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**The Equine Health Program at North Carolina State University's College of Veterinary Medicine brings together horse owners, veterinarians and CVM faculty on the issues, research and advancements concerning horse health in North Carolina and beyond.**

[www.cvm.ncsu.edu/docs/ehp.html](http://www.cvm.ncsu.edu/docs/ehp.html)



## Letter from Associate Dean for Research

To veterinarians and all horse owners and lovers,

Research saves lives. How often have we heard this phrase? We all have witnessed changes in the way diseases that affect our loved ones have changed over time. On a personal note, my father is a retired family practitioner. During his 40 plus year medical career he saw first hand how research discoveries influenced the way he treated his patients. At some point all of the advancements in drugs, diagnostic tools, and approaches were ultimately driven by research. I've likewise witnessed dramatic changes in the level of care that veterinarians can provide to horses and other animals. As the field of human medicine advances so too does veterinary medicine. However, anyone familiar

with horses knows that veterinary medicine can not solely rely on our colleagues in human medicine for the next advancement in equine medicine.

Unfortunately, we don't always appreciate that research also takes money. Financial resources are needed to pay salaries, maintaining and operating facilities, and for the care of animals entrusted to our care. A large percentage of health-related research in this country is funded through the National Institutes of Health (NIH). With the support of the American people, the NIH annually invests over \$28 billion in medical research underway at North Carolina State University and other universities, medical schools, and other research institutions in every state and around the world. The primary mission of the NIH is to improve people's health and save lives. These resources rarely impact equine medicine. The United States Department of Agriculture (USDA) funds basic and applied research with the intent of improving animal health and well being. Less than several million dollars of funding is used to support research that directly benefits horses. Research priority areas in equine medicine include ways to improve diagnosis and treatment of respiratory diseases, laminitis, colic, as well as contagious equine metritis and vesicular stomatitis virus and other diseases that impact horse movement. So many needs and yet very little funding available.

Veterinary research relies heavily on you, the interested horse owner, to fill this gap in funding. Your support of the NC State University Equine Health Program is especially critical at this time when Federal budgets have become increasingly limited. In addition, the veterinary profession is beginning to feel the effects of a loss of researchers that were trained in the 1970's and are now leaving the laboratory. There is an urgent need to identify and train the next generation of veterinarian scientists that will lead our profession for the next twenty to thirty years.

I hope that you enjoy learning more about our Equine Health Program and that you will consider supporting these research efforts. Remember, research saves lives.

Sincerely,

David C. Dorman, DVM, PhD  
Associate Dean for Research and Graduate Studies  
College of Veterinary Medicine  
North Carolina State University



## Letter from Department Head

As the Department Head of Clinical Sciences, I would like to welcome you all to the annual Equine Health Program Research Update. Our research programs are critical to the mission of the College of Veterinary Medicine because they allow us to understand those problems that take the lives of horses, and those that keep our horses out of work. In addition, we actively research new methods of increasing and improving breeding programs so that we can become less dependent on breeding programs that are overseas or out of state. We are constantly assessing new ways of funding this research effort as federal funds become scarce, and private funding becomes more and more competitive. Presently, most of our funding ultimately comes from the horse owner. Anyone interested in assisting in any way should feel free to contact the College of Veterinary Medicine Foundation Office where we now have our own Equine Development Officer (Michael Strader).

As far as our research, we continue to study lameness, particularly imaging. For example, we continue to refine our techniques for assessing the use of magnetic resonance imaging (MRI), particularly for difficult-to-diagnose conditions such as suspensory ligament strain. One of the most exciting areas of research is the age-old question of how to trim and shoe horses, leading to the creation of a dedicated podiatry service. We are also very pleased to welcome new faculty members that study equine pharmacology, so that new drugs can be assessed and given at the right dose, and clinicians that study colic, particularly the factors that place horses at risk of colic and at risk of complications following surgery. In addition, clinicians involved in colic research continue to improve treatment of horses by studying new and established drugs. Ophthalmology is a key area of study, including the study of the vascular supply of the eye (the uvea). Uveitits (moon blindness) has been studied with novel therapeutic approaches, such as anti-inflammatory implants. Finally, our reproductive program continues to focus on the improvement of novel ways of breeding, particularly embryo transfer (ET).

I am particularly grateful to Dr. Dick Mansmann for linking us with the outside world through outreach programs, and our hard working clinicians, students and technicians, who work well beyond the normal work week to promote our programs. I hope to meet with many of you during the research overview, and invite you to contact me with any questions about our equine programs.

Best regards to you and your horses,

A handwritten signature in black ink that reads "Anthony Blikslager". The signature is written in a cursive, flowing style.

Anthony Blikslager, DVM, PhD  
Diplomat, American College of Veterinary Surgeons  
Head, Department of Clinical Sciences  
College of Veterinary Medicine  
North Carolina State University



## Letter from Director of Outreach

2007 was a breakout year for the NC State College of Veterinary Medicine's Equine Health Program. We are a very young veterinary college only 26 years old, compared to the University of California at Davis, 59 years; Colorado State, 100 years; Cornell 113 years; Ohio State 122 years and the University of Pennsylvania 124 years old. NC State's College of Veterinary Medicine is ranked 5<sup>th</sup> in the United States! We had a tremendous teaming up with all our helpers to make horse health move forward in North Carolina – horse owners, equine practitioners, equine oriented companies and our faculty.

The Equine Health Program in the College of Veterinary Medicine is involved with all things horses within the College, especially related to education of veterinary students and veterinarians, research to advanced health care within the Veterinary Teaching Hospital. For students we have increased scholarship monies to help them reduce some of their five figure education debt. The North Carolina Hunter Jumper Association is a model leader in this area giving \$10,000 toward student scholarships in 2007. Our 22<sup>nd</sup> Annual Equine Medicine Symposium in February brought companies together for education with veterinary practitioners on Saturday and horse owners on Sunday.

Our facilities development program at the Equine Health Center in Southern Pines got underway with the Cogdell matching challenge. This development will take our renowned Reproductive Unit to greater heights with additional laboratory, examination and mare/stallion housing. It will help provide space for other out reach services like Ophthalmology, podiatry and other potential services.

Besides the many lectures given within the College the faculty gave lectures at many national and international meetings. Our research area with the help of students and graduate veterinarians continues to set records. We also have a new Associate Dean of Research, Dr. David Dorman. We added two new equine oriented faculty members, Dr. Callie Fogle, a surgeon and Dr. Jennifer Davis, an internist whose research is in pharmacology.

This year we acquired Shannon Hoffman as our administrative assistant and Michael Strader as our equine development officer. Shannon brings NC horse industry knowledge and creativity to our program. Michael has had significant back ground in development to help in the newly expanded development office.

2007 was a major leap forward for the Equine Health Program and the future is very bright. Consider investing in our excellence.

Sincerely,

Richard A. Mansmann, VMD, PhD  
Director of Out Reach, Equine Health Program  
College of Veterinary Medicine  
North Carolina State University

*E*quine Faculty  
*H*orse Owners  
*P*ractitioners



*All Working  
Together  
for Horse Health*

## Your Support

Many times, especially after quality care or lifesaving treatment has been given to someone's horse or other animal, people will ask "*what can I do to help, or how can I help support your facilities or other needs you may have.*" The College of Veterinary Medicine graciously accepts contributions in support of our programs.

Your support can make a difference in the lives of horses and their devoted owners. The North Carolina Veterinary Medical Foundation (NCVMF) accepts donations for the Equine Health Program at the College of Veterinary Medicine and our Equine Health Center at Southern Pines. Tax deductible contributions can be made through:

- **The Gallop of Honor.** Supports the overall mission and goals of the Equine Health Program. With gifts of \$250, \$500 or \$1,000 you will receive a personalized Bronze, Silver or Gold Horse Shoe, which will be placed on our Gallop of Honor Wall at the location of your choosing (either Southern Pines or Raleigh). The horse shoes are a great way to honor a favorite horse, veterinarian or someone important in the life of your horse. Amounts less than \$250 still support the Equine Health Program, but will not earn you a horseshoe.
- **Scholarships for Equine Health Students.** Contributions to this program support fellowships and scholarships for DVM students who are planning to become equine practitioners. These awards will help offset the student debt load that most DVM students experience upon graduation. See page 6 for more information.
- **Endowed Chairs, Professorships and Programs.** Endowment of equine faculty positions and programs provides both salary and operational support to attract and retain eminent and world class equine faculty.
- **Capital Improvements.** Substantial investment is needed for both new construction and renovation of existing equine facilities at our Southern Pines center and our hospital in Raleigh. The future of equine health in North Carolina is dependent upon providing our faculty and staff with the physical resources to ensure exceptional care, research and education.
- **Fund for Discovery.** Provides financial support for training programs for students involved in the summer research internship program. For more information, refer to page 8.

For more information about making a contribution to the Equine Health Program or the Equine Health Center, contact Michael Strader, Director of Development for Equine Health Programs at the NCVMF Office: (919) 513-6856, or [michael\\_strader@ncsu.edu](mailto:michael_strader@ncsu.edu), or to make your gift online, visit [www.cvm.ncsu.edu/ncvmf/](http://www.cvm.ncsu.edu/ncvmf/)

## **Scholarship Information**

There is a continued need of scholarships for equine oriented veterinary students. On average, veterinary students start their careers with a debt of \$70,000 or more. With this large debt load, new veterinarians are tempted to go into a more lucrative small animal practice, where average salaries are higher for the first five years than those in equine practice. Scholarships can offset the cost of this debt, and could be one of the deciding factors for students when choosing their practice.

Our scholarship program continues to grow, and we are grateful for those who have made contributions the past few years. The Raleigh Spring Premiere Horse Show, with manager Ray Cloninger and the North Carolina Hunter Jumper Association both have endowed scholarships and have also increased their financial gifts to students by placing half their annual donations into their endowments and half is given directly to students. These two organizations, along with the Randall B. Terry Horse Racing Scholarship have endowed scholarships established that directly benefit equine oriented students. Additionally, the North Carolina Thoroughbred Association has an annual equine scholarship established as well.

How can you help? Whether you are an individual, a group of individuals, a veterinary practice, a horse organization, a business, etc., your support can make a difference. To set up an endowed scholarship, the minimum contribution is \$25,000. Endowed scholarships are those set up in which only the interest accrued is used each year, not the principal. You can also make annual individual contributions which can be given directly to deserving equine oriented students. Gifts of \$1,000 or more could prove very beneficial to students, helping offset yearly tuition.

If you have questions, or would like more information concerning our scholarships or if you wish to set up a new scholarship, please contact Michael Strader at (919) 513-6856 or email to [michael\\_strader@ncsu.edu](mailto:michael_strader@ncsu.edu).

# Contributions

## **Equine Health Program & Gallop of Honor Donors July 1, 2006 – June 30, 2007**

Animal Eye Care Associates, Inc	Mr. Randy Mogg
Ms. Elaine T. Baillie	Ms. Cynthia A. Morehead
Lee R. Bergman	NC Dressage & Combined Training
Lee Ray Bergman Real Estate	NC Hunter Jumper Association Inc
Rentals	NCSU-SCAAEP
Ms. Amy Bresky	Neuse River Veterinary Hospital
Ms. Denise R. Burrell	Ms. Joyce Hamilton Park
Mrs. Nicki L. Bleich	Partnar Animal Health, Inc.
Ms. Suzanne K. Buchheit	Ms. Eliza K. Pavalko
Mr. Jim Cogdell	Paws Here Awhile Pet Resort
Ms. Frances D. Currey	Mr. & Mrs. Glenn Thomas Petty
Dr. Richard C. Dillman	Pfizer Inc
Janet A. Dolohanty	Ms. Gloria F. Phillips
Ms. Dianne L. Freudenschuss	Raleigh Spring Premier Horse Show
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Mr. Daniel M Kozink	Ms. Barbara J. Robison
Mr. Gregory E. Kuntz	Sand Dollar Saddle Club
Dr. Kristine N. LaFever	Ms. Karen K. Segal
Ms. Linda Dreher	Stars and Bars Farm, Inc
Roger & Tina Fowler	Statewide Campaign Organization
Ms. Robin Freeman	Mrs. Nikki Heston Stewart
Mr. Gregory L. Hassler	Mr. Kenneth A. Steele
Ms. Debora Hayward	Kraig Stemme, DVM
Ms. Gwendolyn T. Horn	Dr. Lloyd P. Tate Jr
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Ms. Marjorie Sanford Ketzler	Triangle Farms Inc
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Ms. Kristen King	Mr. Scott B. Umstead
Ms. Rebecca R. Lula	Ms. Joan P. Valerio
Dr. Richard A. Mansmann	James W. & Lisa H. Valone
Ms. Rowena T. Mason	Visionaire Research and Education
Merck Company Foundation	Ms. Linda L. Whalen
Ms. Kim Liebhart Miller	Mr. Edward R. White Jr

## VETERINARY SCHOLARS PROGRAM SUMMER INTERNSHIPS IN EQUINE RESEARCH

Like other veterinary disciplines, equine veterinary medicine is faced with a shortage of veterinarians trained in research. The importance of research training is not only in producing researchers that work on problems related to equine health and welfare, but also to enrich our students who enter equine practice with knowledge that equips them to better understand diseases and their treatment and to make better use of new information that is being produced every day by equine veterinary research. The equine group at NC State is very involved in all four of the training programs that provide research experience and training to veterinary students.

**Summer Research Internship Program:** Each year, 4-5 students in the summer research internship program work with equine faculty mentors. In the summer of 2007, a record 8 students worked on equine research projects. The members of the equine faculty are well represented in the program; Dr. Sam Jones, Dr. Anthony Blikslager, Dr. Carlos Pinto, Dr. Sarah Gardner, Dr. Jen Davis, Dr. Mat Gerard, Dr. Brian Gilger, Dr. Dick Mansmann, and Dr. Betta Breuhaus are recent mentors who have trained students in the program.



**Jennifer Jones-Shults** worked for the second summer with Dr. Blikslager on a project examining the effects of lidocaine IV infusions on the intestine damaged in a model of strangulating colic. *Jennifer was awarded a prestigious Morris Animal Foundation Veterinary Student Scholar grant for her project entitled “Effect of cyclooxygenase inhibitors on expression of COX isoforms in equine whole blood”.* The objective of this project was to determine the effects of the anti-inflammatory analgesic drugs flunixin meglumine, phenylbutazone, ketoprofen, etodolac, carprofen, deracoxib, meloxicam, and firocoxib on the two forms of cyclooxygenase enzyme (COX) in horse cells. Drugs that are highly selective for COX-2 identified in this project hold promise to be very useful for treating a number of important equine diseases such as arthritis and colic with fewer undesirable side effects on the stomach and intestinal tract.



**Colleen Meyer** worked with Dr. Blikslager on a project examining whether firocoxib, a selective COX-2 inhibitor, provides effective pain control while allowing the intestinal lining (mucosa) to recover quickly after injury resulting from a lack of blood supply to the gut. The results of this study suggest that firocoxib will be a better alternative for pain management in colic patients compared to the current standard of therapy flunixin meglumine. *Colleen was the recipient of the 2007 North Carolina Hunter Jumper Association Summer Research Internship, made possible by a generous donation to the North Carolina Veterinary Medical Foundations Fund for Discovery.*



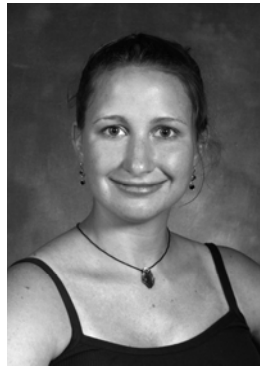
**Laura Douglas** worked with Dr. Brian Gilger studying the toxicity of Rapamycin when administered by injection into the eye in horses. Rapamycin is a powerful anti-inflammatory drug that has potential applications for a number of important eye diseases in the horse. Laura determined that intravitreal and subconjunctival injections therapeutic doses of Rapamycin are not toxic to the equine eye. She expects that this drug will be useful for treating the devastating ocular disease called equine uveitis, also known as moon blindness.



**Blair Holland**



**Shannon Doorhy**



**Laura Heaton**



**Brian Lanier**

**Blaire Holland, Shannon Doorhy, Laura Heaton, and Brian Lanier** (a veterinary student at Ross University) worked with Dr. Carlos Pinto to evaluate luteal function and subsequent estrous cycle in mares treated with the prostaglandin  $PGF_{2\alpha}$  during early diestrus as compared with mid-diestrus. Their preliminary results indicate that complete functional luteolysis can be achieved as early as 2 days after ovulation, potentially improving the effectiveness of this method of short cycling mares. They expect that the results of this project will revolutionize the way estrous cycle manipulation can be performed in cycling mares.



**Sarah James** worked with Dr. Dick Mansmann to evaluate reducing breakover and/or raising heels in the hind limbs of horses as a means to alleviate gluteal muscle pain. The objective of her study was to evaluate the relationship between decreasing breakover in relation to the tip of the bone encapsulated by the hoof (P3) and reducing gluteal pain observed on palpation. She also evaluated whether raising heels resolved gluteal pain in horses when reducing breakover was not effective. Besides potentially eliminating a significant cause for back pain using a trimming and/or shoeing technique, this study begins to address the normal measurement ranges for healthy hind feet. The study also has the potential to help prevent behavior, gait, and posterior limb tendon/ligament problems.

## **FINANCIAL SUPPORT FOR THE SUMMER RESEARCH INTERNSHIP PROGRAM: THE FUND FOR DISCOVERY**

Finding the funds to enable equine oriented students to work on equine research projects in the summer internship program is a challenge. The Fund for Discovery was established by a generous gift from Ms. Deborah Resnick several years ago to provide funds for all veterinary students in the College who were seeking research experience. Over the years, the Fund for Discovery has helped support more than 16 equine oriented veterinary students in our summer research internship program. This year, for the first time, a generous gift from the North Carolina Hunter Jumper Association provided support for an equine oriented student working in an equine research laboratory. Colleen Meyer was the first recipient of this award and worked in Dr. Anthony Blikslager's laboratory this past summer. The College of Veterinary Medicine and the North Carolina Veterinary Medical Foundation are dedicated to growing the Fund for Discovery to provide more opportunities for veterinary students in research experiences. The funding provided by the Fund for Discovery will have a great impact on research training for equine veterinary students and residents. Donations to this fund may be unrestricted or earmarked for those students working on equine projects, depending on the preference of the donor. For more information on the Fund for Discovery, please see the North Carolina Veterinary Medical Foundation website <http://www.cvm.ncsu.edu/ncvmf/>. For online giving click on "Give Now" and select the Fund for Discovery from the Designated Gift drop down menu or contact:

Dr. Sam Jones  
Director, Clinician Scientist Training Programs  
4700 Hillsborough St.  
Raleigh, NC 27606  
Phone: 919-513-7722  
Email: [sam\\_jones@ncsu.edu](mailto:sam_jones@ncsu.edu)

# EFFECTS OF LIDOCAINE AND FLUNIXIN MEGLUMINE ON RECOVERY OF ISCHEMIC- INJURED EQUINE JEJUNUM

**Vanessa Cook**, Research Associate Equine Gastrointestinal Physiology

**Jennifer Jones Shults**, Veterinary Student

**Marsha McDowell**, Veterinary Student

**Anthony Blikslager**, DVM, PhD, DACVS, Associate Professor, Equine Surgery

**Funded by the Morris Animal Foundation**

## Description of the Problem

Colic is the principal cause of mortality in horses because of absorption of endotoxin across damaged intestine. In severe colic caused by strangulating of the intestinal obstruction, reduced blood supply causes ischemic injury necessitating surgical resection. However, complete removal of damaged intestine is not always possible, and, with restoration of blood flow, these areas may undergo further damage from reperfusion injury. Recovery of ischemic-injured intestine postoperatively is critical for survival of the horse. Flunixin is an analgesic and anti-inflammatory drug used routinely in postoperative colic cases. However, our previous work has shown that, although an effective analgesic, it retards recovery of the mucosal barrier in ischemic-injured intestine. Therefore, it is crucial to investigate alternative anti-inflammatory agents to increase survival of colic patients.

## Study Objectives

- Determine if treatment of horses with ischemic-injured jejunum with intravenous lidocaine restores mucosal barrier function and ameliorates up regulation of inflammatory genes associated with ischemia and reperfusion.
- Determine if treatment with flunixin meglumine retards recovery of mucosal barrier function despite a modest reduction in expression of inflammatory genes.
- Determine if treatment with lidocaine and flunixin meglumine will be more effective than either drug alone on recovery of ischemic-injured jejunum.

## Experimental Approach:

Four groups of 6 horses underwent a midline celiotomy and sections of jejunum were subjected to 2 hours of ischemia by temporary occlusion of the local blood supply. At the end of the ischemic event, wedge biopsies were obtained from ischemic and non-ischemic sections of jejunum. Horses were assigned to one of four treatment groups:

1. 10mL 0.9% NaCl IV q 12 hours (control); 2. flunixin meglumine 1 mg/kg IV q 12 hours; 3. lidocaine 1.3 mg/kg loading dose followed by 0.05 mg/kg/min constant rate infusion; 4. flunixin meglumine and lidocaine at the previously mentioned doses. Following recovery from anesthesia, analgesia was provided by butorphanol and horses were monitored for pain using an established behavioral pain scoring system. All horses were euthanized 18 hours following reversal of ischemia and jejunum harvested for the in vitro component of this study. Harvested jejunum was mounted in Ussing chambers for measurement of transepithelial resistance and permeability using fluorescent-labeled *E. coli* lipopolysaccharide. Denuded villous surface area was measured using histomorphometry. Western blot analyses of expression of COX-1 and COX-2 were performed for all groups. Blood samples were obtained at 8 hours post-ischemia and analyzed for TXB<sub>2</sub> and prostaglandins. Data were compared between treatment groups using a 1-way ANOVA. The transepithelial resistance (TER) data were tested by use of a 2-way repeated-measures ANOVA for the effects of treatment and time. Significance was set at P<0.05.

### **Accomplishments/Results:**

No signs of lidocaine toxicity were seen at any time in any horse. Serum lidocaine concentration was highest at the end of ischemia at 4.11 µg/mL. Treatment with flunixin or flunixin and lidocaine combined significantly reduced pain score compared to treatment with saline or lidocaine alone (P=0.003). Treatment with flunixin significantly reduced TER in ischemic-injured tissue from 45-150 minutes compared to the other 3 treatment groups. LPS flux was significantly increased in ischemic-injured jejunum in flunixin treated horses compared to those treated with flunixin and lidocaine combined, lidocaine alone or saline (P<0.05). Treatment with lidocaine and flunixin meglumine combined significantly reduced TXB<sub>2</sub> concentration at 8 hours compared to treatment with saline, flunixin or lidocaine alone (P<0.05). Treatment with flunixin meglumine or lidocaine and flunixin meglumine combined significantly reduced prostaglandin concentrations at 8 hours when compared to treatment with saline (P<0.05). Two hours of ischemia significantly increased histopathologic grade regardless of treatment group (P<0.05). Histopathologic grade significantly improved after 18 hours of recovery regardless of treatment group (P<0.05). COX-1 was expressed in both control and ischemic tissues, while COX-2 was up regulated after ischemia across treatment groups.

### **Benefits to the Equine Industry:**

Systemic lidocaine alone was not an effective visceral analgesic. However, by combining treatment with flunixin meglumine and systemic lidocaine, the negative effects of flunixin meglumine on ischemic injured intestine were ameliorated, while effective analgesia was maintained. Therefore, combining these treatments for post operative colic cases may improve recovery after surgery.

# **EFFECTS OF FIROCOXIB OR FLUNIXIN MEGLUMINE ON RECOVERY OF ISCHEMIC- INJURED EQUINE JEJUNUM**

**Vanessa Cook**, Vet MB, MS,  
DACVS, DAVECC,  
Research Associate Equine  
Gastrointestinal Physiology

**Colleen Meyer**,  
Veterinary Student

**Nigel Campbell**, BVetMed,  
PhD, DACVIM  
Clinical Assistant Professor,  
Anesthesiology

**Anthony Blikslager**,  
DVM, PhD, DACVS, Associate  
Professor, Equine Surgery

**Funded by Merial Limited**

## **Description of the Problem**

Intestinal injury due to colic leads to many horses' deaths each year worldwide. Current drug therapy may actually be amplifying its negative effects because the popular NSAID flunixin meglumine, a non selective COX inhibitor, has been shown to slow intestinal repair. However it is still used because it is an excellent analgesic. The compromise in barrier integrity permits the leakage of lipopolysaccharides directly into the bloodstream, and can result in sepsis and often death. Therefore treatment of these horses with a COX-2 selective NSAID which allows recovery of the intestine while providing effective analgesia would be preferable. Firocoxib is a COX-2 selective NSAID in horses but its use for treatment of colic has not been investigated.

## **Study Objectives**

The purpose of this study is determine whether firocoxib is a sound alternative to flunixin meglumine for treatment of horses with colic. Specifically:

- Determine if treatment of horses with ischemic-injured jejunum with firocoxib will provide effective analgesia.
- Determine if treatment with firocoxib will allow recovery of the mucosal barrier after ischemic injury.

### **Experimental Approach:**

Horses were divided into 3 groups, (n=6 per group) and administered one of the following treatments: 1) 0.9% NaCl 1mL/50Kg IV 2) flunixin meglumine 1mg/Kg IV q12 hours, 3) firocoxib 0.09mg/kg IV q24 hours. Following induction of anesthesia, ischemia was induced in two sections of jejunum for two hours. Full thickness and mucosal biopsies of ischemic and non-ischemic jejunum were taken. After recovery from surgery, horses were monitored via pain behavior scores at regular intervals, while butorphanol was used for analgesia. Horses were euthanized 18 hours post surgery, and sections of both ischemic and non-ischemic jejunum removed. The mucosa was placed on Ussing chambers and analyzed for transepithelial resistance (TER) and permeability using LPS flux data. Biopsy samples were analyzed using histologic morphometry to determine denuded villus surface area and crypt depth. Western blots were used to determine COX-1 and COX-2 expression. Plasma samples pre-surgery and post ischemia were used for determining TXB<sub>2</sub> and PG metabolite concentrations. Data were compared between treatment groups using a 1-way ANOVA. The TER data were tested by use of a 2-way repeated-measures ANOVA for the effects of treatment and time. Significance was set at P<0.05.

### **Accomplishments/Results:**

Treatment with firocoxib or flunixin meglumine significantly reduced pain score compared to treatment with saline (p<0.05). Treatment with flunixin reduced TER in ischemic-injured jejunum. Treatment with firocoxib allowed recovery of TER and was not significantly different from treatment with saline. LPS flux was significantly increased in ischemic jejunum in flunixin treated horses compared to those treated with firocoxib or saline (P<0.05). Treatment with flunixin meglumine significantly reduced TXB<sub>2</sub> concentrations at 8 hours compared to treatment with saline or firocoxib (P<0.05). Two hours of ischemia significantly increased histopathologic grade regardless of treatment group (P<0.05). Histopathologic grade significantly improved after 18 hours of recovery regardless of treatment group (P<0.05).

### **Benefits to the Equine Industry:**

Treatment with firocoxib did not impair recovery of mucosal barrier function and appears to be an effective visceral analgesic. Firocoxib could be useful in the post-operative management of horses with colic.

# INCISIONAL COMPLICATIONS

**Callie Fogle, BS, DVM**  
Clinical Instructor, Equine Surgery

**Mathew P. Gerard,**  
BVSc, PhD, DACVS  
Clinical Asst Professor, Equine Surgery

## **Description of the Problem**

Incisional complications following ventral midline celiotomy for surgery of the gastrointestinal tract in the horse are generally between 15 and 37%. An incisional infection or incisional hernia can have a dramatic effect on the recovery of the patient and on the long-term satisfaction of the client despite a successful surgical outcome.

## **Study Objectives**

- To determine the frequency of incisional infection and incisional herniation at NCSU-CVM
- To discover risk factors for incisional infection and incisional herniation
- To discover treatments which are protective against incisional complications

## **Experimental Approach:**

Using the NCSU-CVM Equine Colic Database, 236 horses undergoing colic surgery with 6 or more months of followup were selected. Signalment, surgical diagnosis, intraoperative variables, postoperative treatments, and incisional complications were recorded.

## **Accomplishments/Results:**

- Incisional drainage occurred in 43/236 horses (18%).
- Incisional herniation occurred in 17/236 horses (7%).
- Resection of intestine, moderate/severe incisional edema, and placement of an abdominal bandage were determined to be risk factors for incisional drainage.
- Further statistical analysis still to be performed.

## **Benefits to the Equine Industry:**

This study will assist clinicians in recognizing the horses that are at increased risk of developing incisional complications and improve perioperative measures for prevention and client education. Early recognition and treatment of incisional drainage may also reduce the frequency and severity of incisional problems.

## USE OF ULTRASOUND TO EVALUATE SURVIVAL FOLLOWING COLIC SURGERY FOR EQUINE LARGE COLON VOLVULUS

**Anthony Pease,**  
DVM, MS, DACVR  
Assistant Professor  
Radiology

**Mary Katherine Sheats,**  
DVM  
Equine Internal Medicine  
Resident

**Samuel Jones,**  
DVM, PhD, DACVIM  
Associate Professor of  
Equine Medicine

**Vanessa Cook,** VetMB,  
MS, DACVS, DAVECC

**Anthony Blikslager,**  
DVM, PhD, DACVS  
Interim Head and  
Associate Professor  
Equine Surgery

### **Description of the Problem:**

**Large colon volvulus (LCV)** is the most fatal form of colic in horses and has a relatively high prevalence. This disease is characterized by ischemia, edema, and severe abdominal pain associated with at least 360° twisting of the colon around its mesenteric axis. Rapid surgical intervention is required to correct LCV; however, due to vascular compromise, post-operative management is intensive with a poor prognosis for survival.

### **Study Objectives:**

- Determine the time after surgery for the colon wall to return to normal (5mm thickness) in horses with a large colon lesion; otherwise referred to as ‘colon wall involution’.
- To compare colon wall involution time with other blood work parameters typically used to monitor horses after surgery. Parameters and designated abbreviations are as follows: **packed cell volume (PCV)**, **total protein (TP)**, **colloid oncotic pressure (COP)**, and **blood lactate concentration (BL)**.
- Determine if the measured parameters serve to predict survival in horses that undergo surgery for large colon volvulus.

### **Experimental Approach:**

Ultrasound measurements of colon wall thickness was performed every 8 hours for the first 48 hours after surgery and then every 24 hours to 4 days post-operatively. Blood will also be obtained during this time to obtain PCV, TP, BL and COP for comparison to ultrasound.

### **Accomplishments/Results:**

- 15 horses evaluated to date
- Based on preliminary results, rapid reduction in colon wall thickness within the first 12 hours post-operatively seems associated with survival to discharge.
- Based on preliminary results, patients receiving advanced post-operative treatment seem to have more rapid colon wall involution and higher survival rates than previously published reports.

### **Benefits to the Equine Industry:**

For the horse industry and horse owners, this research provides new statistics on survival rates for horses affected by this devastating type of colic; as well as a novel approach to post-operative monitoring of these intensive care patients. Depending on future data analysis, this management approach may provide invaluable information to owners that will assist them in making both medical and financial decisions in regards to treating their horses.



# DIAGNOSTIC TOOLS FOR OCCULT LARVAL CYATHOSTOME INFECTION

**Bruce Hammerberg, D.V.M., PhD**  
Immunoparasitology

## **Description of the Problem**

Small strongyle nematodes or cyathostomes are the cause of the most common and costly infectious disease in horses. Larval stages of cyathostomes in the mucosa of the large bowel are refractory to treatment, can not be detected antemortem and are a source of acute and chronic inflammation leading to diarrhea, colic and poor condition. Synchronous emergence of larval cyathostomes from the mucosa in large numbers can be fatal. At this time there is no diagnostic method for measuring occult larval cyathostome infection burdens.

## **Study Objectives**

- Non-invasively measure nematode specific gut mucosal antibody response to larval cyathostomes.
- Non-invasively measure markers of intestinal inflammation and inflammatory cell activity occurring in the gut mucosa.
- Correlate measurements of cyathostome-specific responses to individual horse health status before and subsequent to larval emergence.

## **Experimental Approach:**

Develop immunoassays to detect larval cyathostome-specific IgE, IgG/T and IgA in feces as a non-invasive measurement of horse infection/response status to mucosal larvae. Develop fecal assays for tumor necrosis factor-alpha, tryptase and eosinophil cationic protein to determine mucosal inflammatory status due to mast cells and eosinophils. Conduct measurements on feces from horses over time to capture larval emergence events.

## **Accomplishments/Results:**

- Immunoassay (ELISA) for fecal antibodies specific for larval cyathostomes have been completed and demonstrate good results with dynamic changes over time in individual horses on pasture.
- Reagents for detecting inflammatory markers in feces assembled.

## **Benefits to the Equine Industry:**

Detection and staging of larval cyathostomiasis will aid control and help prevent health loss from this ubiquitous disease.

# COMPARISON OF THE DIAGNOSIS AND MANAGEMENT OF UNILATERALLY CASTRATED AND CRYPTORCHID HORSES AT A REFERRAL HOSPITAL: 60 cases (2002-2006)

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Oklahoma State University

## Description of the Problem

Cryptorchidism is a frequently occurring congenital defect in the horse. It is recommended that prior to castration the horse be examined to locate both testicles and select the appropriate anesthetic and surgical method. When failure to remove the second testicle occurs, through inability to locate or physically remove the testicle, the result is a unilaterally-castrated horse.

## Study Objectives

- This aims of this study were to determine the incidence of unilateral-castration and compare the distribution of retained testicles and management of unilateral-castrate and cryptorchid horses.

## Experimental Approach:

The medical records of horses that were presented for castration, including cryptorchids and unilateral-castrates, between January 2002 and December 2006 were reviewed. The medical records of castrates and cryptorchids were examined for age, breed, history, diagnostic procedures, surgical technique of cryptorchidectomy, location of the retained testicle, and the cost of

surgery. Statistical analyses were performed using the rank sum test,  $\chi^2$  test, or Fisher Exact test as appropriate. Statistical significance was set at  $p < 0.05$

## Results:

Of 160 horses presented for castration, 16 (10%) were diagnosed as unilateral-castrates and 44 (27.5%) as cryptorchid. The unilateral-castrate group (mean  $\pm$  SE,  $4.09 \pm 0.49$  years) was significantly older than the cryptorchid group (mean  $\pm$  SE,  $2.36 \pm 0.22$  years) ( $p < 0.001$ ). There was no significant difference in the overall left versus right distribution of testicles. There was no significant difference in the abdominal versus inguinal distribution of left-sided testicles. The unilateral-castrate group contained a significantly lower proportion of right inguinal testicles than expected ( $p < 0.05$ ). The cost of diagnosis and management of the unilateral-castrate group was significantly greater than the cryptorchid group ( $p < 0.05$ ).

## Benefits to the Equine Industry:

The results of this study show that despite current recommendations for the complete castration of horses, the practice of unilateral castration still occurs. Also, the distribution of testicles is significantly different in the unilateral castrate when compared to the cryptorchid horse and this may affect the selection of diagnostic and surgical approach by the veterinarian.

## DETECTION OF *BARTONELLA HENSELAE* IN BLOOD FROM ADULT HORSES

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**Ricardo Maggi,** PhD  
Research Assistant  
Professor

### **Description of the Problem:**

*Bartonella spp.* are Gram-negative aerobic bacilli classified in the alpha subdivision of the class *Proteobacteria*. At least 20 species and subspecies of *Bartonella spp.* have been identified. Infection with *Bartonella spp.* causes fever and lymphadenopathy, CNS disorders, bacillary angiomatosis and bacillary peliosis, endocarditis, hepatosplenic involvement, cutaneous vasculitis, and osteomyelitis in domestic animals and human beings.

*Bartonella spp.* have been isolated from numerous species of domestic and wild animals, including cats, dogs, coyotes, deer, cattle, foxes, lions, rabbits, rodents, and porpoises, but not horses. We hypothesized that *Bartonella spp.* infect horses and may be a cause of disease.

### **Study Objectives:**

- **Determine whether *Bartonella spp.* could be detected in the blood of adult horses.**

### **Experimental Approach:**

Two horses were tested for the presence of *Bartonella henselae* in their blood, one with acute vasculitis and one with chronic arthropathy. Blood samples were tested for the presence of *Bartonella sp.* using a combination of a highly sensitive multiplex real-time PCR, specifically designed to detect all *Bartonella spp.*, and the alpha-*Proteobacteria* sample enrichment culture that promotes bacterial growth and enhances their detection. In addition, conventional PCR targeting of two independent genes, the intergenic transcribed sequence (ITS) and a consensus sequence of the phage associated gene (Pap31), was performed in order to establish genus and species identification through cloning and sequencing. This approach involves the following phases:

- a) screening for *Bartonella* DNA in blood samples using real-time and conventional PCR
- b) enrichment culture of the original blood sample in BAPGM for seven days with subsequent molecular screening.
- c) blood agar plate sub-culturing of the enriched culture material, followed by molecular screening of isolated colonies.

**Results:**

*Bartonella henselae* DNA was detected by PCR in the blood of both horses and live *Bartonella henselae* organisms were isolated by enrichment culture from one of the horses.

**Benefits to the Equine Industry:**

This is the first description of *Bartonella henselae* infection in horses. The results of this study suggest that *Bartonella henselae* infection should be investigated as an emerging disease in horses, and a potential cause of vasculitis and arthritis in horses.

**Publications:**

Jones SL, Maggi R, Shuler J, Alward A, Breitschwerdt EB. (2007) Detection of *Bartonella henselae* in the blood of two adult horses. *J Vet Intern Med* (In Press).



# BREED ASSOCIATED INSULIN RESISTANCE IN HORSES

## B.A. Breuhaus

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## D.H. LaFavers

MS Research Technician



Students collecting blood samples

## Description of the Problem

Laminitis is a significant clinical problem in horses, resulting in pain and decreased quality of life, decreased usefulness or athletic ability, and even loss of life itself. The pathophysiology of laminitis is incompletely understood, but its cause is almost certainly multifactorial. It has been proposed that insulin resistance predisposes horses to bouts of recurrent laminitis. Insulin resistance can be caused by genetic, prenatal and environmental factors. In horses, differences in insulin sensitivity have been associated with gender, diet, age, exercise, pregnancy, stress, obesity, pituitary pars intermedia dysfunction (PPID) and with the relatively newly described equine metabolic syndrome (EMS). Obesity is a clinical feature of EMS and has been proposed as a risk factor for development of laminitis in mature horses, but metabolism of glucose or insulin in non-laminitic obese horses that do not have PPID or EMS has not been studied. Recently, relative insulin resistance has been documented in ponies, confirming a long-held suspicion that ponies are different metabolically from horses. In addition to ponies, there are certain breeds of horses that are predisposed to obesity, particularly regional adiposity (ie accumulation of fat in the crest of the neck, over the tailhead, in the sheath, etc). These horses are thought to be more prone to develop laminitis, but to date there have been no studies to show breed associated differences in insulin sensitivity. The hypothesis of the proposed study is that lean horses from a breed that typically develops regional adiposity (eg Paso Fino) will be insulin resistant compared to lean horses from a breed that does not typically develop regional adiposity (eg Thoroughbred)

## Study Objectives

To compare the insulin response to an intravenous injection of glucose (IV glucose tolerance test, IVGTT) in lean (body condition score 4-6) Paso Fino horses to that of lean Thoroughbred horses. To compare results of an IVGTT in lean (body condition score 4-6) Paso Fino horses to obese (body condition score 7-9) Paso Finos. horses

### **Experimental Approach:**

Enrollment of lean and obese Paso Fino and Thoroughbred horses was solicited throughout the state of North Carolina. Horses included in the study had a normal physical exam and baseline ACTH. An attempt was made to have an even distribution between the two breeds regarding age, gender, work level and diet. IVGTTs were performed in each horse at its own farm. Carbohydrate concentrate feeds and supplements were withheld after 6pm the evening before and the morning of the tests. Roughage (hay, pasture) was not withheld. Each horse remained in its stall for the duration of the IVGTT. The morning of the IVGTT, a short 16gauge catheter was inserted into one jugular vein for blood sampling. After control blood was drawn, 0.33g/kg glucose was given rapidly into the opposite jugular vein, as a 50% dextrose solution. Subsequent blood samples were taken for the next 6 hours. Samples were spun, transferred to storage tubes, and frozen on site, and later analyzed for glucose and insulin.

### **Accomplishments/Results:**

The summer of 2006 we enrolled and studied 10 lean Pasos, 7 obese Pasos, 5 lean Thoroughbreds and 2 obese Thoroughbreds. The data showed a statistically significant difference in the area under the insulin curve between lean Pasos and lean Thoroughbreds. Obese horses from both breeds had much greater areas under the insulin curves, but the numbers of horses were too small to compare between the two breeds.

The summer of 2007 we enrolled and studied an additional 2 lean Pasos, 6 obese Pasos, 8 lean Thoroughbreds and 2 obese Thoroughbreds. Data from these horses is currently being analyzed. If the data from the horses we collected in 2007 supports what we found in 2006, this will be the first study to show a difference in insulin sensitivity between two breeds of horses.

### **Benefits to the Equine Industry:**

Breeds of horses that are insulin resistant may be more likely to develop laminitis, even when these horses are prevented from becoming obese. Within certain breeds, it may be possible to gradually breed lines of horses that have greater intrinsic insulin sensitivity. Breed-specific normal values may have to be determined for diagnostic tests such as the IVGTT.

**We are grateful for funding by the North Carolina Horse Council for this study.**



**Veterinary School Students on Farm visits collecting samples.**

# CHARACTERIZATION OF A NEW SURGICAL MODEL OF TENDONITIS OF THE SUPERFICIAL DIGITAL FLEXOR TENDON IN HORSES

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## **Description of the Problem:**

Equine tendonitis is a common devastating injury in horses. Although the collagenase model of tendonitis (Spurlock *et al.* 1989) has been used for many years to study the effect of different treatment modalities on the rate and quality of tendon healing in horses (Dahlgren *et al.* 2002), this model is dissimilar to naturally-occurring tendonitis. As a result, extrinsic healing factors from the peritendinous connective tissues contribute to cellular infiltration and neovascularisation of the lesion, rather than just intrinsic healing factors arising from the tendon's own cell population and blood supply, as is more likely to happen in naturally occurring disease. Furthermore, treatment of SDF tendonitis may rely on accurate delivery and containment of the therapeutic agent into the tendon's core (Smith 1992, Dahlgren *et al.* 2002, Hertsch *et al.* 1989, Dyson 2004). As an example, the differentiation of therapeutically delivered mesenchymal stem cells (MSC) (Smith *et al.* 2003) into tenocytes is likely to be mediated by their location within the tendon's core, where the appropriate mechanical (tensional forces) and biochemical (growth factors) environment exists for optimal differentiation. It is therefore important that the MSCs can be placed in a contained 'lesion receptacle' where they can be expected to stay and be subjected to this local differentiating environment. Naturally occurring tendonitis typically presents with such a centrally located core lesion that forms a perfect receptacle for the therapeutic MSCs. The proposed model of tendonitis is a modification of surgical window models in laboratory animals that have used variable amounts of tendon transection (Young *et al.* 1998, Awad *et al.* 1999).

## **Study Objectives:**

1. to create a core lesion within the distal metacarpal region of the SDFT
2. to monitor the clinical progression of pain, lameness, swelling and tenderness
3. to monitor ultrasonographically the size of the SDFT, the size and the echogenicity of the core lesion and the fiber alignment in the core lesion
4. monitor the MR signal characteristics of the core lesion and the parent SDFT with MRI
5. to evaluate and grade the structural characteristics of the tissue contained within the core lesion with histology
6. to compare the ultrasonographic characteristics and the MRI findings with each other and with histological observations

### **Experimental Approach:**

Four horses of 3-6 years of age were recruited for the study and a core lesion was created in the SDF tendon of each front limb. The legs were assessed qualitatively for heat, lameness and pain on palpation of the tendon each day for the first week and thereafter once a week for the remainder of the study. The core lesion in each SDF tendon was monitored ultrasonographically at 1, 2, 4, 6, 8 and 12 weeks after injury. The core lesion in each SDF tendon was also monitored with high-field MRI (Siemens Symphony 1.5 Tesla) at 2, 4, 8 and 12 weeks after injury in transverse, dorsal and sagittal planes. 2D and 3D T1-weighted and T2 weighted sequences with and without fat saturation and a 2D short tau inversion recovery (STIR) sequence were used. Tendon segments were embedded in paraffin, sectioned to 6 micron sections on a rotary microtome and stained with haematoxylin and eosin and Masson trichrome. Sections are being evaluated under plain and polarized light. Levels of the tendon with homogenous histological abnormality were chosen for correlation with imaging studies.

### **Accomplishments/Results:**

All of the horses were not consistently lame at walk and only moderately lame at the trot during the initial exercise period. Lameness at the trot resolved rapidly within 5-10 days after lunging exercise was discontinued. Ultrasonographic lesions were 8-14 cm long. Maximum cross-sectional area (CSA) of the core lesion occurred at 17-21 cm distal to the accessory carpal bone (ACB) and was a mean 18.55% of total CSA. Hypoechoic core lesions with disruption of longitudinal fibres pattern were evident during and immediately after surgery. Core lesions increased in size following the initial exercise period by an average of 7% of total CSA. Mean time to maximum lesion CSA was 27 days. Echogenicity scores of core lesions improved between 6-8 weeks after injury and longitudinal linear echoes appeared between 8 and 12 weeks.

On MRI, CSA of the tendon was smaller in T1 than in T2 weighted sequences, but CSA of the lesion was consistently larger in T1 images than in T2. Core lesions produced a more hyperintense signal in T1 sequences than T2 sequences at all time points. The hyperintense signal at the site of the lesion persisted for a longer period of time in T1 compared to T2, PD or STIR sequences, and T2 signal was normal in core lesions from 2 months after injury. Mean maximum CSA of the lesion was 20.13% of the total CSA in T1 sequences, and occurred at 11-23 cm distal to the ACB.

Histological examination showed that at two weeks post-injury, the core defect was already filled in with numerous proliferating fibroblasts, capillaries and small calibre blood vessels. The fibroblasts could be observed migrating from the connective tissue around the pre-existing, mostly intact tendon bundles at the periphery of the core lesion. There were only small numbers of inflammatory cells (hemosiderin-laden macrophages and lymphocytes) and small scattered areas of haemorrhage within the core lesion. From approximately 4 weeks post-injury, fibroblasts at the centre of the core lesion were producing small amounts of ground substance and immature collagen fibres. From this time to 12 weeks post-injury there appeared to be only a small increase in the amount of ground substance and immature collagen. Thus, by 12 weeks post-injury, the major component of the core lesion was still largely composed of fibroblasts with little or no reconstitution of normal tendon architecture.

## Benefits to the Equine Industry:

Use of this model will make application and investigation of novel intra-tendinous therapies such as stem cell injection easier, by reducing the amount of concurrent peritendinous reaction and allowing for better comparison, so that ultimately stem cell therapies can be tailored properly to the specific demands of equine tendonitis. Improved monitoring of tendon integrity with MRI will enable veterinarians to identify horses at risk of injury better at an earlier stage of the disease and patients with a high risk of re-injury better during the late stages of convalescence.

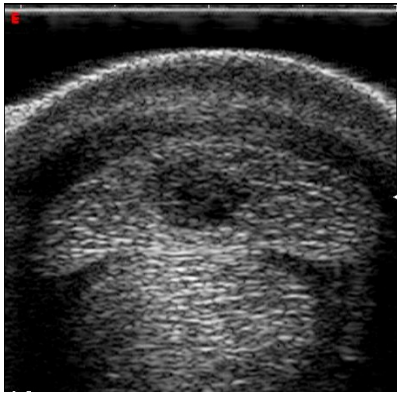


Figure 1. Ultrasonographic image of the core lesion at 19 cm distal to the ACB, 4 weeks after lesion induction

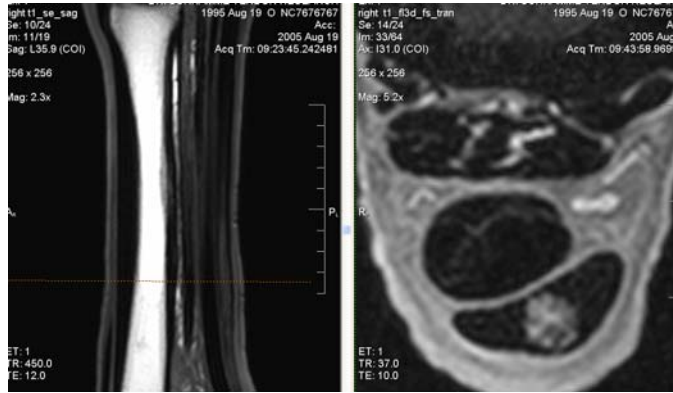


Figure 2. MR images (Sagittal 2D T1 SE and transverse 3D T1 FLASH) of the core lesion at 19 cm distal to the ACB, 4 weeks after lesion induction



# **COMPARISON OF ULTRASOUND AND MRI IN THE DIAGNOSIS OF PROXIMAL PLANTAR METATARSAL PAIN IN 25 HORSES**

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## **Description of the Problem:**

Proximal suspensory desmitis (PSD), defined as desmitis occurring within 10 cm of the origin of the suspensory ligament (SL), is a common injury in the hindlimbs of performance horses of many different disciplines. Once lameness of the distal limb has been eliminated, lameness should be abolished or substantially improved following anesthesia of the deep branch of the lateral plantar nerve. Pain confirmed to originate from the proximal plantar aspect of the metatarsal region of the limb should prompt both a radiographic and sonographic examination of this area. However, accurate sonographic definition of structures in the proximal plantar metatarsal region is difficult. The position and depth of the SL, the presence of variable amounts of muscle fiber within the SL in the hindlimb, the interference between the axial borders of the splint bones and the borders of the SL, as well as the presence of overlying large vessels in the proximal plantar metatarsal region all compromise definition of the SL and complicate the sonographic interpretation of this structure. Therefore sonographic diagnosis of PSD remains equivocal, MRI is a cross-sectional imaging modality that provides better soft tissue contrast and definition than any other imaging modality. MRI has now been introduced to several veterinary hospitals and is being utilized more frequently for evaluation of horses with proximal plantar metatarsal pain. The purpose of the study was to define the abnormalities encountered in the proximal plantar metatarsal region of horses in which lameness was abolished with anesthesia of the deep branch of the lateral plantar nerve and to define the sensitivity and specificity of ultrasonography for the diagnosis of PSD using MRI as the gold standard.

## **Study Objectives:**

1. to determine the incidence of injuries defined by MRI as the cause of lameness emanating from the proximal plantar metatarsal region
2. to determine the accuracy of the sonographic definition of the cross-sectional area of the SL at 2, 4 and 6 cm distal to the tarsometatarsal joint, using MRI as the gold standard
3. to define the sensitivity and specificity of ultrasonography for the diagnosis of desmitis of the proximal part of the SL, as defined by the presence of abnormal MR signal.

### **Experimental Approach:**

Horses identified as having proximal plantar metatarsal pain were selected for this study. Radiographic and ultrasonographic examination was performed on 23 horses. MRI (1.5 Tesla Siemens Symphony magnet) was performed with horses under general anaesthesia. Images were obtained in sagittal, dorsal and transverse planes and included 2 dimensional (2D) dual echoes (proton density and T2 weighted), 3D spoiled gradient echoes (T1 weighted FLASH) and short inversion recovery (STIR) sequences. Agreement between ultrasonography and MRI was calculated as the sensitivity and specificity of sonography. Only when abnormalities in the sonographic examination could be detected at the same level of the SL as in the MR images, was the result considered ‘true positive’. Abnormalities detected on ultrasonography that were not observed during MRI or not at the same level as indicated by the MRI were considered ‘false positive’. Abnormalities detected on MRI but not ultrasonographically were ‘false negative’ and the absence of lesions on images of either technique were labeled ‘true negative’. Cross sectional areas (CSA) of the SL was measured sonographically and with MRI at 2, 4, and 6 cm distal to the level of the tarsometatarsal joint. Using the MRI CSA at each level as the gold standard, the precision of ultrasonography was assessed by comparing the ultrasonographically determined CSA with the MRI CSA for each level in each horse with a paired t-test.

### **Accomplishments/Results:**

Of 25 horses with proximal plantar metatarsal pain that underwent MRI at North Carolina State University between January 2005 and May 2007, 17 horses suffered unilateral lameness (of which 2 had bilateral signs of PSD on MRI) while 8 were bilaterally lame (of which 2 horses had no significant findings in either limb while 2 other horses had unilateral signs of PSD only). Six horses were diagnosed with primary PSD, 7 horses with a combination of primary PSD and osseous abnormalities, 8 horses with primary osseous abnormalities and 4 horses with no obvious abnormalities (table 1).

Primary desmitis without osseous abnormalities	6/25
Primary desmitis with osseous abnormalities	7/25
Primary osseous abnormalities without desmitis	8/25
No obvious abnormalities	4/25

**Table 1:** Breakdown of diagnoses in 25 horses with proximal plantar metatarsal pain

Lesions of the SL were generally identified as focal or generalized areas of signal hyperintensity in the proximal part of the SL, extending distally from the origin, with or without enlargement of the CSA and, in some cases, an adhesion between the dorsal surface of the affected lobe of the SL and the plantar cortex of the metatarsus. Of the 13 horses with primary desmitis, 10 horses had focal to generalized hyperintense signal within the ‘core’ of the SL, clearly indicating the presence of architectural change in the ligament. Eight of these core lesions were localized more in the dorsocentral aspect of the SL, while 2 occurred in the plantarocentral area. Two horses had peripheral signal changes in the lateral aspect of the lateral lobe of the SL. One horse had overall enlargement without architectural change. In 9/12 horses with a ‘core’ lesion, the architectural change occurred in the collagenous part of the SL rather than the muscular

part. In one horse architectural change occurred throughout the entire cross-section of the SL, therefore also involving both the lateral and medial muscle bundles. In one other horse, architectural change was limited to one muscle bundle and some of the surrounding collagenous tissue. In the majority of horses, hyperintense signal extended between 6 and 11 cm distal to the level of the TMT joint.

In the 7 horses with primary desmitis and coexisting osseous abnormalities, 4 presented with an endosteal reaction on the dorsal aspect of the plantar metatarsal cortex, 2 with intense bone edema in the proximal aspect of the 4<sup>th</sup> metatarsal bone or in the 4<sup>th</sup> tarsal bone and 1 horse had evidence of dorsal cortical modeling in the affected limb..

The MR diagnosis in 8 horses with primary osseous abnormalities included exostosis of the 4<sup>th</sup> metatarsal bone with an associated adhesion to the SL in 2 horses, focal bone edema of the 3<sup>rd</sup> and central tarsal bones associated with the attachment sites of the intertarsal ligament in 2 horses, fracture of the plantar aspect of the 3<sup>rd</sup> & 4<sup>th</sup> tarsal bone in one horse, bone edema and a diffuse endosteal response in the dorsomedial aspect of the metatarsus in 1 horse, an osseous cystic lesion of the central tarsal bone in 1 horse and OA of the distal intertarsal joint in 1 other horse.

No obvious desmitis or osseous pathology could be found in 4 horses. While there were no obvious architectural changes associated with the origin of the SL there was mild enlargement in the dorsopalmar dimension of the SL, mild to moderate change in the shape of the proximal part of the SL, or a small adhesion to the plantar metatarsal cortex.

Ultrasonographic examinations were available for 23 horses. Agreement between the appearance of the lesion on MRI and ultrasonography was generally poor. There were 9 'true positive' ultrasonographic examinations, 12 'false positive', 1 'false negative' and 1 'true negative' in 23 horses with positive anesthesia of the deep branch of the lateral plantar nerve. Of the 13 horses with MRI evidence of primary PSD, 9 had 'true positive' ultrasonographic findings and 1 had 'false negative' readings at the level of the MRI lesion. Of the 10 horses without MRI evidence of PSD for which ultrasonographic images were available however, 9 had 'false positive' ultrasonographic findings. We concluded that the specificity of ultrasonography was 8%, indicating a high risk of a false positive diagnosis based on ultrasonography alone. The positive predictive value of an ultrasonographic abnormality in the proximal part of the suspensory ligament was found to be 43%. There was poor agreement between the CSA measurements performed with both imaging techniques at 2, 4 and 6 cm distal to the metatarsal joint. When compared to the CSA measured on MRI, ultrasonographic CSA were smaller in 32/34 limbs at 2 cm, 27/34 limbs at 4 cm and 20/31 limbs at 6 cm distal to the tarsometatarsal joint.

### **Benefits to the Equine Industry:**

PSD has become the most common diagnosis in horses with mild to moderate hindlimb lameness. However, ultrasonography however is highly inaccurate and produces a high number of false positive diagnoses. Therefore the ultrasonographic diagnosis of PSD has to be considered with caution and MRI should be used where possible to reach the most accurate diagnosis.

**Funded by the Bernice Barbour Foundation.**

# **THE USE OF MRI IN THE DIANOSIS OF MUSCULOSKELETAL ABNORMALITIES IN THE HORSE**

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## **Description of the Problem:**

MRI produces a grey-scale image of hydrogen protons in tissues, based on the measurable energy release when protons alter their orientation in a large magnetic field. Depending on the number and density of these protons, and on the weighting of the particular MR sequence, different tissue types will produce MR signal of different intensity. In addition tissue alterations caused by inflammation and tissue remodeling will change the proton content and density, and therefore the MRI characteristics of a particular tissue.

Although the use of regional analgesia is relatively successful at localizing the region where pain arises in the limb, the exact cause of lameness in horses often remains elusive with current imaging methods. This is especially true in areas of the limb where radiography is insufficiently accurate or where soft tissue structures are deeply buried and therefore inaccessible to satisfactory ultrasonographic examination (i.e. the foot, the origin of the suspensory ligament, the palmar cortex of the metacarpal condyles). MRI is a cross-sectional imaging modality that can produce digital imaging slices in any plane, as thin as 1.5 mm, of body regions that can be positioned in or close to the isocentre of the magnet. MRI results in superior anatomical detail and soft tissue contrast and provides information on the fluid and mineral content of bone.

## **Study Objectives:**

1. To validate a Siemens Symphony 1.5 T Magnet for use with horses and explore the accessibility of different anatomical areas of interest.
2. To develop a set of MR sequences for different anatomical areas of interest, that maximize the diagnostic information without prolonging the anesthesia time unnecessarily.
3. To document the frequency of examinations of different anatomical areas of interest.
4. To document the incidence of specific diagnoses for each area of interest.
5. To determine the proportion of patients in which MRI was able to produce a conclusive diagnosis that could not be obtained with other diagnostic modalities

### **Experimental Approach:**

Horses presented for MRI examination between October 1<sup>st</sup> 2004 and September 30<sup>th</sup> 2007 were included in the study. MRI was considered indicated if other imaging modalities (radiography, ultrasonography and/or scintigraphy) had failed to reveal any significant abnormalities or produced equivocal results. A final diagnosis was based on the integration of the clinical history and the results of physical examination, regional analgesia and imaging methods including MRI.

### **Accomplishments/Results:**

Sequences were developed for examinations of the foot, the fetlock, the suspensory ligament, the hock and the skull (including the brain). It was determined that all areas distal to and including the carpus and tarsus in front and hindlimbs could be examined satisfactorily using MRI. MRI was performed on 197 horses during the period of investigation. One hundred and twenty one MRI examinations involved both front feet, 37 examinations the origin of the suspensory ligament, 27 examinations the fetlock, 1 examination of a spine, 6 examinations the head and 5 examinations the hock. Four horses were examined twice.

➤ The following diagnoses were made in 121 horses with foot lameness.

<b>FOOT MRI DIAGNOSIS (n=121)</b>	<b>PRIMARY %</b>	<b>TOTAL %</b>
Navicular bone abnormalities	32	53
DDF tendonitis and navicular disease (occasionally with DSIL or CSL abnormalities)	20	
DDF tendonitis	13	31
DIP joint abnormalities	10	
Collateral ligament desmitis	9	13
Pedal osteitis	5	
Digital annular ligament desmitis (distal/prox)	5	
Impar ligament desmitis	3	6
Focal bone edema distal P2	2	
Navicular suspensory desmitis	2	6
Laminitis	2	
Distal sesamoidean ligament desmitis	2	
Chondrocompedal ligament desmitis	2	
Navicular bursitis	1	
Proximal interphalangeal OA	1	
No abnormalities detected or open	13	

Several horses had simultaneous occurrence of 2 or more injuries. (For example 53% of the horses had navicular bone abnormalities) Only the primary lesions are listed in the table, with exception of combinations between navicular degeneration and DDFT tendonitis. (For example 32% of the horses their primary diagnosis was navicular bone abnormalities)

- The following diagnoses were made in 37 horses with proximal metacarpal/metatarsal pain:.

<b>MRI DIAGNOSIS (n=37)</b>	<b>PRIMARY</b>
Suspensory ligament desmitis	16 (43%)
Osteitis or stress reaction proximal plantar third or fourth metacarpal/metatarsal cortex	5 (14%)
Suspensory ligament desmitis and osteitis proximal plantar third or fourth metacarpal/metatarsal cortex	4 (10%)
Splint bone reactions with focal suspensory desmitis	3 (8%)
Distal tarsal OA	3 (8%)
Focal tarsal bone edema	2 (5%)
Central tarsal bone cyst	2 (5%)
Dorsal metatarsal cortical stress reaction	1 (3%)
No obvious abnormalities	5 (14%)

In addition to 5 horses with concurrent presence of palmar/plantar osseous remodeling and proximal desmitis, 4 horses had simultaneous occurrence of 2 injuries.

- The following diagnoses were made in 27 horses with fetlock pain; Several horses had simultaneous occurrence of 2 or more injuries.

<b>MRI DIAGNOSIS (n=27)</b>	<b>PRIMARY</b>
Sesamoiditis (including small cystic lesions)	6 (22%)
Subchondral bone disease (edema)	4 (15%)
Palmar metacarpal condylar necrosis	4 (15%)
Suspensory branch desmitis	4 (15%)
Straight distal sesamoidean ligament desmitis	4 (15%)
Chip fracture	3 (10%)
Collateral ligament desmitis	3 (10%)
Intersesamoidean ligament desmitis	2 (7%)
OA	2 (7%)
DDFT tendonitis in digital sheath	1 (4%)
SDFT tendonitis in digital sheath	1 (4%)
Annular ligament tear	1 (4%)
Digital annular ligament desmitis	1 (4%)
No obvious abnormalities	4 (15%)

### **Benefits to the Equine Industry:**

MRI is a realistic and rewarding imaging technique in horses available at NCSU-VTH, especially for musculoskeletal imaging of areas that are poorly accessible to other imaging modalities. The Siemens Symphony 1.5 T magnet offers the advantage of fine anatomical detail and improved accessibility over other magnets, as objects can be imaged to within 20 cm of the isocenter of the magnet. In addition the diagnostic rate is high and the incidence of examinations without abnormal findings low. However, the significance of subtle abnormalities is still uncertain and further studies are on-going to determine the sensitivity and specificity of MRI for the identification of known pathological abnormalities.



Figure 1. Sagittal 2D PD SE image of a right foot with a core lesion (high signal) in the lateral lobe of the DDFT, extending from the proximal border of the navicular bone to the distal aspect of the digital synovial sheath. Reference level of transverse image shown.



Figure 2. Transverse 3D T1 Flash image of a right foot with a core lesion in the lateral lobe of the DDFT. The core lesion is characterized by high signal intensity, suggesting a high focal concentration of hydrogen protons.

# REDUCING BREAKOVER IN THE HIND LIMBS OF HORSES AS A MEANS TO ALLEVIATE GLUTEAL MUSCLE PAIN

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## Description of the Problem

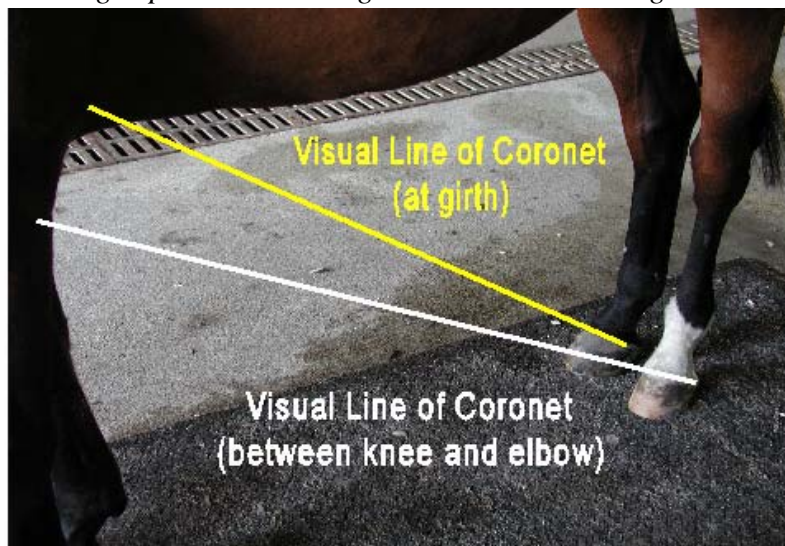
Lameness in the horse is the most significant contributor to loss of work and decreased performance of horses. Many sub clinical or subtle causes for pain could be a contributor to decreased performance, shortening training and pleasure riding sessions and create the potential for compensatory injury.

Several causes of back pain have been described in horses but none have been specifically related to hind foot conformation. Medical, physiotherapeutic and interventional treatments are often suggested as treatments for back pain without addressing foot conformation and shoeing. This study involves horses with palpable bilateral back pain in their gluteal muscles and how it may be related to foot conformation.

## Study Objectives

1. To evaluate the relationship between decreasing breakover in relation to the tip of the hind coffin bones and reducing gluteal pain observed on palpation.
2. To evaluate the clinical use of the role of visual line of the hind coronet band and where it hits the horse. If the line hits between the carpus and elbow presumably the horse has a proper toe length and heel height. The further posteriorly, the more abnormal the foot conformation is; meaning the longer the toe and/or lower the heel.

*This figure shows the visual line of the hind coronets.  
The black hind leg is prior to trimming and the white hind leg has been trimmed.*



## **Experimental Approach:**

Four categories of horses have been included in the study.

1. Clinical cases of horses with hind long toes, low heels and palpable gluteal pain as determined by a single examiner (RAM). These horses have standardized lateral radiographs of both hind feet at the time of the gluteal pain evaluation and immediately post shoeing or at the next shoeing. The back was checked within five weeks.
2. Clinical cases of horses with palpable gluteal muscle pain had their breakover measured in their hind feet via standardized lateral radiographs.
3. Clinical case of horses with no palpable muscle pain had their breakover measured in their hind feet via standardized lateral radio graphs.
4. In a group of barefoot, non ridden mares with palpable gluteal muscle pain had their breakover measured via standardized lateral radiographs. The breakover was reduced, measured and palpation of gluteal muscles was palpated within a week.

## **Accomplishments/Results:**

At this time, combining all four categories of horses there were twenty-four horses, that had palpable gluteal muscle pain. The average breakdown measured from the tip of P-3 on the standardized lateral radiographs for the painful group was 23.5 mm. The average of the 24 horses in the non painful group was 10.95 mm.

To bring this preliminary study to conclusion more number of horses will be added to the four categories and statistics applied for evaluation for the hypothesis.

## **Benefits to the Equine Industry:**

Besides potentially eliminating a minor or significant cause for back pain using a trimming and/or shoeing technique, this study can begin to address the normal measurement ranges for healthy hind feet. The study also has the potential to help prevent behavior, gait and posterior limb tendon/ligament problems. For example, of the 18 retrospective horses measured, histories prior to reducing breakover included front and/or hind limb lameness, poor performance, decreased stride length and/or behavioral issues when ridden. Five of the measured horses had previous treatment to try and resolve these issues including shockwave therapy, fetlock/hock/stifle/sacroiliac injections, acupuncture and massage.

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