerable to trauma in comparison to other mammals. Sporting accidents are second only to motor vehicle accidents as the leading cause of emergency department visits involving neck injuries. These injuries range from simple sprains to severe fractures/dislocations, sometimes resulting in neurological damage with potential devastating consequences. Some sport-specific mechanisms, known for increasing the risk of injury will be described.

In chronic neck pain the degenerative process of the motion segments is a frequent problem. Although studies are showing that common degenerative changes on cervical MRI aren't strongly correlated with neck pain symptoms. Often the neurological symptoms are the main concern in these cases. Untreated myelopathy can result in major neurological deficits with little chance of improvement, even after surgical treatment.

Diagnostics include classic history and clinical examination. Like in most pathology "red flags" have to be excluded. Radiological investigations are often needed to determine the underlying structural cause. Electrodiagnostic tests are frequently indicated in the case of neurological symptoms.

Treatment for neck pain is mainly conservative. Active and passive physiotherapy plays an important role in the treatment of neck pain. Additional infiltrations often complete the non-surgical treatment of neck pain and radiculopathy. Operative treatment is very rarely indicated for axial neck pain, but traumatic injuries and neurological symptoms more often are in need for surgical therapy.

It's common knowledge that physical activity has a positive effect on mechanical complaints and also plays a role in its prevention. Competitive sports, on the other hand, are physically demanding and certain precautionary measurements can prevent future problems.

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Approaches to management of RLN: discipline-based differences

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Recurrent laryngeal neuropathy (RLN) is the most common cause of left laryngeal dysfunction in horses. The treatment is only surgical and options for affected horses include laryngoplasty (tie-back), partial arytenoidectomy, ventriculectomy, cordectomy or ventriculocordectomy (performed alone or in combination with laryngoplasty), and laryngeal reinnervation.

RLN can take several forms. Laryngeal grading both at rest and during exercise (Havemeyer workshop 2004) will define the severity of the disease but clinical symptoms, age and expected athletic performance of the horse are to take into consideration to proceed with the best surgical option.

Why are the consequences of RLN different among the various disciplines ?
As an obligate nasal breather, the horse is dependent on the reactivity of its airway to adapt to changes in airflow. Diseased laryngeal muscles will quickly lead to performance limitation as respiratory obstruction becomes apparent. Duration of exercise at speed is a major factor in the tolerance of RLN and horses racing or working at speed over 800-1000m will invariably suffer clinical signs of exercise intolerance. Laryngeal stability is the key factor to the onset of exercise intolerance and, although racehorses are most affected, horses from many disciplines (show jumping, eventing, driving…) will exhibit exercise intolerance in forms of early fatigue or laboured breathing when laryngeal collapse occurs.

Horses working at low speed (dressage, pleasure riding) or over short distances will show less exercise intolerance and the main presenting complaint for these animals might be the presence of noise. However, a thorough assessment should be done as subtle signs of exercise intolerance might be missed by the trainer/rider. Also, as the disease progresses or the horse continues in training, exercise intolerance might become more present.

In some horses, training with poll flexion might exacerbate clinical signs of exercise intolerance. Under strenuous exercise, head and neck extension has been shown to have little effect on airway flow mechanics, but head and neck flexion does induce inspiratory obstruction (Petsche 1995). Poll flexion has been shown to worsen laryngeal collapse (Strand 2012). Disciplines where poll flexion is required include dressage, eventing, driving and some harness racing.

Progression of the disease and age of the horse will play a role in selection of a surgical treatment. RLN will progress unfavorably in 80% of cases (Dixon 2003).

Young racehorses that will train early at submaximal exercise speeds will need a fully functional airway as young sport horses where training is done over a longer period of time might perform well with the disease until they enter advanced or elite levels.

How to evaluate RLN in a pre-surgical assessment ?
Endoscopy at rest provides interesting information regarding the degree of left arytenoid abduction, changes in shape or inflammation of the intraluminal laryngeal structures. Upon swallowing, the degree of active abduction, symetry and synchrony of both ayrtenoids can be assessed. However, in most horses, resting endoscopy is insufficient to evaluate the degree of laryngeal dysfunction and pre-surgical assessment should not be based on resting endoscopy alone.

Laryngeal ultrasound is diagnostic for the presence of RLN and predicitive for laryngeal collapse at exercise (Garrett 2011). This technique should be used pre-operatively to assess the echogenicity of laryngeal muscles and anomalies of the laryngeal cartilages. However laryngeal stability during exercise and other forms of dynamic airway collapse will not be observed using ultrasound.

Overground endoscopy allows for evaluation of the laryngeal function during exercise in the same environment as the horse is asked to work, using the same tack and head-neck position. Therefore, it is the most sensitive test to detect all aspects of RLN in the exercising horse.

In summary, resting endoscopy and laryngeal ultrasound give useful pre-surgical elements but overground endoscopy is to date the most informative tool to tailor the surgical treatment for each individual. It should be done in conditions that reproduce real working conditions of the horse (including working speed and head neck position).

Which treatment for which RLN affected horse?
For decades, laryngoplasty has been the gold standard to treat performance limiting RLN. Laryngoplasty restores upper airway function and decreases noise effectively. Combined with ventriculocordectomy, it is currently the most perfomed surgery worldwide to treat RLN in speed and distance horses. Published clinical success for this procedure ranges from 50 to 70% in racehorses and is close to 90% in non racehorses. The main reason for this limited success can be attributed to the post-operative loss of abduction that occurs in the first 6 weeks after surgery. Other complications including suture pull-out, infection, dysphagia and chronic bronchitis also contribute to the limited success of the procedure. Arytenoidectomy is an alternative but does not seem as effective as laryngoplasty in some populations (Witte 2009). Although much work has been done to improve the surgical approach and technique of laryngoplasty, these complications can be serious and horses that do not suffer from exercise intolerance might benefit from other surgical options.

Ventriculocordectomy alone offers a surgical option for horses where noise is the main problem (« unsound of wind ») or that have minimal left laryngeal instability. It does not restore upper airway mechanics and has not be shown to be successful in stabilizing left arytenoid instability in most grade C horses (Barakzai and Cramp 2017). This technique can be done in a minimally invasive fashion using laser and exercise can be resumed shortly after surgery. Ideal candidates include horses working at lower speed/distances, where noise is the main complaint and where arytenoid instability on overground endoscopy is limited.

Laryngeal reinnervation offers the most physiological strategy to restore normal CAD function and laryngeal abduction in RLN affected horses. C1 and C2 nerve transplantation (occasionnally the spinal accessory nerve) into the CAD muscle in horses allows for progressive reinnervation without the adverse effects of laryngoplasty (Rossignol 2018). Laryngeal abduction will be evident during exercise only and overground endoscopy is necessary to evaluate the success of surgery. Pre-requisites for this technique include the presence of remaining CAD muscle fibers visible on ultrasound, as well as sufficient time allowed for the reinnervation to be fully effective. In most horses where reinnervation is successful, 6 months are necessary to observe a complete arytenoid abduction at exercise. Time necessary to achieve maximal abduction plays a role in the decision making for surgery in case of mature race- or sport horses. Complications are few and horses can be trained in that interval if the laryngeal instability is not severe as nerve stimulation occurs during exercise. In cases of pre-operative laryngeal collapse, a new technique combining a moderate-abduction laryngoplasty and laryngeal reinnervation can be offered (see Dr Rossignol's presentation). Ideal candidates for reinnervation include young racehorses before training and young sporthorses in training that do not yet compete at maximal speed/effort.

In conclusion, surgical treatment of RLN needs to be tailored towards the specific needs of each individual, considering the stage of the disease evaluated using overground endoscopy if possible, the use of the animal (or intended use) and the age of the horse.

Reinnervation of the larynx: where are we in 2021?

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Principles
Selective laryngeal reinnervation consists of transposing one or several nerve branches activated during inhalation to the cricoarytenoideus dorsalis muscle in order to reinnervate muscles fibers no longer innervated by the affected recurrent nerve. The problematic is different in horses compared to humans. Recurrent laryngeal neuropathy (RLN) in horses is usually a progressive disease marching towards a nearly complete denervation and fibrosis of the cricoarytenoideus dorsalis muscle (CAD). The donor nerve should be close to the larynx and should be activated during exercise and in phase with inspiration at trot and gallop. It is also important that the activated nerve at exercise recruits a good balance of fiber type 1 (slow, resistant to fatigue) and fiber type 2 muscle fibers (fast) in the reinnervated CAD muscle. This is the ultimate goal to reach, in order to get a functional CAD muscle at exercise. The nerve transplantation should also lead to minimal side effects after denervation of the donor site.

EMG of the sternomandibularis muscle
Numerous research work, in particular electromyography studies, have made it possible to find the appropriate nerves, and make sure that denerving the muscles originally innervated by the chosen nerves for laryngeal reinnervation, does not have any clinical consequences. Currently the nerves grafted are the cervical nerves C1 and C2 (essentially innervating the omohyoid muscle), and the ventral branch of the accessory nerve (SAN). This is a large motor nerve, located at the caudal aspect of the larynx. Its dorsal branch innervates the brachiocephalicus and trapezius muscle, and its ventral branch innervates the sternomandibularis STM (or sternocephalicus) muscle. The function of the latter includes flexion and rotation of the neck (Fig 1). We have recently performed an electromyographic study and shown that the SAN is highly activated at canter and galop, with muscle activation beginning at the end of the expiration phase (2/3 of expiration) and ending at the end of the inspiration phase (3/4 of inspiration). This is an ideal timing for CAD contraction at exercise (Fig 2). Mean muscle activity increases with speed at trot and galop. EMG signal amplitude is comparable between high-speed trot and galop.

Patient selection
As CAD rehabilitation needs time, nerve grafting is indicated in very young horses, two-year-olds or yearlings, at the onset of disease. Young sport horses with grade 3 RLN are also excellent patients for reinnervation, as these horses have a long career. Horses with recent roaring following an injection and that do not respond to conservative treatments, often involving the right recurrent nerve, are also excellent candidates for laryngeal reinnervation. Such physiological procedures should provide optimal long-term functional results while preventing complications such as coughing or dysphagia. The procedure was initially performed under general anesthesia but is now performed in the standing patient in almost all cases.

Standing nerve graft
Patient preparation, positioning, anesthetic protocol, and the initial surgical approach are similar to laryngoplasty (Fig 3). The main branch of the C1/C2 nerve is identified with the help of a single pulse nerve stimulator (1mA). The nerve branch that produces the strongest contraction of the OH is selected and gently dissected proximally, as well as one or two other smaller branches. Once they have been sufficiently freed, the distal ends of the nerves are cut.

A caudal approach, by approaching the CAD muscle and MP caudal to the cricopharyngeus muscle, has replaced the initial lateral approach. This technique offers improved access to the CAD, does not involve any myotomy of the cricopharyngeus muscle, and reduces the risk of post-operative constriction of the nerve by scar tissue. The selected main branch of the nerve is implanted within the CAD tunnel using a Reverdin needle from medial to lateral and secured to the lateral belly of the CAD muscle. Any additional nerve branch is implanted directly in a small slit in the lateral muscle belly of the CAD as described

Since January 2019, we are using the ventral branch the Spinal Accessory Nerve (SAN, cranial nerve XI), for laryngeal selective reinnervation. The nerve is isolated at the caudal aspect of the skin incision, just dorsal to the STM muscle. It is freed from connective tissue first dorsally, then caudally along the STM using blunt dissection, and cut. The SAN is brought from caudal to cranial just adjacent to the carotid artery, to be placed adjacent to the larynx and CAD without any tension. It can be grafted alone or in association with the C1-C2 nerve.

Horses resume training at 6 to 12 weeks postop depending on the remaining postoperative function of the CAD, and the expected improvement after ventriculocordectomy. Exercising endoscopy and ultrasound-guided per cutaneous stimulation of the first cervical nerve at the level of the alar foramen, or stimulation of the SAN ventral to the atlas, are used to confirm successful reinnervation postoperatively.

Advantages and limits of laryngeal reinnervation

Laryngeal reinnervation is a more physiological treatment of laryngeal hemiplegia because the larynx is closed at rest and open only for exercise. There is therefore very little risk of coughing or dysphagia on the long term. On the other hand, the rehabilitation of the larynx takes about 6 months to be effective, even if the horse is already partially improved by the removal of the vocal cords and ventricles (laser ventriculocordectomy). The current success rate of this procedure is comparable to that of prosthetic laryngoplasty with fewer complications but only horses with early grade of LH and enough CAD muscular volume can usually be successfully reinnervated. In July 2021, the author has performed about 220 standing nerve grafts with 85% success rate in terms of resolution of the clinical signs. Fifteen percent (mainly racehorses) showed some signs of CAD fatigue with insufficient or not maintained arytenoid abduction at exercise.

Performing the technique in the standing patient is very well tolerated, improves visualization, and reduces the risks associated with general anesthesia and recovery.

For young horses that have never been raced and horses of high value because of their breeding potential, reinnervation can be proposed as it is a physiological and efficient method of treating RLN that enables functional restoration of the CAD muscle.

If the result of laryngeal reinnervation isn’t satisfying, laryngoplasty can still be performed.

Dynamic neuroprothesis (DNP): emerging treatment

This is a concept of enhanced nerve graft based on the observations 1) that some horses with more advanced RLN take a longer time to rehabilitate and 2) that some horses with less severe RLN and having undergone tie-back surgery show an abduction level at exercise beyond the resting tieback level. Therefore, in a subpopulation of RLN horses, DNP may be indicated in cases of laryngeal reinnervation in which a more advanced degree of muscular atrophy of the CAD is present, requiring a longer period of muscle rehabilitation. In this situation, rehabilitation time might be too long with nerve implants alone and the final strength of the CAD may be insufficient to achieve satisfying abduction of the arytenoid cartilage and counteract the negative inspiratory forces during intense and/or prolonged exercise. The goal of the DNP is 1) to reduce the rehabilitation period currently needed to allow time for reinnervation and 2) to improve the effect of reinnervation on the degree of abduction. The principle of the technique is to place a modified laryngoplasty suture over the separation of the medial and lateral compartment of the CAD muscle and add nerve implants. The suture stabilizes the arytenoid in a neutral/ resting position, that is sufficient to reduce the driving airway pressure during inhalation and make it very likely that stimulations of the transplanted nerves (+/- native nerve) will be strong enough to increase the airway diameter at exercise. This technique also enables to reduce fatigue of the re-animated CAD and prevent associated midline collapse of the arytenoid cartilage. Up to this day, 130 horses have been operated with very promising results. Objective data needs to be collected before drawing conclusions about this new concept.

Figures

Fig 1: Contraction of the sternomandibularis muscle during inspiration in a thoroughbred race horse

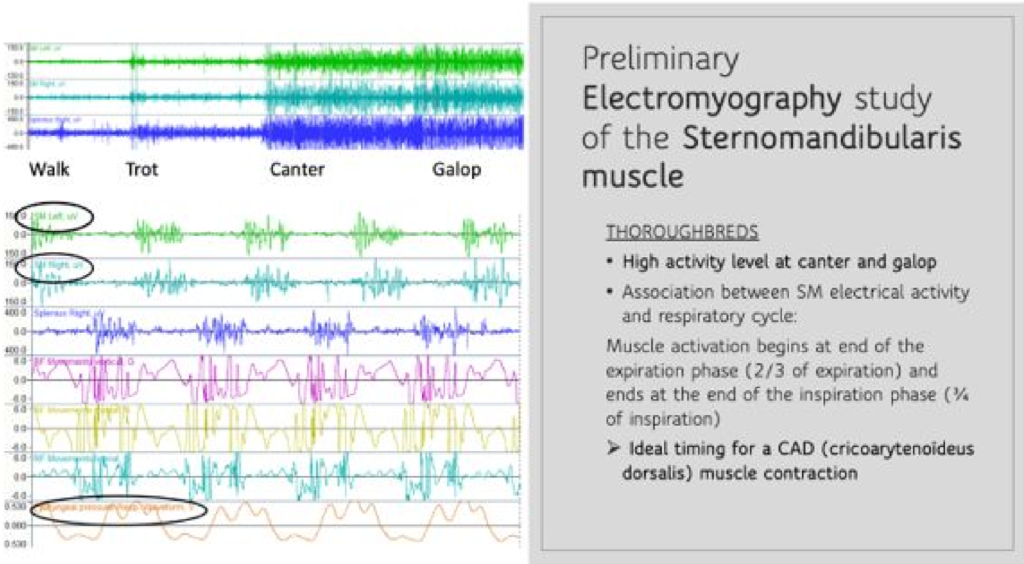

Fig 2: Electromyography of the sternomandibularis muscle innervated by the ventral branch of the spinal accessory nerve

Fig 3: Preparation of the horse for standing nerve graft. Note the head support that can be adjusted forward and backward depending on the horse and neck size and can be elevated or lowered easily.

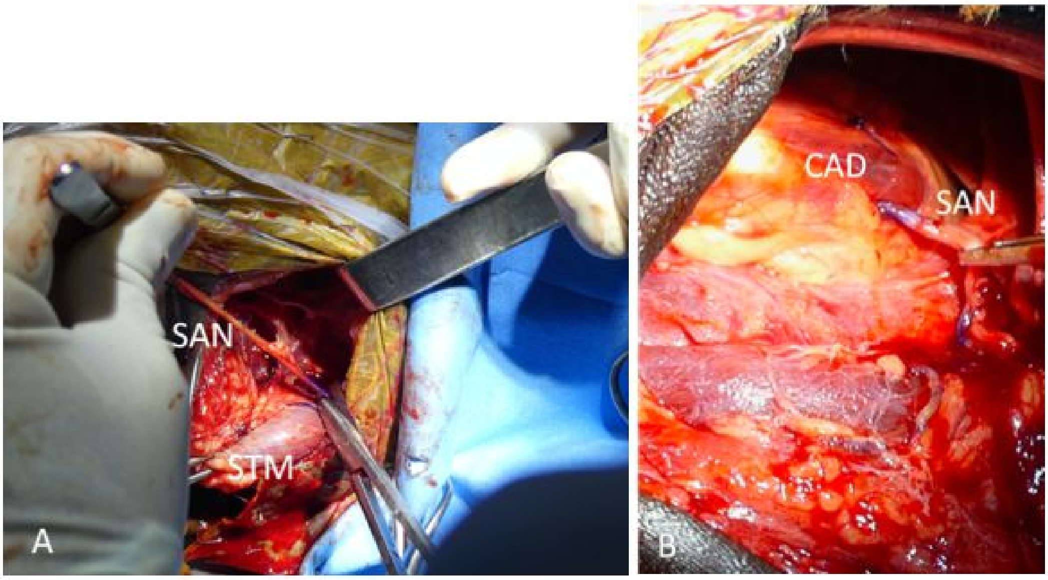

Fig 4: SAN graft in a standing horse. A: Isolation of the main branch of the SAN B: Nerve implanted into the CAD midway between the two bellies. SAN: ventral branch of spinal accessory nerve; STM: Sternomandibularis m.; CAD: Crico-arytenoideus dorsalis m.

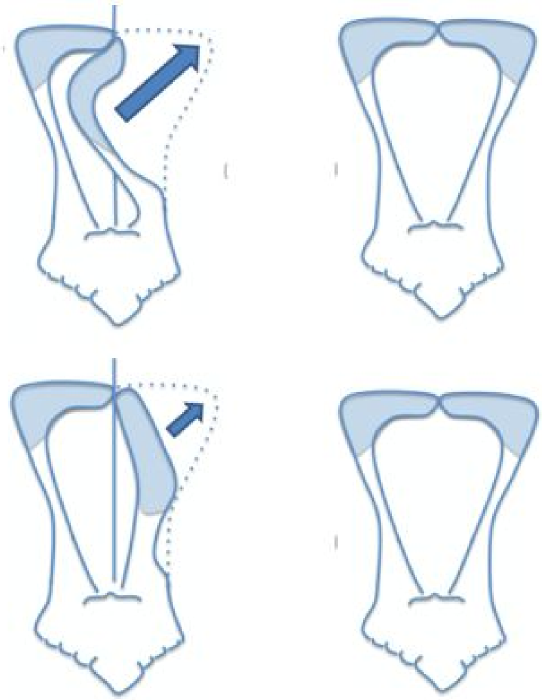

Fig 5: Comparison of the muscular forces required for full abduction between a nerve graft (top) and a DNP (bottom)

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Standing laryngoplasty

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Introduction
Laryngoplasty or “tie back” surgery has become the time honoured standard technique for the treatment of moderate to severe recurrent laryngeal neuropathy in equine athletes. The surgical technique remained relatively standard for a prolonged period of time, but in the last decade there has been considerable evolution. Varying implants have been evaluated for implantation in the cartilage of the arytenoid and the cricoid, the complex anatomy of the oesophageal vestibulum and the muscle bellies of the cricoarytenoideus dorsalis has been studied, and the role of the soft tissues such as the vocal cord and aryepiglottic fold has been expanded. However, by far the most dramatic change has been the trend to performing the surgery in the standing sedated horse.

We have performed standing laryngoplasty for several years now and have developed some techniques to assist with the challenges of surgery.

Draping and Asepsis
The primary problem with any standing surgery is maintaining asepsis. We have observed infection of the seroma following standing laryngoplasty. Our practice policy with perioperative antibiotics is reasonably limited, with none for routine arthroscopy, and three days of potentiated sulphonamides following laryngoplasty under general anaesthesia. Based on experience, we do use three days of penicillin and gentamicin for perioperative treatment of standing laryngoplasty.

Draping is one of the primary problems of standing laryngoplasty. The usual approach to overcome the effect of gravity on drapes is to use adhesive drapes. These can increase the risk of post operative sepsis and we did observe this in several cases. We have had custom lycra hoods manufactured, with Velcro on the left ear so it can be stuck down. The left eye has a complete cover to limit the horse’s reaction. There is large window over the left side of the neck for access to the larynx. After this is placed an adhesive incise drape is placed over the surgical site which adheres much better to the lycra. A translucent plastic drape is then used to cover the lateral head, headstand, and side of the neck. This can be easily clipped or stapled to the hood.

Approach
A nerve block of the cervical nerve has been described. We did not find this easy, and continue to use local anaesthetic in the skin and topically during the approach. We also use topical local anaesthesia, squirting lidocaine into the incision to prevent the horse reacting to the sensation of “digging” on its dorsal larynx.

We have experienced cases where retraction to expose the dorsal larynx was very difficult. As a result of this we have modified our surgical approach. We now incise dorsal to the linguofacial vein. This requires dissection through the distal margin of the parotid gland, which can be separated easily. Care must be taken to avoid the parotid duct in the cranial margin of the incision. Trauma to this results in marked swelling. The duct can be palpated overlying the sternocephalic tendon quite easily.

Under general anaesthesia we used the technique of drilling the muscular process with a 16ga needle, and passing a wire loop through it, which would be used to retrieve the suture from medial. However, with standing surgery we have adopted the simpler approach of driving the suaged taper point needle through the muscular process of the arytenoid. We have always used a caudal approach, retracting the cricopharyngeus cranially rather than establishing a septum between crico and thyro pharyngeus. Recently, we have adopted the use of the Arthrex Fast Tak® or Corkscrew® implants, which can be screwed into the lateral aspect of the arytenoid. These appear quite flimsy, but published data and our experience at post mortem suggests they are surprisingly strong.

We have used the technique of curetting the cricoarytenoid joint for many years, and continue to use this standing. The joint is not necessarily easy to expose and it is an extra step. However, we have removed implants from horses which have undergone joint curettage and have been impressed by the limited post operative adduction. Under general anaesthesia we did use the technique of packing the joint with bone cement. This proved highly effective, in fact too effective. It almost completely prevented subsequent collapse of the arytenoid, and as a result we did see post operative pneumonia in two horses. Therefore we abandoned this technique about the same time we adopted standing surgery, but not because of the change to standing.

Hobday

Most surgeons resect a combination of left or left and right laryngeal ventricles, left or left and right vocal cords, and right aryepiglottic fold in combination with laryngoplasty. However, we have observed problems with laser surgery, including the formation of “web larynx”, or adhesion of the resected left vocal cord to the right cord. Experience with laser surgery has led to respect for the problems it can create, so we avoid it if possible. We have found standing laryngotomy to be quite feasible. Local anaesthetic is injected subcutaneously on the ventral larynx at the same time as the laryngoplasty site is anaesthetised. A ventral midline incision is made with the surgeon on a stool looking up. An assistant can support self retaining retractors. The larynx is anaesthetised with topical transendoscopic local anaesthetic at the start of surgery. However, despite this the horse will “gag” during excision of the laryngeal ventricles. From a standing approach it is easy to guide a 2” needle up into the ventricle and inject a small volume of local anaesthetic into the base of the ventricle.

Advantages

The key advantage of standing laryngoplasty is the reduced incidence of acute failure. The proportion of horses which show complete failure of abduction the day after surgery appears to be much lower. Presumably the degree of trauma during anaesthetic recovery was previously underestimated. By comparison, obviously, the disadvantages are the increased risk of infection, and the difficulty of dealing with a horse which may move. However, in our hospital, all tie backs are conducted standing.

Update on treatment methods for DDSP

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There are still a huge number of treatments (fig 1) being used for equine idiopathic DDSP and this likely reflects both the poor reliability of these treatments and the largely unknown aetiology of this disease. This lecture will solely focus on research that has been presented or published in the last 2-3 years regarding DDSP treatment.

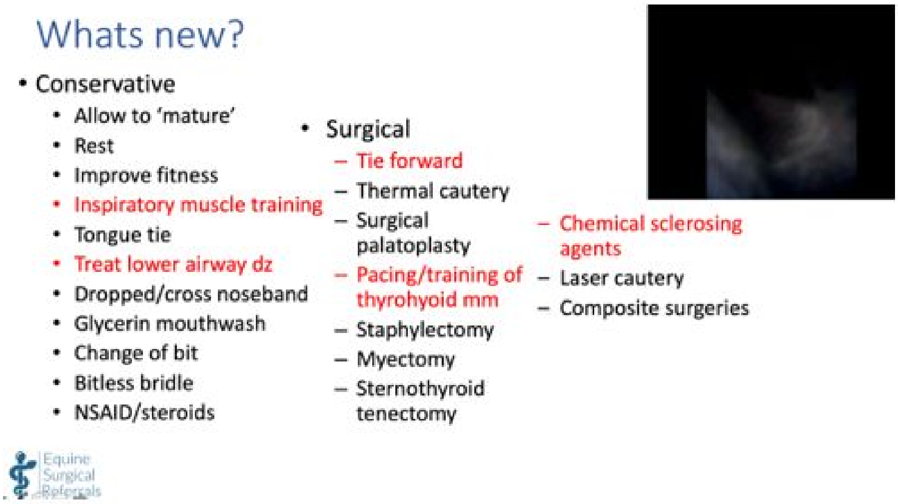

Figure 1: treatments available for DDSP and those that are 'new' highlighted in red print

Non-surgical treatments
The concept of respiratory muscle training has been brought into the equine veterinary world by Dr Kate Allen and the Bristol University group. Respiratory muscle training is used for some human diseases such as exercise induced laryngeal obstruction and for selected patients with chronic lung disease. The principle is that the subject wears an air-tight mask with valves in it, and is made to inhale against resistance, to train the skeletal muscles of the upper airway and respiratory 'pump' muscles. The first study investigating the feasibility of respiratory muscle training in the resting horse has been published in 2020 (Allen et al.). In theory it makes sense, particularly for equine palatal and nasopharyngeal collapse, but we await the results of its use in clinical cases.

The relationship between lower airway disease and palatal dysfunction also needs to be re-iterated. Previous studies have shown a likely relationship between higher neutrophil ratios in DDSP affected racehorses than controls (Courouce-Malblanc et al 2010) and an association between palatal instability and lower airway inflammation in sports horses (Van Erk 2011). Two more recent studies have now corroborated these findings (ter Woort and van Erk 2018, Joo et al. 2021), with ter Woort et al. finding a high prevalence (89%) of lung or tracheal inflammation in 27 sports horses they definitively diagnosed with DDSP. In these horses, DDSP commonly occurs at low speeds (trot and canter) and is initiated when horses cough during exercise, and can then be sustained for some time. Medical treatment resolved the DDSP in the majority of ter Woort et al's cases.

Surgical procedures
The original publications for laryngeal tie-forward (LTF) suggested that it was successful in around 80% of horses (based on racing records), and that it restored racehorse's earnings to baseline values (Woodie 2005, Cheetham 2008). More recent papers have not replicated this success (24-62% improved, Franklin et al. 2012, Koskinen et al. 2019). However, race performance is reliant on so many variables that it is not ideal for assessment of the success or failure of a wind surgery and really offers little proof that there has been resolution of the condition. Post-operative overground endoscopic examination is the gold standard test, and

Barnett et al. (unpublished data) have recently examined results for 58 racehorses that have undergone LTF surgery for DDSP (93%) or palatal instability (7%) and then had overground endoscopy performed. They found that DDSP was unresolved in 25% of horses after LTF, but that palatal instability was still present in 73% (reduced from 95% pre-operatively). LTF therefore does appear to produce a significant improvement in preventing the 'final event' of DDSP from occurring. However, it seems that the underlying problem has not been resolved in most. With any DDSP study, it should also be remembered that spontaneous resolution will undoubtedly occur in some cases, thus bolstering the success rate.

There has also been some experimental interest in 'pacing' of the thyrohyoid (TH) muscles. To understand the rationale for this, one must look at the recent paper by Cercone et al. (2019), where the authors looked at EMGs of TH muscles of a small number of horses exercising on the treadmill. They found that during episodes of pro-dromal palatal instability, activity of the TH muscles initially increased, but then tailed off prior to full DDSP occurring. They suggests that fatigue of the TH muscles may be occurring in horses with DDSP, perhaps due to sub-optimal fiber-type distribution, small muscle size, or perhaps the muscles become fatigues because they are trying to 'fight' the pro-dromal palatal billowing. In theory, endurance-type training regimes that increase the proportion of type 1 muscle fibres (fatigue resistant) or training the TH muscles with an electrical pacemaker might be useful for horses with DDSP – however, we are currently a long way off these theories becoming a clinical reality. The TH fatigue theory does not fit with DDSP and PI seen in non-racehorses, because these horses experience dysfunction at slow paces, when horses are clearly not fatigued (similar to horses with DDSP post tie-back surgery).

Finally, there has also been a paper looking at a potential new intra-palatal injection material to 'stiffen' the soft palate and thus prevent palatal billowing (Hunt et al. 2019). Genipin is a minimally toxic protein crosslinker which is supposed to preserve microstructural integrity whilst increasing strength and stiffness. In vivo studies showed few clinically apparent side effects in treated horses, however, success was relatively poor (1/2 horses that underwent repeat exercising endoscopy still had DDSP) and there were regions of patchy necrosis in the palate with fibroplastic reactions present – which was not the aim of the treatment. Nevertheless, I understand that some surgeons are trying this treatment currently for affected horses in Europe and the USA.

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Sinoscopy: an update on outcomes

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Sinusitis in the equine patient has a number of causes, with primary empyema and dental-associated infections predominating the aetiology. Conservative medical treatment, with antibiotics, is often unsuccessful due to the formation of inspissated purulent exudate in the sinuses, which acts as foreign material (1-3). Trephination of the sinuses with subsequent lavage has shown success rates of just over 42% (2), however, this relies on only one group of sinuses being exclusively affected, which is considered unlikely (4). Sinusotomy, either under general anaesthesia or using sedation and local anaesthesia, with debridement of the sinus compartments has a reported success rate for clinical resolution up to 94% (5,6). This is an invasive surgery with a prolonged convalescence (7)and an elevated risk of morbidity, with one study reporting 22% having prolonged incisional infections (6)and in another 24% of cases having long term scars or defects as a result of the surgery (3).

Sinoscopic techniques, allowing a minimally invasive approach to the sinus compartments were described in the nineties using both rigid (8)and flexible endoscopes (9). The portal described by Ruggles et al (8), which allows access to the conchofrontal sinus (CFS) through a frontal approach, was shown to provide the most consistent access to the rest of the caudal sinus compartments (10). Following fenestration of the maxillary septal bulla (MSB) the rostral maxillary (RMS) and ventral conchal sinuses (VCS) could also be accessed through this single portal in the majority of cases (10). This approach also permits lavage of the rostral and caudal sinuses at the same time through one catheter. Direct approaches to the RMS through the maxillary bone have also been described, but are considered inappropriate for access to the VCS (10)in some individuals, and there is always a risk of damage to the maxillary cheek teeth apices in young patients (12).

Anatomical variation will sometimes render the MSB inaccessible using a frontal portal, and has been reported to be obscured in as many as 10% of cases in one study (11). In these cases an additional, more caudal maxillary portal is required (10). The infraorbital canal has also been observed to obscure surgical access to the VCS with endoscopes in some individuals (6). In a currently unpublished case series from the authors practice 5/167 cases required creation of a second portal to access the obscured MSB. To prevent premature closure of the MSB fenestration it has been suggested the fenestration should be as large as possible (6), and all fragments should be removed to prevent subsequent sequestration (6).

Direct lavage and debridement of necrotic and inspissated material can be undertaken using transendoscopic instruments, ensuring that all sinus compartments are examined and thoroughly treated. Particular attention should be paid to ensure that no inspissated purulent exudate remains in the rostral compartments (6). A lavage catheter can then be placed through the frontal portal, and in some cases a second one placed directly into the rostral group of sinuses in cases refractory to initial lavage methods. Two to four times daily lavage with isotonic saline is usually advised, with repeat sinoscopy performed to monitor resolution of clinical signs. Dixon et al (6)reported cases underwent a mean of 3.9 days of flushing, however, those that were very inflamed or continued to discharge required longer, along with continued systemic antibiotic and anti-inflammatory medication. Strict attention to prevention of sinus contamination was also suggested, with lavage catheters securely attached with a good seal and at the completion of treatment incisions ideally closed with sutures or securely covered (6).

Contrary to earlier reports and anecdotal assumption; creation of a sinonasal fistula to aid in sinus drainage appears to be rarely indicated in cases undergoing sinoscopy, with only 4/155 cases reported in one study (6), and corroborated by a similar findings frequency in the author's own case series. With careful debridement, isotonic lavage, antibiotics, anti-inflammatories and patience, retarded drainage will usually improve over the first few days of treatment.

The main intraoperative complication reported has been haemorrhage when creating the MSB fenestration. This does not seem to cause systemic compromise of the patients, but may delay initial endoscopic examination of the sinuses. Despite high levels of contamination; wound infections and problems appear to be infrequent, with Dixon et al (6)reporting infections in 6% of cases. In the case series at the author's practice

4/167 cases developed inflammation of the fronto-nasal suture line following surgery, which has been suggested as a cause for prolonged incisional infections (6). One/167 of the authors cases developed a sinocutaneous fistula, which resolved soon after debridement.

Perkins et al (7)reported clinical resolution in 43% of cases undergoing sinoscopy, however this series included all causes of sinus disease. More specifically in this study 77% of cases presented with a primary sinusitis showed full clinical resolution. The recent study by Dixon et al (6)reported 96% of 155 patients having a full long term improvement, with similar findings in 167 cases in the author’s own cases. In the latter series 11 cases necessitated a repeated sinoscopic surgery for full resolution. In addition, 11 cases required a sinus osteotomy (6.6%) and creation of a sinonasal fistula.

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Challenging surgical treatment by tendinoplasty of an Achilles tendon rupture in a goat.

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Introduction
Achilles tendon ruptures (ATR) are mostly traumatic. The current treatment consists in re-apposition of the tendon ends by various suturing methods and immobilization of the operated limb by transarticular external skeletal fixator (TESF).

Case description
A 1-year-old goat was presented for right hindlimb lameness after a fall. Orthopedic examination followed by X-rays and ultrasonography diagnosed an ATR. A surgical repair was decided, consisting in a tendinoplasty: implantation of an UHMWPE implant, fixed proximally by simple interrupted suture along the tendon and distally by a calcaneus interference screw. A Kessler suture was also performed to re-apposition the tendon ends. Immediate postoperative X-rays showed satisfactory implantation of the interference screw following the drilling axis, but a caudal calcaneus splitting line was found. A bi-valve cast immobilized of the tibio-tarsal joint in extension in order to reduce the muscular tension on the Achilles tendon for six weeks.

Results
At first postoperative follow-up, a wound infection was found on the caudal end of the calcaneus and immediately treated by ampicillin (14 mg/kg) for four weeks and non-adherent hydrogel dressing re-applied every three days. Follow-up X-rays at 51 and 72 days postoperatively showed the beginning of bone healing around the split line. At 97 days, the calcaneus split line had disappeared. One year after the surgery, the goat had recovered full function of her hindlimb.

Discussion/Conclusion
This case describes a novel surgical repair of ATR in a small ruminant that showed promising results, despite intra- and postoperative complications without the use of a TESF.

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Arthroscopic Fragment Removal for Treatment of Equine Cervical Articular Process Joint Osteochondrosis

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Introduction
Pathological conditions of the articular process joints (APJs) include osteochondrosis dissecans (OCD), fracture and degenerative joint disease. Osteochondrosis of the cervical APJs may be an incidental finding but has also been associated with cervical nerve root and spinal cord compression, leading to clinical signs like decreased cervical range of motion, lameness and ataxia. The arthroscopic approach and anatomy of the cervical APJs has been described recently. To the best of the authors knowledge this is the first report detailing successful arthroscopic OCD fragment removal in the equine cervical spine APJs including long-term follow-up.

Materials and Methods
Five Warmblood horses (aged 4-11 years) weighing 550 – 680 kg presented with intermittent forelimb lameness and/or reduced range of motion of the cervical spine associated with osteochondral fragments between the cervical vertebrae C5/C6, C6/7 or C7/Th1. Surgery was performed under general anesthesia in lateral recumbency. The arthroscopic approach to the APJ was guided by radiographic and ultrasonographic imaging.

Results
All horses made an uneventful recovery from surgery and remained comfortable thereafter. Fifteen to thirty-two months post-surgery three of the five horses performed in their intended use. The other two horses were still in the rehabilitation period (two to five months post-surgery). None of the horses showed any sign of ataxia or reduced mobility of the cervical spine.

Discussion/Conclusion
Arthroscopic removal of osteochondral fragments can be performed safely in the equine caudal cervical articular process joints resulting in a favorable long-term outcome.

The radiographic assessment of medial femorotibial periarticular osteophytes is most reliable at the equine femoral condyle for the diagnosis of osteoarthritis

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Introduction
The equine medial femorotibial joint (MFT) is the stifle compartment most commonly affected with osteoarthritis (OA) and it is frequently diagnosed by radiographic assessment of the medial tibial plateau (MTP). We hypothesized that there is a good correlation between μCT and radiographic assessments of osteophytes at the medial femoral condyle (MFC) but not at the MTP.

Material and methods
MFTs (n=24) were macroscopically assessed for cartilage lesions and categorized into 2 groups (healthy and OA). Specimens were scanned with radiography and micro-CT (μCT) and scored for periarticular osteophytes (0-3). Osteochondral sections from all specimens were decalcified and stained with Safranin O fast green to characterise osteophyte histology and grades at both sites.

Results
Interobserver (n=2) agreement for MFC, cranial and caudal MTP μCT osteophyte scores were moderate to good ($\kappa = 0.53$, 0.61 and 0.74 respectively). MFC μCT osteophytes grades were higher than corresponding MTP grades ($p < 0.005$). There was a higher and significant positive correlation between radiographic and μCT osteophyte scores at the MFC ($\rho = 0.6$, $p = 0.004$) when compared with the cranial MTP ($\rho = 0.5$, $p = 0.02$). The correlation was not significant at the caudal MTP.

Discussion/Conclusions
Although many veterinary textbooks stress the importance of assessing periarticular changes at the MTP for the diagnosis of MFT OA, assessment of MFC periarticular osteophytes is more accurate for this purpose. Caution should be exercised when interpreting morphology of the abaxial equine MTP. Further anatomical studies are necessary to assess normal MTP anatomical variation.

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Immediate pre-operative computed tomography for surgical planning of equine fracture repair: a retrospective review of 55 cases.

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Introduction
Fracture configuration is often more complex than is radiographically appreciable. The objective of this study is to describe the influence of pre-operative computed tomography (CT) for surgical planning in a variety of fracture types. This has not been described in previous studies.

Materials and Methods
All cases with pre-operative radiographs, admitted for CT and surgical repair of a suspected limb fracture from January 2010-December 2020 were reviewed. CT was acquired under general anaesthesia in a multi-slice helical scanner; any surgery was then performed immediately. Three diplomates (two surgical; one diagnostic imaging) performed a blinded retrospective review of the radiographs and CT for each horse. A consensus decision was made on any change in surgical plan prior to and after CT review, and cases divided into three categories: CT of major, intermediate or minor relevance, as previously described by Genton et al, 2019.

Results
55 cases were collated. Thoroughbred racehorses predominated. The median age was 3 years. A diverse range of fractures were presented: proximal phalanx(18/55), carpal(17/55), metacarpal/tarsal(11/55), sesamoid(5/55), tarsal(3/55), and middle phalanx(1/55). In 13/55(23.6%) CT was of major relevance, in 21/55(38.2%) intermediate, and in 21/55(38.2%) of minor relevance. A Chi-square test demonstrated no statistical difference in CT relevance between fracture types, except tarsal fractures in which it was significantly less useful ($p<0.05$).

Discussion/Conclusions
This study demonstrates that CT has a significant role in surgical planning, and in the majority(61.8%) of cases added additional information or significantly changed the surgical plan. In all cases CT ensured confidence in surgical planning.

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Microstructural changes at the osteochondral junction in naturally occurring osteoarthritis of the equine medial femorotibial joint

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Introduction
The medial femorotibial (MFT) joint is the compartment of the equine stifle most commonly affected with osteoarthritis (OA). High density mineralized protrusions (HDMP) have been recently observed in osteochondral sections from equine OA carpal bone employing microCT (μCT) and their significance remains unknown. We hypothesized that μCT assessment of MFTs (Healthy and with naturally occurring OA) will provide new insight into this disease.

Materials and methods
Medial femoral condyles (MFC) and tibial plateaus (MTP) were macroscopically categorized into 2 groups (n =24; Healthy and OA). Specimens were scanned with μCT and scored (0-3) for hyaline articular cartilage (HAC) fibrillation, surface mineralization (SM) and HDMP.

Results
Seventeen Healthy and 7 OA MFTs were studied. HDMPs were more prevalent (p=0.03) in MFCs compared with MTPs and located in the cranial MFC (p=0.003). HDMPs were observed in OA (57%) and healthy MFCs (47%) but scores (s) were more severe in OA (s1-14%, s3-43%; Healthy: s1-12%, s2-12%, s3-23%). HDMPs were more prevalent in the OA MTPs (43%; Healthy-18%) and scores were similar. SM was observed in MFCs (OA-71%; Healthy-100%) and MTPs (OA-71%; Healthy-82%) and scores were similar. Fibrillation was more prevalent in the OA MFCs and MTPs (100%) compared with Healthy (71% and 94% respectively) and scores were also more severe.

Conclusions
μCT assessment of MFTs permitted cartilage structural assessment (HAC fibrillation) and revealed mineralization at the surface and protruding (HDMP) into the HAC from the calcified cartilage. HDMP scores were more severe in OA joints and may be involved in OA pathophysiology.

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A scoping review to identify factors associated with treatment outcome following synovial sepsis

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Introduction
Synovial sepsis is a frequent cause of morbidity and mortality in horses. Despite advances in diagnostics and treatments persistent infection or chronic lameness are possible outcomes. This scoping review aims to identify and evaluate the evidence on outcomes following synovial sepsis.

Materials and Methods
A Joanna Briggs Institute scoping review was undertaken. A systematic literature search was performed on CAB abstracts, Medline, Scopus and Embase using broad search terms. Inclusion and exclusion criteria were developed and studies systematically reviewed against this. Studies relating to factors affecting treatment success were retained and data were extracted on study method, population characteristics and factors significantly associated with treatment outcome.

Results
Two thousand three hundred and thirty-eight studies were identified, and 61 were included to full paper analysis. Eight papers reported significant factors, identifying 15 factors associated with two measurements of outcome, either survival and/or return to athletic function. These factors were categorised into groups, and this identified that there were six pre-operative, six intra-operative and three post-operative factors affecting outcome.

Discussion/Conclusions
The most important factors affecting outcome included the number of synovial structures involved, presence of pannus, tendon or bone pathology and the use of systemic antimicrobials. Future research is important to establish criteria for tendon, bone and synovial pathology, and the effect of early recognition of synovial sepsis and implementation of treatment on desirable outcomes.

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Retrospective Study on Surgical Management of Laryngoplasty Complications and Associated Outcome

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Introduction
Laryngoplasty (LP) alters the initial laryngeal physiology. Associated anatomical changes can lead to well-known post-operative complications such as coughing, dysphagia and recurrent poor performance.
Objective: Show that repeated LP on horses previously treated by LP is feasible and improves their outcome.

Materials/Method
Between 11/2015 and 10/2020, 27 horses (20 warmbloods, 3 standardbreds, 4 thoroughbreds, 3-15 yo) were presented for dysphagia/coughing (10) or loss of left arytenoid abduction associated withv roaring/ poor performance (17) following left side LP. Upon admission, history was recorded, clinical exam, resting and/or dynamic endoscopy and laryngeal ultrasounds were performed. All horses underwent standing (24) or GA (3) repeat LP. Long-term outcome was assessed by phone questionnaire.

Results
In 14,8%(4/27) of the cases, no protheses were found and two protheses were placed. In the other 85,2% (23/27), protheses were found. They were removed and replaced in 52,17%(12/23), removed and not replaced in 21,74% (5/23), left in place in 26,09%(6/23) and new protheses were placed in 33,3%(2/6) of patients. A third suture was added in one case. Adhesions between larynx, protheses and peripheric structures (mainly carotid, cricopharyngeal muscle, esophagus adventitia) were constantly observed. A grade 2 abduction was obtained in 51,85% (14/27) and a grade 3 in 48,15% (13/27) of cases after repeat LP. Presenting clinical signs resolved and all horses resumed activity.

Discussion/Conclusion
Repeated LP is a valuable treatment for horses facing disabling complications from first LP. The procedure allows protheses removal/replacement, adhesion separation and the reestablishment of a rima glottidis opening suitable for the horse’s needs.

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Use of passive surveillance of multidrug-resistant organism to improve infection control program

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In equine hospitals, isolation of multidrug-resistant organism (MDRO) from bacterial samples is common. MDRO isolation is associated with increased morbidity, mortality, cost and length of hospital stay. When an infection with MDRO is identified isolation measures are established to minimise spread to other patients and clinical personnel. However, at hospital level, this information can be used to identify susceptible patient population, critical types of treatments processes and high-risk clinical areas to subsequently establish a targeted approach to infection control. This study describes the use of passive surveillance of MDRO isolates to improve infectious control measures in an equine hospital.

Retrospective analysis of bacteriological samples and associated patient records of horses admitted between January 2018 and January 2020 was conducted. Potential predictors of MDRO carriage were assessed by uni- and multivariable analysis with particular focus on types of treatment, location and movement of horses within the hospital.

MDRO were isolated in 13.7% (52/380) of bacteriological samples. High-risk areas could be identified (e.g. the intensive care unit vs. the orthopaedic ward, OR:14.1,95%CI 3.5 to 56.3; p=0.001). Similarly, if more than one invasive procedure (e.g. iv-catheter placement, endoscopy,…) was performed MDRO isolation was 2.6-times more likely (OR:2.6,95%CI 1.1-5.9;p=0.025). Ponies carried MDRO more commonly than large breed horses (15.6%vs.5.3%;p=0.04).

Knowledge of high-risk areas, procedures and patients was subsequently used to install active surveillance measures via targeted environmental sampling and selective surveillance of high-risk patient populations.
Use of passive surveillance data can be used to develop a more targeted infectious control program.

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One-stage standing laparoscopic gonadectomy and genitoplasty in an equine male pseudohermaphrodite with XX karyotype.

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Introduction
Hermaphroditism, when chromosomic sex does not correspond to gonadal sex and reproductive organs, is uncommon in the horse. The most common presentation in the horse is the male pseudohermaphrodite, presenting as a bilateral cryptorchid with a rudimentary penis, often exhibiting male behavior. In these cases, intersex surgeries have been described under general anesthesia or neuroleptanalgesia.

Case description
A 4-year-old Arabian horse presented for abnormal female-like genitalia and stallion-like behavior. Examination of the external genitalia revealed an ambiguous phallic-like structure approximately 20 cm below the anus, measuring 4x5cm. Mammary structures were also present. Female reproductive organs could not be identified on rectal examination, however transabdominal ultrasonography revealed 2 intra-abdominal structures adjacent to the inguinal rings, bilaterally, with a parenchymal appearance consistent with testes.

A one-stage surgical correction was performed under standing sedation with locoregional anesthesia, consisting of two steps. Step 1: laparoscopic removal of intra-abdominal gonads; step 2: partial phallectomy of the rudimentary penis, with permanent urethrostomy, and reconstruction of the perineal region.

Results
Despite partial dehiscence of the genitoplasty distally at 12 days postoperatively, the urethral stoma healed well, remained patent with healthy mucosa, and maintained a good stream of urine. The stallion-like behavior subsided in the weeks following surgery and the horse is now ridden safely. Histology confirmed gonads to be testicular, and results showed an XX karyotype.

Conclusion
A one-stage, two-step standing surgical technique for correction of male pseudohermaphroditism, consisting of laparoscopic gonadectomy and genitoplasty, is a viable option with good functional and aesthetic outcomes.

Internal Fixation of Type II Distal Phalangeal Fracture in 51 Horses

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Type II fractures are oblique, articular fractures of the palmar or plantar process of the distal phalanx (DP). The abaxial fragment position leads to a bending force that, combined with lateral hoof expansion during loading, increases fragment instability. Internal fixation helps minimize instability and improve fracture healing, though technically challenging due to the complex surface geometry and narrow anatomic margin for error. Computed tomography (CT) has improved our ability to accurately repair these fractures. Reports on outcome following internal fixation of type II DP fractures are lacking with little emphasis on associated complications. The purpose of this study was to describe a technique for internal fixation of type II fractures, and to evaluate whether specific patient or treatment variables influenced both the ability of horses to return to work and the occurrence of postoperative complications.

Methods
Medical records of 51 horses with CT-guided internal fixation of type II DP fractures were reviewed, and signalment, history, and surgical technique recorded. Outcome information was obtained such that there was a minimum 6-month follow-up period for each horse, collected from racing records, telephone interviews, and medical records from repeat visits. A successful outcome meant a horse returned to work at the previous or expected level of use, or returned to racing. Fracture healing (non-union, partial union, or complete union) was assessed on the last available radiograph of each horse, or the first image in which complete union was observed. Horses with a partial or non-union were classified as having an 'incomplete union,' in which a portion of the fracture line was still present on radiographs. The development of osteoarthritis (OA) of the DIPJ was also recorded. Outcome measures included ability and time to return to work, radiographic healing, and postoperative complications. Associations between patient and treatment variables were analyzed using multivariable logistic regression; cox regression for 'time to return to work'. P-values, odds (or hazard) ratios, and 95% confidence intervals were calculated.

CT-imaging with adhesive-backed radiopaque markers and 3D multiplanar reconstruction was used for surgical planning. Cortical bone screws were inserted in standard lag fashion, with intraoperative CT performed to assess implant positioning and fracture reduction. One variation in surgical technique came when an 8.0mm femoral stepped reamer was acquired in January 2014, adapted for use as a cannulated countersink tool (CCT) to deeply countersink the screw head. Proper countersinking was not possible prior to this as the standard countersink instrument would not fit through the hoof wall defect. An amikacin-soaked collagen sponge was then placed over each screw head to the level of the inner hoof wall. In all cases treated prior to November 2013, the hoof wall defect was filled with amikacin-impregnated polymethylmethacrylate (PMMA) and the edges sealed with cyanoacrylate adhesive, referred to as the PMMA plug. In these cases, bleeding was frequently observed through the sealed patch; therefore, beginning in November 2013, the hoof wall defect was filled with freshly mixed acrylic hoof adhesive. Lastly, a braided polyester fiber sleeve patch was placed over the filled defect, and a cuffed glue-on shoe with aluminum hospital plate was applied.

Results
This study included 33 Standardbreds, 8 Thoroughbreds, and 10 non-racehorses of various breeds, and 86% returned to work after a median of 328 days. One or two screws were placed in 33 and 18 horses, respectively. Deeply countersinking the screw head using the CCT was performed in 34 horses. The hoof wall defect was filled with the PMMA plug in 38 horses and the acrylic hoof adhesive in 13. Complete radiographic union was seen in 49% after 182 days (median). Postoperative complications were recorded in 25/48 horses (52%). The most common complications were delayed implant infection (31%) and OA of the DIPJ (18.7%). Five horses developed miscellaneous complications, including proliferation of dysplastic laminar tissue over the screw

head, recurrent lameness in the affected limb (n=2), development of a subchondral bone cyst at the proximal fracture margin, and re-fracturing of the DP. Three were euthanized for complications from implant infection.

Variables affecting 'return to work' included breed – Thoroughbreds were 92% less likely to return to work compared to Standardbreds (P=0.02, OR=0.08, 95% CI=0.01-0.7) – and the occurrence of OA (P=0.02, OR=0.09, 95% CI=0.01-0.7). The occurrence of postoperative infection, when adjusted for age, was associated with a prolonged time to return to work (P=0.03, HR=0.5, 95% CI=0.2-0.9). The odds of postoperative complications were reduced in horses with more average racing starts/year after surgery (P=0.04, OR=0.9, 95% CI=0.8-0.997).

Not all horses had radiographs after the minimum 6-month timeframe, thus the analysis for 'incomplete union' was adjusted for how far postoperatively each horse was at follow-up. Odds of an incomplete union were decreased in horses with more average racing starts/year after surgery (P=0.02, OR=0.8, 95% CI=0.7-0.96) and with radiographic follow-up further out from surgery (P=0.03, OR=0.94, 95% CI=0.9-0.995). There was no significant association between 'incomplete union' and when a horse reached its final documented degree of healing. Compared to horses in which the hoof wall defect was filled with acrylic hoof adhesive, horses with the PMMA plug were 15.3 times more likely to develop an implant infection at some point following surgery (P=0.006, OR=15.3, 95% CI=2.2-107.0). For delayed infection, specifically, horses that had the defect filled with the acrylic hoof adhesive and had the screw head deeply countersunk were 92% less likely to develop a delayed infection (P=0.001, OR=0.08, 95% CI=0.02-0.4) compared to horses in which it was filled with the PMMA plug without deep countersinking of the screw head. No independent variables evaluated were associated with OA of the DIPJ, euthanasia, or miscellaneous complications.

Discussion
Internal fixation of type II DP fractures using cortical screws placed in lag fashion was an effective treatment that allowed horses to return to athletic use, with accurate screw fixation afforded by CT-guidance. Success rates were subjectively better compared to the 63-69% reported for conservative management, though a direct comparison to previous reports was not performed. Complete bony union of DP fractures has not been shown to be essential for a successful return to work, with no association between radiographic union and outcome, thus re-commencement of training should be based on clinical rather than strictly radiological findings.

Delayed implant infection was the most common complication. As these horses had a history of recurrent hoof abscesses, it appears that routine hoof infection may allow bacteria to travel proximally and contaminate exposed metal. Changes in technique intended to reduce infection rates included more deeply countersinking the screw head such that it would eventually be completely covered by tissue, and filling the defect with an adhesive hoof acrylic that mimics hoof wall flexibility and provides a complete watertight seal. As there were no horses that had the defect filled with the PMMA plug and also had the screw head deeply countersunk with the CCT, the independent fixed effect of these treatments could not be determined. Study limitations include those inherent to its retrospective nature, variable follow-up method and duration, and lack of control population for comparison. The level of racing to which racehorses returned was not evaluated, and bias related to the level of races entered could not be avoided. Finally, all cases were treated by a single surgeon and outcome is expected to vary based on surgeon experience.

Limb Deformities in Farm Animals

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Congenital respiratory tract malformations

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From the nares to the trachea, the upper portion of the respiratory tract of the horse is affected by an array of congenital malformations. These include those physical abnormalities that are present at birth and those that are diagnosed later in life, often at the point of the onset of athletic work. Some of these abnormalities are acquired during development in utero, and may result from exposure to teratogens, or as a result of foetal malpositioning, while others may be inherited. It is rarely possible to determine what event or events have led to the malformation, and the prevalence rate at which many of these anomalies occur is frequently unknown since there are few large case series and by their nature many such malformations occur sporadically.

While some of these malformations such as bilateral choanal atresia are rapidly fatal within the first few moments of life, some such as the effects of branchial arch defects only become evident with the onset of moderate amounts of athletic work. Others, such as guttural pouch tympany may appear to develop spontaneously within the first few months of life, nevertheless, these are just manifestations of congenital structural abnormalities.

Equine congenital respiratory tract malformations can further be categorised in terms of those that are fatal or have the potential to be fatal, such as choanal atresia, cleft palate, those that compromise welfare, such as wry nose, some epiglottic and pharyngeal cysts, guttural pouch tympany and those that are performance limiting, including 4^{th} branchial arch defects, and some epiglottic and pharyngeal cysts. Finally, some of these abnormalities, for example atheromas, are simply curiosities with their effect being principally on cosmesis alone.

While horses affected by a malformation such as wry nose may be straightforward to diagnose, identification of some congenital tract malformations is less straightforward and may require advanced imaging, resting and overground endoscopy.

There are a variety of surgical approaches for the correction of some of these malformations, and surgical planning, and success has been greatly facilitated in recent years using advanced imaging modalities.

The treatment of overjet / overbite in the horse

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Orthodontia is a specialization within dentistry that focuses on the optimization of the position of the teeth within the arcades in order to optimize occlusion of the teeth. In equids compared to humans and small animals this discipline is not very well developed. However, every general and routine floating, or better named odontoplasty of the teeth could fall under this definition as it is aimed at correcting malocclusions in order to prevent others.

In horses, congenital dental disorders that lead to malocclusions are not uncommon. Brachygnatio inferior or a shortened mandible is reported as the most common congenital dental disorder in the foal (Knottenbelt and Pascoe 1999). Another type of deviation is proganthia, that can be presented in the upper or lower jaw but typically is found in small pony breeds in the lower jaw and termed monkey mouth. Without any form of approved measures, the use of brachygnatia or prognatia is difficult to apply as one is not able to identify the shortened from the elongated jaw. In fact in defined cases of overjet in horses, it is most likely the condition is a prolonged maxilla, in other words prognatia superior according to recent morphometric analysis (Domanska et al 2018, 2019). Therefore, the use of the clinical terms overjet and overbite are more easily applicable.

Overjet is defined as the horizontal projection of the maxilla compared to the mandible, the overbite is defined as the vertical projection of the maxilla compared to the mandible (Ferraro 1997) and can only be present after a certain degree of overjet. Once overbite has occurred, the treatment of the disorder will be more difficult as not only an elongation of the mandible but also a dorsal inclination of the pre-maxilla will have to be obtained.

Even if foals can be born totally normal, overjet can appear in the first weeks or months of live as illustrated by Gift, Debowes et al. (1992) and more recently by Domenska et al.(2018,2019). In the latest study 2% of foals were normal at birth and developed overjet in the first six months of live. Possibly, crossing of breeds with different head morphology can predispose to the development of the condition and relationship with developmental orthopedic diseases has been postulated. On the other hand as occurs in human medicine, trauma to the developing temporomandibular joint structures could be the initiating factor for those animals developing the condition in the first few months of live (Shafer, Hine et al. 1983). However this has never been reported or investigated in the horse.

As the mandible presents some degree of rostro-caudal mobility compared to the maxilla, the degree of occlusion can vary with the position of the head. Maximal occlusion will be present when the horse is grazing, with the mandible most rostrally and upper and lower incisors in occlusion. When the horse raises the head, the mandible is pulled caudal and a variation in occlusion from 3 to 9 mm can occur according to a study performed by Carmalt et al. (2003). Therefore evaluation of the degree of overjet should be performed systematically with the horses head in a lower position.

Conservative treatment
In mild cases and considering the potential genetic basis of the disorder, possibly no treatment should be initiated.

If treatment is initiated, the growth potential of the animal should be used at its maximum to correct the disorder. Therefore, first of all every origin of dental interlock should be removed (Klugh 2004). And in foals with one or two mm of overjet rasping of the occlusal surfaces of the molars to remove transversal ridging and rostral and caudal hooks creating interlock will help in ease rostro-caudal movement of the jaws and is often sufficient to correct overjet.

In more pronounced cases and in cases presenting not only overjet but also overbite, the placement of a biteplate on the upper incisive arcade will ease the sliding of both jaws and push the pre-maxilla dorsally (Klugh 2004) in order to correct/prevent overbite.

Surgical treatment
Surgical correction using cerclage wire and biteplate is the treatment of choice in foals that still have growth potential left. According to cephalometric studies performed in Warmblood foals, individuals with an increased Premaxiallar/ mandibular body length ratio are unlikely to self correct after 22 weeks of age. Those would then be optimal candidates to receive surgical treatment. The principal idea of the treatment is to obtain a growth retardation at the level of the maxilla. The maxillary corpus is fixed with cerclage to the third maxillary premolar (07-08 interdental space). The brace is optimally placed when the foal is about three to four months of age and left in place till full correction is obtained. About 5 to 9 mm correction can be obtained in this way every 3 to 6 months. The exact application technique has been fully described (Easley 2005; Dixon and Gerard 2006; Verwilghen 2008; Verwilghen and Vlaminck 2010)

In some cases even after successful treatment the condition has been described to reoccur. It is therefore important not to heavily feed the animals after treatment has ended as a growth spurt after introduction of concentrate feeding was reported as a reason for failure of the therapy (Verwilghen and Vlaminck 2010).

In older horses where the benefit of natural growth can not be obtained, other surgical corrective techniques should be considered. Osteodistraction as a corrective technique for mandibular shortness in humans was first described in dogs in 1973 (Snyder, Levine et al.) and is widely used nowadays.

Distraction osteogenesis is governed by the principles of tension-stress were the tissues subjected to gradual, slow, and steady traction become metabolically active, stimulating proliferative and biosynthetic cellular functions and combining controlled osseous healing with remodeling of bone and soft tissues. Specific latency time (time between osteotomy and initiation of the distraction), distraction rate (mm/day of bone stretching), rhythm (number of distractions/day) and consolidation period (neutral fixation) are not available for use in horses. However the technique is applicable as was shown in a report by this author (Verwilghen, Van Galen et al. 2008). Since has also been successfully applied in another horse.

A One step technique is not favored, at least not in human medicine due to occurrence of relapses and lack of adaptation possibilities for soft tissues. Several case reports or series (Klaus et al, 2013, Spoormakers and Wiemer 2019) describe one step techniques. Most with long standing complications of infections, prolonged antibiotic use and or doubtful surgical principles involving opening all incisor pulp cavities. When applying one step techniques, use of sliding osteotomies would be preferential compared to transverse section. The use of a reciprocating saw instead of a oscillating saw can facilitate the achievement of this cut.

In horses where the overjet has not been corrected, overgrowths (ramps and hooks) of the 06 and 11 occur leading to different dental and gastro-intestinal pathologies. Frequent dental investigation and floating is therefore mandatory in these patients.

Take home message
Overjet is the most common dental congenital disorder of the foal and can be corrected with little invasive orthodontic techniques early in life. Once the benefit of natural growth is exceeded more invasive techniques as osteodistraction can be applied.

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Surgical management of gastro-intestinal malformations

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Anomalies of the gastrointestinal tract are rare findings in the horse. In literature only case reports or papers with very limited numbers are available. The anomalies found can give health problems throughout life but can be divided in three time frames according to the functionality of the lesion.

Problems like mesenteric rent, mesodiverticular band and Meckel's diverticulum can cause acute colic during the whole lifespan of the horse. Moderate anatomical and functional lesions commonly appear when the diet is changing to more solid food like hay and give signs at the period of weaning or some month later on. When there is a severe anatomical or neurological defect like an atresia, colic signs will start at 24-48 hours after birth.

Besides the previous mentioned anomalies there is a great variety in causes and extent that will appear as a once in a lifetime experience, that will not be discussed here.

Herniation through a mesenteric rent / mesodiverticular band or a strangulating volvulus caused by a mesodiverticular band / Meckel's diverticulum can be treated as any other strangulation with resection and anastomosis. The prognosis is not depending on the cause of the lesion but on the viability of the intestines left in the abdomen. Sometimes a mesodiverticular band or Meckel's diverticulum not causing any problem is found during a laparotomy. In these cases a resection or excision is recommended to prevent these anomalies to cause colic problems later on in life.

Anomalies that give rise to acute problems, in the first days of life, are more severe anatomical or neurological defects. The most common neurological defect, an agangliosis, is seen in the lethal white foal syndrome in the Quarter Horse. Anatomically, atresia of the intestinal tract appear in the horse aboral to the caecum, contrary to humans where the small intestine is more often involved. The atresia can occur in various forms, a stenosis, a membrane, a cord without lumen or complete absence of the affected part of the intestine including the mesentery. In cases of atresia a continuity of the tract should be attempted. Due to the hypoplasia, in general smaller diameter, of the aboral part an end to side or side to side anastomosis is necessary to achieve an anastomosis of sufficient diameter. Any anastomosis in the foal should be made without inverting the tissue because this will further reduce the already small diameter. A double layer is possible but in a strict appositional pattern. Despite a surgically correct repair there may be a dysfunction or not adequate adaptation of the intestines closely to the anastomosis that will be fatal to the patient. In human literature this dysfunction is attributed to muscular and neurological defects. The mesentery in the foal is very fragile and should be handled with care, a rupture can easily progress till deep in the abdomen and partial rupture of mesenteric blood vessels can occur at the same time. Closure of the defect can be complicated when the mesentery was torn along the border of a mesenteric blood vessel. In these cases the suture line can be placed along the other side of the blood vessel leaving the blood vessel undamaged at the free border. When a blood vessel is damaged and the blood supply to the local part of the intestinal wall is impaired a resection must be considered. Care must also be taken to minimize the peritoneal erosions, caused by manipulation of the intestines, which can lead to adhesions and future colic symptoms. The omentum of the foal is thin and has a tendency to get sucked by some leakage of peritoneal fluid in the wound. A fine and thight closure of the linea alba will prevent this.

In conclusion, the surgery of neonatal intestinal anomalies is technically challenging and not always rewarding despite state of the art performed surgery.

3D Printed Innovations in Human Reconstruction

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Introduction
Patients requiring reconstruction of the craniofacial skeleton commonly present with posttraumatic defects (e.g., of the orbital wall), congenital hypoplasia (e.g., hemifacial microsomia, orofacial clefts), oncological resection gaps, condylar resorption (mainly postorthognathic), end-stage degenerative joint disease, alveolar crest disuse atrophy, and aesthetic concerns (underprojection of the malars, chin, and jaw angles). Less common indications are bone losses resulting from ballistic trauma, bisphosphonate-related osteonecrosis of the jaw, and maxillectomy. Past and present surgical strategies are distinct.

The past
Dr. Paul Tessier (1917–2008), founder of the subspecialty of craniomaxillofacial surgery, was convinced that autoplasty—that is, reconstruction using parts of the patient's body—was the preferred approach for craniomaxillofacial surgery. For the repair of skull defects, bone was harvested from the iliac crest, rib cage, or neurocranium. Smaller grafts were obtained from the buccal mandibular cortex or symphyseal region of the mandible. Sliding segment repositioning and self-locking osteotomies were then used according to the same principle: *Rob Peter to pay Paul.*

The present
Three-dimensional (3D) printing with titanium necessitates specialized software. Multi-slice or cone beam computed tomography data in the Digital Imaging and Communications in Medicine (DICOM) format are transformed into a 3D model (.STL) with the use of medical 3D image-based engineering software (e.g., Mimics Innovation Suite 23, Materialise, Heverlee, Belgium). Freeform design software (e.g., Geomagic Freeform Plus or Sculpt, 3D Systems, Rock Hill, SC, USA), which is often used with a haptic mouse, allows a medical engineer to design the implant under guidance from the surgeon. The finalized design (.CLY to .STL) is handled using a virtual building platform and yet-another data preparation software package (e.g., Materialise Magics, Heverlee, Belgium), which is imported into the build processor. The object is 3D printed, distressed, biofunctionalized (microshot peening, acid etching), and cleaned. Optical scan control (e.g., Atos GOM optical blue light scanner) compares the object's surface topology with the original .STL file. Other postprocessing steps may include computer numeric controlled (CNC) milling, coating, packaging, labeling, and sterilization.

Material and methods
Over the last five years, 11 patient-specific concepts using 3D printing with titanium have been researched with the help of CADskills BV engineers and support of the biomedical engineering departments of the Universities of Leuven and Ghent. Clinical testing was done at several national and international hospitals. Of the 11 concepts, six pertained to craniofacial reconstruction. The others included scaphoid and capitate replacement, use of clavicular hook plates, high tibial osteotomy fixation, first metacarpal joint replacement, and bone-anchored hearing aid fixture.

The implants were printed by selective laser melting using a titanium Gr23 extra-low interstitial (SLM Solutions, Lübbeck, Germany). Joint surfaces were optimized using medical-grade, ultra-high molecular weight polyethylene (Quadrant EPP, Vreden, Germany) and coated with nondisclosed HadSat®. Surfaces were roughened for increased tissue integration using alumina grit peening (Æ = 550 mm) and etching using 2 wt% oxalic acid at 85 °C for 10 min. Epithelial reattachment and cleansing were promoted by manual polishing of the transmucosal regions with ceramic discs, rubber points (Edenta AG, St. Gallen, Switzerland), and an animal fat-free polisher (Luxi Green Polishing Compound; HS Walsh, Biggin Hill, Kent, UK) on rotary bristles (Bison; Renfert, Hilzingen, Germany). CNC milling to 0.02-mm accuracy, anodization, and gamma sterilization were outsourced.

Accurate customized shaping and the option to print a lattice structure proven to induce bone formation are the main assets of 3D printing with titanium. For all nonheavy loadbearing implants, it is crucial to avoid Ch-Co-Ni-Mo alloys and polymethyl-methacrylate cement, as one-third of all patients are allergic to these substances.[1-3]

Results and discussion
Six concepts were fully elaborated.

Facial contouring and orbital floor implants are often segmentalized and assembled in vivo using a 3D puzzle connection for a minimally invasive surgical approach and sparing of nerve structures.[4,5]

The scaffolded border of the **ceramic-titanium cranioplasty**[6] is intraoperatively filled with calcium phosphate paste for improved osseointegration and stress distribution upon traumatic impact.[7] The calcium ions, apart from being a local depot for the extracellular matrix of osteoblasts, also have antimicrobial properties.[8]

The **additively manufactured subperiosteal jaw implant** constitutes an alternative to zygomatic implants or extensive bone grafting for Cawood and Howell class V–VI maxillary bone atrophy.[9-11] Left and right subunits are inserted subperiosteally and connected intraorally to a third section to establish a fixed prosthesis (EU and US patents pending). Reducing the extent of degloving by segmentalizing the implant minimizes pain and edema and allows for the procedure to be performed on an ambulatory basis. Osseointegration is also promoted by scaffolding the interface to the facies anterior of the maxilla. Terminal dentition can be handled by simultaneous edentulation and the use of vertical and horizontal ostectomy guides.[12]

The inclusion of individual variables into the total **temporomandibular joint replacement *Parametro*** (condylar path, condylar axis angle, Bennet shift) is the basis for full functional restoration.[13] The patented reconstruction of the enthesis of the lateral pterygoid muscle allows for select patients to regain normal mastication, comfortable mouth opening, a normal diet, and reduce pain.[14] The 3D-printed scaffold is essential for osseointegration and enthesis repair.[15] A lingual extension reduces both the number of fixation screws high in the mandibular component and the risk of facial nerve paresis.

A paradigm shift is happening in the reconstruction of mandibular continuity. Microvascular bone transfer is no longer considered the primary option unless radiotherapy is involved.[16] Patient-specific **mandibular segment replacement implants** rely on scaffolding for osseointegration, surface biofunctionalization for soft tissue attachment, and finite elemental analysis for proper biomechanical function.

The sixth concept is an outlier since it is not implanted in the tissues but instead is glued onto them. The **3D-printed arch bars** are acid-etched and the composite is fixed to the dentition's enamel for intra- or intermaxillary fixation after premaxilla osteotomy in patients with bilateral cleft lip or after bimaxillary repositioning osteotomies in patients with obstructive sleep apnea.

Conclusions
The use of 3D printing with titanium signifies a revolution in craniofacial reconstructive surgery. Six concepts have emerged. We expect that artificial intelligence will reduce the lead time for design and that biofabrication overlaying the titanium implants will enhance soft tissue integration. Cyborgization of the implants will be explored in future studies.

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Author's statement
Conflict of interest: The author is an innovation manager and co-owner of the CADskills BV company. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies, was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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Recognising a surgical complication

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The term ‘surgical complication’ is frequently used in the medical profession, but its definition in the medical literature has been inconsistent over the years. The World Journal of Surgery defined ‘surgical complication’ as ‘any undesirable, unintended, and direct results of an operation affecting the patient that would not have occurred had the operation gone as well as could reasonably be hoped’ [1]. This definition suggests that a surgical complication is dependent on the surgical skill of the surgeon, the facilities and equipment available and the condition of the patient.

‘Surgical complications’ otherwise referred to as ‘operative complications’, are not restricted to the time window of the surgical procedure itself but comprise both intra- and postoperatively complications [2]. The duration of surgery defines the time window for intra-operative complications; meanwhile, postoperative complications are not restricted to those occurring whilst hospitalization but are defined according to a time period. A 30-day period after the surgical procedure either during or after hospitalization has been used in human medicine [2].

All surgical procedures are associated with a degree of risk and the benefits of any procedure need to be weighed against any potential complications so that the clinician and the patient or animal owner can make a balanced and informed decision. This discussion should also cover complementary techniques that augment results to optimize physical, occupational and societal goals [3]. In veterinary medicine, owners’ expectations, engagement and commitment, animal welfare and economics need also be balanced.

Surgical complications can be classified into patient-related complications (related to patient-specific characteristics, rather than to a procedural error), and practitioner-related complications (arising from errors that directly led to undesirable and unintended results affecting the patient, but also as a result of a faulty technique) [3]. Although surgical errors may be frequently linked to complications, some errors may not result in complications.

Recognition of errors and complications give unique instances to learn from and to work towards avoiding or preventing their re-occurrence [4]. To maximize this process the following practitioners goals have been defined in human medicine [3, 5]:

1. Minimize errors by applying an appropriate surgery technique.

2. Identify and manage errors timely and in a way that would prevent ensuing complications.

3. Identify and manage complications timely and appropriately.

4. Identify and consider patient-related complications in the decision-making process, so they can be anticipated, prevented or managed correctly.

It is not uncommon that clinicians adopt routines to prevent and manage complications on the basis of personal experience. However, in some cases this may be associated with ‘making the same mistakes with increasing confidence over an impressive number of years’ [6]. In human medicine standards of expected outcomes for groups of patients require evidence-based practice, making seniority and individual experience less important [7]. Evidence-based literature in this area has quickly developed over the last decades, and several textbooks and journals dedicated to surgical complications are available in the human field. The application of an evidence-based approach for prevention, identification and management of surgical complications should result in a reduction of mistakes in the clinical decision-making process. In addition, it will also identify areas on which further research is warranted.

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Complications of synovial endoscopic surgery

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Complications of arthroscopic surgery, while well recognised, are fortunately uncommon in clinical practise. They generally fall into intra operative or post operative complications. Intra operative complications include iatrogenic damage to articular cartilage or other intra articular structures, extravasation of fluids which hampers visualisation, instrument breakage and contamination of the joint with foreign material. Good technique and adequate distention of the joint prior to insertion of the arthroscope will decrease the chances of iatrogenic intraarticular damage. Extravasation of fluid can be minimised with appropriate portal size and shape, and adjusting fluid rate when fragments are being removed through the portals. Instrument breakage is most commonly caused by poor instrument choice, using too much leverage, or poor choice of portal location.

Post operative complications, of which synovial infection is the most concerning, are fortunately rare and are on the order of 1% or below. Draught breeds and the tarsocrural joint appear to be over represented. The use of antimicrobial drugs does not give a statistically convincing difference for the occurrence of post operative infection; however, there is some evidence to suggest that perioperative antibiotics may have a role in reducing anaesthetic risks including pulmonary congestion and atelectasis of the lung. Potential detrimental effects of antimicrobials include contribution to antimicrobial resistance and the development of antibiotic induced colitis. Septic fasciitis is very uncommon but when it occurs, seems to involve the stifle most frequently. Reactions at the site of sutures in the arthroscopy portals can lead to small abscesses or sinus formation, which as long as they do not progress to an inch articular infection are generally self-resolving. Residual synovitis or effusion within the joint post operatively seems to be most common in the tarsocrural joint but may also indicate an unresolved intra articular lesion. Fragments remaining within the joint can result from several causes and are of concern both clinically and legally. Loose fragments within the joint will migrate to recognise locations such as the suprapatellar pouch in the femoropatellar joint or the intercondylar fossa of the medial femorotibial joint. Fragments can be missed during examination of the joint, but also can be contained within the joint capsule or synovium, giving the radiographic appearance of an intra-articular fragment. There are also anaesthetic considerations including post anaesthetic myopathies and neuropathies related to both positioning on the table but also prolonged traction or lack of support of extended limbs during surgery. The incidents of intra operative and post operative complications well never decrease to zero but will decrease with experience of arthroscopic procedures.

Complications of Reproductive Surgery

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To provide some detailed information on a broad topic, during this talk I will focus on reproductive surgeries of the broodmare and ones which I perform with some frequency. These will include rectovestibular lacerations and fistulas, urethral extensions, cervical tears, ovariectomy, cesarean section, laparoscopic application of prostaglandin to the oviducts, and uterine laceration repair.

Reproductive tract surgery in broodmares is typically performed with the mare sedated and in stocks. This creates some risk for the handlers and surgeon so a well sedated mare, using a sedation protocol your familiar and comfortable with is advisable. Also, as you need access to the mare, the stocks may not be the most robust which will pose additional risks. Should the mare have a foal at foot then the foal will always remain with the mare to keep both the mare and foal relaxed. An additional handler is generally necessary if a foal is present. I will, if I can, allow the foal to nurse the mare during surgery and usually this will keep the mare and foal more relaxed.

For surgeries of the caudal reproductive tract, I will use epidural anesthesia. The combination I use is 100 mgs of 2% xylazine and 40 mgs of 2 % mepivacaine hydrochloride. This gives a total volume of 7mls and when used at the first palpable coccygeal space (typically between Co1 and Co2). With this volume I rarely have any issues with ataxia. Also, at the completion of surgery I try not to reverse the mare and prefer to walk the mare forward out of the stocks to avoid the mare from becoming recumbent. Also, I will put the mare in a small paddock for a few hours for the same reason and should she become recumbent it is easier to attend to the mare than f it happened in a standard sized stall.

The main complication associated with rectovestibular lacerations and fistulas is dehiscence secondary to obstipation. Regardless of surgical technique used, diet has the biggest impact on this. If possible, it is best to repair a rectovestibular laceration or fistula when a mare has access to green grass. It is difficult to maintain soft manure with laxatives and I do not fast these mares prior to surgery. Performing the surgery when the tissue has healed and dissecting the tissues sufficiently lateral and cranial to minimize tension is also important to avoid dehiscence.

Dehiscence with fistula formation is the most challenging postoperative complication with urethral extensions. In my experience, the development of fistulas in the tunnel is greatly reduced when the modified McKinnon, as described be Prado et al, is used. This technique recruits an extra layer of tissue, the dorsal part of the transverse urethral fold, to cover the cranial portions of the tunnel. I also always try to maintain a urinary catheter in these mares for 10-14 days following surgery, changing the catheter every 2-3 days. When a fistula does develop it is important to delay the second surgery, typically 6 weeks, until all the tissue surrounding the fistula is healed.

Access to the cervix for repair of a cervical tear and visualization of the tear can be a challenge when repairing a cervical tear. A good head light is important, and repair of ventral tears may be facilitated by repairing them under anesthesia in a trendeleburg position. In my experience the biggest disappointment following repair of a cervical tear is further trauma at subsequent foaling's. It is likely at subsequent foaling's that the cervix will tear again and will need to be repaired. One technique, demonstrated to me by Dr Dwayne Rodgerson, which may allow the previously repaired cervix to tear easier at subsequent parturitions involves only removing the mucosa during the dissection of tissue along the margins of the tear. Once the mucosa is removed and not the muscle, as is generally described, then the defect is closed in 2-3 layers. Repairing it in this manner may minimise the strength of the scar that forms allowing the cervix to tear more easily and with less overall loss of functional tissue at subsequent parturitions. This in turn may facilitate easier future repairs. Alternatively, an elective cesarean section could be performed. I will typically follow the pH of the mares' milk and when it gets lower than 6.5, I am comfortable performing an elective section once I have a full team assembled. Finally, adhesion formation during the healing process is possible and to minimize the chances of this happening I advise that the cervical os is palpated once or twice a week for the first two to three weeks. I will also apply a steroid ointment to the cervix during these palpations.

I typically only carry out ovariectomy for removal of unilateral pathologic ovaries. This is performed as a standing hand assisted laparoscopic procedure using the ligasure for haemostasis. The size of ovary can be a challenge when it comes to removal and ovaries more than 15 cm in diameter will likely need to be removed using a bag of some description. I have often found sterilised plastic bags not robust enough and I use a modified material xray cassette bag for this reason. The very large ovaries (>20-25cm diameter) are, in my experience, usually fluid filled, and I will drain these of fluid prior to removal. Following removal of the ovary I take care in closing each later of the modified grid, typically 4 layers, lavaging between layers. Then I apply a stent for 48 hours and I keep the mare on stall rest with hand grazing for three weeks. With this approach to the incision I have had very few incisional seromas or incisional infections. Adhesions to the mesovarium stump and body wall are possible complications and while I have not seen this happen, I always advise that the mesovarium and body wall are “swept” transrectally once or twice a week for 2-3 weeks after surgery. I always submit the ovary for histopathology as there is a chance that the remaining ovary will become pathologic. This reduces any potential conflict regarding whether the correct ovary was removed or not. The duration from removal of the pathologic ovary to regaining normal function can, in my experience, take up to three years and I will advise the client of this.

Cesarean section is generally performed as an emergency to correct a dystocia. The best results, regarding recovery of the mare, are to perform the section without excessive attempts at resolution of the dystocia by controlled vaginal delivery. Furthermore, trauma to the caudal reproductive tract will be kept to a minimum increasing the likelihood of the mare producing live foals in the future. A tired surgeon during the c-section and a tired mare in the recovery box will have detrimental consequences on the overall decision making and outcome of the situation. While the development of peritonitis is possible this can be reduced by careful draping, lavaging of the abdomen and if necessary, placing an abdominal drain to facilitate postoperative abdominal lavage. I place my abdominal drains in the left cranial ventral abdomen and in that position occlusion of the drain with omentum seems to occur with less frequency. While I do not place a haemostatic stitch on the uterus, I do close the uterus in three layers with the first appositional which is likely like a haemostatic stitch. The two subsequent layers are inverting.

Laparoscopic application of prostaglandin to the oviducts is a relatively uncomplicated procedure. I use a chest drain to create a pneumoabdomen in the left flank and then I insert my trocars and cannulas. I don’t use insufflation unless necessary, but I will fast the mares for at least 36 hours. If a mare is a crib-biter it might be beneficial to apply a muzzle prior to surgery as I have had mares fasted for over 48 hrs remain with a lot of gas distended colon during surgery. By avoiding insufflation with CO2 the mares may be more comfortable during surgery. Following surgery, I will give the mares 15-20 liters of LRS at a maintenance rate as they can remain quite depressed and inappetant in the 12–24-hour period following surgery. If possible, to encourage these mares to eat I will turn them out in a paddock the day after surgery.

Uterine lacerations have presented me with some challenges over the years and, despite what has been published, I had some poor results with this condition. A few of the first mares I did this surgery on either died under general anesthesia or had a catastrophic injury during recovery from anesthesia, so I began to perform this surgery with the mare standing and sedated. When these mare present to a referral clinic they usually are in septic shock and are poor anesthetic candidates. For lacerations involving the uterine horn I will repair these through a flank incision. Once the correct uterine horn is identified on uterine palpation, I make an incision (modified-grid approach) on the corresponding flank and the horn is easily exteriorized and closed. It is relatively straight forward to identify the laceration on palpation and if it is not possible to palpate a laceration in the uterine horn, but suspected based on the clinical, then making a flank approach on the same side as the gravid horn could be performed. For lacerations in the body of the uterus or vagina I will also repair these with the mare standing, approaching the laceration though the vagina. Additionally, during the surgery I will often put 10-15 liters of LRS into the abdominal cavity to facilitate ease of placement of a ventral abdominal drain, for postoperative abdominal lavage, following the surgery. With repair of these uterine lacerations with the mare standing over 80 percent of the mares have survived (13/16).

Complications of tendon surgery

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Introduction
Tendon surgery encompasses a wide range of surgical techniques; from intra-tendinous injections and minimally invasive options such as tenoscopy and bursoscopy, to open approaches for tenectomy, tenotomy/desmotomy and neurectomy. This presentation will discuss the most common complications that occur with these procedures intra-operatively, in the immediate post-operative period, or longer-term, with suggestions for strategies to avoid them.

Intra-operative complications

- Injection into an open tendon lesion will result in minimal retention of the injected product thereby resulting in no therapeutic benefit. When the needle is advanced too far and penetrates the far surface of the tendon, the injected product will be deposited outside the tendon and have the same negative therapeutic effect. A lack of therapeutic benefit can also occur when using orthobiological treatments through poor (or variable) preparation and handling.
  Strategy to avoid complication: Intratendinous injections should only be administered when there is a contained lesion and under ultrasound guidance.

- Intraoperative iatrogenic damage to tendons and adjacent vascular structures can occur during tenoscopy, especially when creating instrument portals close to blood vessels and with transection of the ALSDFT because of the blood vessels lying on the proximal margin of the ligament. Overzealous manipulation of the endocope during tensocopy or bursoscopy can also damage the surface of the tendon. In addition, blind transection of the fascia has been associated with iatrogenic damage to the proximal suspensory ligament[1]and the incidence of this appears to have been reduced using a fasciotome in an in vitro study on cadaver limbs[2].
  Strategy to reduce risk of complication: Care when making portals near tendons/vessels; gentle movement of the endoscope when performing endoscopy or bursoscopy; use suction punch rongeurs when transecting ALSDFT; and use a fasciotome under ultrasound guidance for fasciotomy.

Early post-operative complications

- Tendon haemorrhage which can make the ultrasonographic (and clinical) appearance of the tendon lesion worse. This has been seen with a number of different injected products but appears to be anecdotally more common after platelet-rich plasma (PRP) injection. Significant haemorrhage can occur intra-thecally after an Esmarch bandage is removed and in the immediate post-operative period resulting in sudden exacerbation of the lameness, which can easily be confused with synovial sepsis.
  Strategy to reduce risk of complication: Avoid intratendinous injections too early after the injury (<7 days) and minimise movement of the horse after surgery.

- Incisional breakdown, haematoma formation, synovial fistulae after open tendon sheath surgery, and tendon or synovial sepsis can also occur in the immediate post-operative period. Suture removal, while rarely problematical, has been observed associated with digital flexor tendon sheath sepsis when tenoscopic portals have not healed normally. Carpal sheath tenoscopy has also been considered a higher risk for post-operative synovial sepsis [3].
  Strategy to reduce risk of complication: Monitor tenoscopic portal healing and remove sutures with care (sterilely) if there has been any concern. Avoid open tendon sheath surgery.

Late post-operative complications

- Needle tracts are frequently very obvious ultrasonographically after intratendinous medications. They are also often associated with a subtle swelling at the injection site. They are more of a cosmetic

blemish than having a significantly adverse effect on outcome but can be of significant concern to owners. The reason for their occurrence is not clear and they are difficult to predict.
Strategy to reduce risk of complication: Possibly consider the use of small needle bores (but beware of minimal needle sizes for cellular therapies[4]). Warn owners of the risk but that they are unlikely to impact outcome significantly.

- Abnormal (dystrophic) tissue formation can form inside a tendon after intratendinous injection or tendon damage (including through surgery). Dystrophic mineralisation has been most associated in the past with depot corticosteroid intra-tendinous medication but has also been observed by the author after neat bone marrow injection.
Strategy to reduce risk of complication: Avoid administering products intratendinously that can cause dystrophic tissue formation (eg corticosteroids).

- Post-operative neuroma formation is a well-described complication after neurectomy, which is performed for proximal suspensory desmitis in the hindlimb and occasionally for tendon pathology such as DDFT lesions in the foot. In addition, this is observed clinically when peripheral nerves are damaged through endoscopic portal creation, which has been most frequently seen in the pastern when the transthecal approach is used for navicular bursoscopy.
Strategy to reduce risk of complication: Take care when creating tenoscopic/bursoscopic portals close to nerves by ensuring the digital nerves are retracted out of the way. Minimise nerve trauma and inflammation post neurectomy.

- Adhesion formation/excessive fibrosis. Any surgical approach to a tendon sheath or bursa carries the risk of post-operative adhesion formation that can result in the restriction of tendon movement and long term lameness post-operatively. Generally adhesions form within a tendon sheaths or bursa when there are opposing damaged surfaces but has also been anecdotally associated with orthobiological use.
Strategy to reduce risk of complication: Minimise iatrogenic damage to the tendon and overlying synovial membrane during tensocopy/bursoscopy

- Exacerbation of tendon or ligament pathology or tendon rupture. Removing sensation from a damaged tendon or ligament can risk the exacerbation of the injury after neurectomy because of the removal of the protective pain response. Protective loading of a tendon for a long period of time can result in significant weakening that can predispose to rupture once normal weight-bearing is restored .
Strategy to reduce risk of complication: Avoid performing a neurectomy when there is recent or active tendon or ligament pathology present. Minimise duration of casting if possible and/or provide joint support after cast removal.

- Fragmentation of the apex of the patella is a well-described complication after medial patellar ligament desmotomy [5]which is thought to be due to altered tracking of the patella.
Strategy to reduce risk of complication: Medial patellar ligament desmotomy should only be performed for the most severely affected cases. If performed, it should be followed by a period of rest to allow the ligament to heal and the tracking of the patella to be restored.

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