Pferdeheilkunde 25 (2009) 6 (November/Dezember) 576-580

Atypical laminitis after orthopedic surgery in eight horses

Annina Widmer[1] , Martin Kummer[1], Regula Bettschart[2] and Anton Fürst[1]

Equine Department Vetsuisse - Faculty Zurich, Section Surgery[1], Section Anesthesia[2], University of Zurich

Summary

A retrospective study was carried out to investigate the prevalence and causes of laminitis affecting limbs other than the contralateral healthy limb after orthopedic surgery in horses. Of 3,500 horses referred for orthopedic surgery at the Equine Clinic, Vetsuisse-Faculty, University of Zurich, between 1992 and 2007, eight horses that developed laminitis in one or more limbs, but not primarily the contralateral limb, were identified. The reasons for referral were synovial space infection (n = 4), pastern joint arthrodesis (n = 1), fracture of the central tarsal bone (n = 1), bilateral stifle osteochondrosis (n = 1) and luxation of the superficial digital flexor tendon (n = 1). Postoperative complications included infection of the surgery site (n = 1), severe postoperative pain (n = 2), postoperative myopathy (n = 1), urticaria (n = 1) and cecal impaction (n = 1). The administration of analgesics was discontinued eight days after surgery because of urticaria in one horse and one day after surgery because of cecal impaction in another horse. Seven of the eight horses were euthanized because of severe laminitis. Elimination of infection and effective postoperative analgesia appear important in the prevention of laminitis. Severe postoperative pain should be prevented with adequate, continuous and multimodal pain management. It should also be noted that laminitis may occur in response to excessive weight bearing in limbs other than the contralateral limb after orthopedic surgery.

Keywords: laminitis, horse, orthopedic surgery, orthopedics, surgery

Atypische Hufrehe nach orthopädischen Operationen bei 8 Pferden

Es handelt sich in dieser Fallserie um eine retrospective Studie über die Häufigkeit der Entwicklung von Hufrehe nach orthopädischen Eingriffen, welche nicht primär die kontralaterale Gliedmaße betrifft. Von 3500 Pferden, welche für einen orthopädischen Eingriff an die Pferdeklinik der Vetsuisse-Fakultät der Universität Zürich zwischen 1992 und 2007 überwiesen wurden, entwickelten 8 Pferde eine Hufrehe, welche nicht primär das kontralaterale Bein betraf. Die Gründe der Einlieferung waren synoviale Infektionen (n=4), Krongelenksarthrodese (n=1), Fraktur des os tarsi centrale (n=1), bilaterale Osteochondrose im Kniegelenk (n=1), und Fersenkappenluxation (n=1). Vor dem Eintreten der Hufrehe traten postoperativ folgende Komplikationen auf: Nahtinfektion (n=1), starke postoperative Schmerzen (n=2), postoperative Myopathie (n=1), Urtikaria (n=1) und Caecumobstipation (n=1). Bei einem Pferd wurden die Analgetika 8 Tage und bei einem anderen Pferd einen Tag nach der Operation abgesetzt infolge Urikaria beim ersten und Caecumobstipation beim zweiten Pferd. Sieben der acht Pferde wurden wegen hochgradiger Hufrehe euthanasiert. Die effektive Elimination von Infektionen und gute postoperative Analgesie sind von großer Wichtigkeit, um eine Hufrehe zu verhindern. Starke postoperative Schmerzen sollten durch adäquates und kontinuierliches multimodales Schmerz-Management verhindert werden. Es muss ebenfalls beachtet werden, dass Belastungsrehe nicht nur an der kontralateralen Gliedmaße vorkommen kann.

Schlüsselwörter: Hufrehe, Pferd, orthopädische Operationen, Orthopädie, Chirurgie, Komplikation

Introduction

Laminitis is a known complication after colic (*Hunt* et al. 1986) or orthopedic surgery in horses (*Levine* and *Richardson* 2007, *Peloso* et al. 1996) and frequently results in euthanasia of the patient. In most orthopedic patients, excessive weight bearing of the contralateral limb, especially for long periods, is thought to cause laminitis (*Peloso* et al. 1996). In a retrospective study on the clinical use of the locking compression plate (LCP) for long bone fractures and arthrodesis, five of 31 horses developed laminitis in the contralateral limb and four of these were euthanized (*Levine* and *Richardson* 2007). Of 44 horses with limb cellulitis, eight developed laminitis in the contralateral limb and were euthanized; laminitis in the affected limb was seen in only one horse. The authors of that study concluded that in horses with unilateral lameness, prompt administration of analgesics is imperative (*Adam* and *Southwood* 2007). Laminitis in horses can also be secondary to systemic diseases, such as severe rhabdomyolysis (*Sprayberry* et al. 1998) and enteritis (*Cohen* et al. 1994), or dystocia (*Carluccio* et al. 2007).

The aim of the present retrospective study was to describe 8 horses with laminitis, which not primarily involved the contralateral limb after orthopedic surgery.

Materials and methods

The medical records of horses admitted to the Equine Clinic, University of Zurich, were searched for patients that had undergone orthopedic surgery between 1992 and 2007 and had developed laminitis postoperatively while in the hospital. A total of 23 horses were identified. The records of 15 horses that developed laminitis in the contralateral limb first were excluded, and the remaining eight horses that developed laminitis in one or more limbs, but not primarily in the contralateral limb, were used in the study.

All patients were premedicated with phenylbutazone (Butadion®, Streuli Pharma, Switzerland) and sedated with medetomidine (Domitor®, Pfizer AG, Switzerland) or xylazine (Xylazin®, Streuli Pharma, Switzerland). All horse received tetanus

vaccination prior to surgery. Anesthesia was induced with ketamine (Narketan® 10, Vetoquinol AG, Switzerland) and diazepam (Valium®, Roche, Switzerland) and maintained with halothane or a combination of medetomidine and isoflurane. Morphine (Morphini hydrochloridum Streuli®, Streuli AG, Switzerland) was administered before recovery, and phenylbutazone (Equipalazon®, Veterinaria AG, Switzerland) was used for postoperative analgesia. All horses were routinely treated with antibiotics, which consisted of a combination of penicillin (Penicillin G®, Streuli Pharma, Switzerland) 30'000 I.U./kg bw bid iv and gentamicin (Vetagent®, Veterinaria AG, Switzerland) 7mg/kg bw sid iv.

A diagnosis of laminitis was based on clinical signs (lameness, increased hoof temperature, increased pulsation of the digital arteries, positive reaction to hoof testers), the results of nerve blocks and radiographic changes (rotation and/or sinking of the distal phalanx). Lameness was scored using the Obel grading system (*Stashak* 2002). Atypical laminitis was defined as laminitis in a limb other than the contralateral limb and that did not appear to be a sequel of systemic disease. Laminitis was treated with cooling of the hoofs (ice shoes) for 48h, 2 mg/kg phenylbutazone orally every 12 hours, 50 IU/kg heparin (Heparin®, Streuli Pharma, Switzerland) administered subcutaneously twice daily and intravenous infusion of dimethylsulfoxide (DMSO; 0.4g/kg iv; DMSO 20%, Streuli Pharma, Switzerland) every 12 hours. The feet were padded and a frog support made out of plaster of Paris was provided.

The following variables were analyzed: breed, sex, age, primary presenting problem, presence of infection, duration of the disease, duration of lameness, weight bearing pre- and postoperatively, type of orthopedic procedure, duration of surgery, intraoperative complications, anesthetic complications, intraoperative blood pressure, intraoperative oxygen saturation, intraoperative position of patient, use of a tourniquet, medications administered (antibiotics, non steroidal anti-inflammatory drugs [NSAIDs], other analgesics, anticoagulants, infusions), duration of postoperative analgesic management and mean dose of drugs used, postoperative complications (orthopedic, gastrointestinal, respiratory), postoperative laminitis prophylaxis, number of days to first signs of laminitis postoperatively, affected limb, radiographic changes, response to treatment and outcome. Because of the small number of patients the data are presented in a descriptive manner.

Results

Of 3,500 horses referred for orthopedic surgery at the Equine Clinic, Vetsuisse-Faculty, University of Zurich, between 1992 and 2007, eight horses that developed laminitis in one or more limbs, but not primarily the contralateral limb, were

Table 1 Summary of signalment and presenting problem

Case No	Signalment	Presenting problem	Surgery	Weight bearing preop	Weight bearing postop	Complications
1	Warmblood gelding (7 years; 670 kg)	Tendon sheath infection after pitchfork injury right front limb	Tendon sheet lavage	poor	good	Incisional dehiscence
2	Warmblood mare (13 years; 670 kg)	Pastern joint arthrosis left front limb, Osteochondrosis tarsal (left) and fetlock (left front) joint	Pastern joint arthrodesis, Arthroscopy	fair to good	Very poor	Severe postoperative pain Neurectomy because of poor weight bearing
3	Warmblood stallion (1 year; 460 kg)	Three-day-old open injury to tarsocrural joint right hind limb	Arthroscopy	good	good	Good outcome; no radiographic changes
4	Warmblood gelding (15 years; 480 kg)	Fracture of left central tarsal bone	Lag screw fixation	poor	Moderately good	Severe postoperative pain, myopathy of contralateral limb
5	Quarter horse gelding (2 years; 500 kg)	Infection of the proximal interphalangeal joint right hind limb	Arthroscopy	fair	good	Urticaria, NSAID discontinued
6	Thoroughbred gelding (4 years; 570 kg)	Infection of nuchal bursa	Bursoscopy	good	good	Concomitant hoof crack left forelimb
7	Thoroughbred stallion (2 years; 500 kg)	OCD of both stifle joints	Arthroscopy	fair to good	good	Caecal impaction; phenylbutazone discontinued
8	Warmblood mare (7 years; 580 kg)	Luxation of superficial digital flexor tendon in right hind limb		good	Moderately good to good	No complications

identified. Five horses were Warmbloods, 2 Thoroughbreds, and 1 Quarter horse. The range of weight was between 460kg and 670kg. All horses were operated in general anesthesia. The reasons for referral were synovial space infection (n = 4), pastern joint arthrodesis (n = 1), fracture of the central tarsal bone (n = 1), bilateral stifle osteochondrosis (n = 1) and luxation of the superficial digital flexor tendon (n = 1). Postoperative complications included infection of the surgery site (n = 1), severe postoperative pain (n = 2), postoperative myopathy (n = 1), urticaria (n = 1) and cecal impaction (n = 1). The administration of analgesics was discontinued eight days after surgery because of urticaria in one horse and one day after surgery because of cecal impaction in another horse. Seven of the eight horses were euthanized because of severe laminitis. The results are summarized in table 1 and 2.

Discussion

Atypical laminitis affecting the operated limb or a limb other than the contralateral limb after orthopedic surgery is rare in horses; of 3,500 orthopedic surgical patients over a 15-year period, we encountered only eight such cases. However, atypical laminitis frequently leads to euthanasia of the horse, similar to laminitis caused by excessive weight bearing on the contralateral limb.

There are numerous reports on laminitis attributable to excessive weight-bearing or metabolic disease (*Parsons* et al. 2007, *Peloso* et al. 1996). However, there is a paucity of information on laminitis occurring in an operated limb or in all four limbs after orthopedic surgery. Even in cases in which the contralateral limb is not primarily involved, laminitis may be attributable to excessive weight bearing. In our study, laminitis occurred in one or both forelimbs after hind limb surgery in cases 3, 4 and 5, and case 7 developed laminitis in all four feet after arthroscopy of both stifles. The laminitis in these four horses may have been attributable, in part, to excessive weight bearing. However, the cause of laminitis in the other four horses, especially the horse with infection of the nuchal bursa, is more difficult to identify; three of them had laminitis in the operated limb, and one had postanesthetic myopathy. Hypotension during anesthesia is considered to be the main cause of postanesthetic myopathy (*Grandy* et al. 1987). During hypotension, blood flow to the laminae of the hoof is decreased and hypoxic damage may induce laminitis. It is possible that postanesthetic myopathy and certain cases of laminitis are the result of hypoperfusion during anesthesia. Two horses (cases 2 and 4) with laminitis in the operated limb suffered severe postoperative pain. In patients with severe pain, neurovascular mechanisms result in vasoconstriction. The veins of the laminae of the hoof are predisposed to vasoconstriction, which can be elicited by various mediators, such as prostaglandins, catecholamines and serotonin (*Baxter* et al. 1989, *Peroni* et al. 2006). A tourniquet, which is known to cause pain in animals and humans (*Takada* and others 2007), was used intraoperatively in two of our patients. The use of a tourniquet was shown to result in an increase in blood pressure in anesthetized horses; the cause of the increased blood pressure was thought to be pain induced by hypoxia (*Abrahamsen* et al. 1989, *Copland* et al. 1989). In human medicine, pain caused by a tourniquet and surgical manipulation of tissues resulted in an increase in systemic coagulation, which could be inhibited by concurrent extradural anesthesia (*Hollmann* et al. 2001, *Kohro* et al. 1998). It is known that microthrombi occur in laminitis (*Weiss* et al. 1998; 1997; 1994; 1995) but whether the use of a tourniquet is a risk factor for this is not known. Sepsis and endotoxaemia also result in a systemic inflammatory reaction with an increased release of tumor necrosis factor alpha

Table 2 Summary of laminitis-associated parameters

Case No	Affected limbs with laminitis	Obel Grade of the most affected limb	Radiographic changes of the most affected limb	Number of days from operation to onset of laminitis	Number of days from initial operation to euthanasia	Reason for euthanasia
1	All 4 limbs, ipsilateral limb most affected	4	Mild rotation	25	37	Severe Pain
2	Ispilateral limb	4	Severe Rotation	37	41	Severe Rotation Severe Pain
3	Both front feet	2	none	6		none
4	Right front and left hind (ipsilateral limb)	4	Severe Rotation and sinking	5	12	Severe Rotation and sinking Severe Pain
5	Both front feet	4	Rotation and sinking	12	13	Severe Pain
6	Both front feet	3	Severe Rotation and sinking	4	7	Severe Rotation and sinking
7	All 4 feet	3	Rotation	4	36	Rotation Poor prognosis for athletic use
8	Both front feet	3	Moderate Rotation	14	47	Rotation

(TNFα) and interleukin 6 (IL-6). These factors are known to induce the production of microthrombi via increased fibrin production and decreased fibrinolysis (*Dallap Schaer* 2006). Five horses with septicemia subsequently developed acute arterial limb thrombosis (*Brianceau* and *Divers* 2001). Certain bacteria have been shown to activate thrombocytes (*Fitzgerald* et al. 2006), which also can result in the production of microthrombi. In our study, three horses had severe inflammation of a synovial space (increased cell count in synovial fluid), although bacterial cultures of synovial fluid revealed no growth. In human medicine, severe streptococcal infection may cause thrombosis (*Shannon* et al. 2007), and a number of veterinary studies have shown that streptococcal exotoxins may play a role in laminitis. *Weiss* and others (1998) reported that inhibitors of thrombocyte aggregation could prevent laminitis caused experimentally by carbohydrate overload. In-vitro studies by *Mungall* and others (2001) demonstrated that streptococcal exotoxins activate metalloproteases, which damage the basal membrane of the hoof laminae. These authors postulated that inhibitors of thrombocyte aggregation prevent laminitis by binding to metalloproteases and streptococcal exotoxins. Regardless of whether bacterial toxins activate the clotting cascade, which then leads to microthrombosis, or whether activation of metalloproteases results in separation of the basal membrane and laminae of the hoof, elimination of the infection may be critical in preventing laminitis. Failure to use antibiotics at all or too short may have been the cause of laminitis in some of our patients.

In addition to antibiotic therapy, the administration of an NSAID is extremely important. Non-steroidal anti-inflammatory drugs reduce inflammation and thus decrease the deleterious effects of cytokines, which include coagulation, decreased fibrinolysis and vasoconstriction. Localized inflammatory processes including the activation of metalloproteases lead to progression of laminitis, during which the attachment between the basal membrane and laminae is destroyed (*Johnson* et al. 1998). In horses with gastrointestinal disease, which are predisposed to the development of laminitis, NSAIDs are recommended to decrease microthrombosis and the production of inflammatory mediators (*Divers* 2003).

Inhibition of prostaglandin synthesis by NSAIDs also results in analgesia, which is important in horses with unilateral lameness. In addition to the inhibition of the neurovascular cascade, analgesia promotes locomotion of the horse, which enhances blood circulation in the affected limb and prevents excessive weight bearing and thus, possibly, laminitis in non-operated limbs. Our patients received analgesia pre-, intra- and postoperatively: an NSAID was given preoperatively, medetomidine and ketamine were used for induction, halothane or medetomidine and isoflurane were used for general anesthesia, morphine was given on recovery and phenylbutazone was used postoperatively. One horse had severe pain postoperatively (increased heart and respiratory rate, obvious discomfort) and was also given morphine and lidocaine infusions. It is possible that our pain management regime was inadequate to control severe pain following major surgery. This may have resulted in wind-up and central sensitization causing pain that was refractory to phenylbutazone (*Muir* and Woolf 2001). Prevention of wind-up may be achieved by intraarticular administration of morphine for arthroscopy (*Sammarco* et al. 1996, *Sheehy* et al. 2001), epidural administration of an opioid (*Valverde* et al. 1990) as well as continuous-rate infusions of ketamine (*Wagner* et al. 2002) or lidocaine (*Robertson* et al. 2005). Whether a more aggressive and multimodal pain management regime would have prevented laminitis in the present cases is unknown.

Conclusion

It is important to remember that excessive weight bearing can lead to laminitis after surgery in one or more limbs other than the contralateral limb. Adequate pre- and postoperative analgesia is recommended to reduce pain, improve weight bearing and decrease the prevalence of complications, such as laminitis. Non-steroidal anti-inflammatory drugs provide analgesia, reduce inflammation and have anticoagulative properties. In severe pain, other analgesics, including opioids, ketamine or lidocaine, should be considered to prevent pain on different levels (multimodal). Infection must be prevented by appropriate surgical techniques and antibiotic therapy based on the results of culture and sensitivity testing.

References

Abrahamsen E., Hellyer P. W., Bednarski R. M., Hubbell J. A. and *Muir W. W.* 3rd (1989) Tourniquet-induced hypertension in a horse. J. Am. Vet. Med. Assoc. 194, 386-388

Adam E. N. and *Southwood L. L.* (2007) Primary and secondary limb cellulitis in horses: 44 cases (2000-2006). J. Am. Vet. Med. Assoc. 231, 1696-1703

Baxter G. M., Laskey R. E., Tackett R. L., Moore J. N. and *Allen D.* (1989) In vitro reactivity of digital arteries and veins to vasoconstrictive mediators in healthy horses and in horses with early laminitis. Am. J. Vet. Res. 50, 508-517

Brianceau P. and *Divers T. J.* (2001) Acute thrombosis of limb arteries in horses with sepsis: five cases (1988-1998). Equine Vet. J. 33, 105-109

Carluccio A., Contri A., Tosi U., De Amicis I. and *De Fanti C.* (2007) Survival rate and short-term fertility rate associated with the use of fetotomy for resolution of dystocia in mares: 72 cases (1991-2005). J. Am. Vet. Med. Assoc. 230, 1502-1505

Cohen N. D., Parson E. M., Seahorn T. L. and *Carter G. K.* (1994) Prevalence and factors associated with development of laminitis in horses with duodenitis/proximal jejunitis: 33 cases (1985-1991). J. Am. Vet. Med. Assoc. 204, 250-254

Copland V. S., Hildebrand S. V., Hill T. 3rd, Wong P. and *Brock N.* (1989) Blood pressure response to tourniquet use in anesthetized horses. J. Am. Vet. Med. Assoc. 195, 1097-1103

Dallap Schaer B. L. (2006) Hemostasis, Surgical Bleeding, and Transfusion. In: Equine Surgery, 2 edn., Eds: J.A. Auer and J.A. Stick, Saunders Elsevier. pp 32-44

Divers T. J. (2003) Prevention and treatment of thrombosis, phlebitis, and laminitis in horses with gastrointestinal diseases. Vet. Clin. North Am. Equine Pract. 19, 779-790

Fitzgerald J. R., Foster T. J. and *Cox D.* (2006) The interaction of bacterial pathogens with platelets. Nat. Rev. Microbiol. 4, 445-457

Grandy J. L., Steffey E. P., Hodgson D. S. and *Woliner M. J.* (1987) Arterial hypotension and the development of postanesthetic myopathy in halothane-anesthetized horses. Am. J. Vet. Res. 48, 192-197

Hollmann M. W., Wieczorek K. S., Smart M. and *Durieux M. E.* (2001) Epidural anesthesia prevents hypercoagulation in patients undergoing major orthopedic surgery. Reg. Anesth. Pain Med. 26, 215-222

Hunt J. M., Edwards G.B. and *Clarke K. W.* (1986) Incidence, diagnosis and treatment of postoperative complications in colic cases. Equine Vet. J. 18, 264-270

Johnson P. J., Tyagi S. C., Katwa L. C., Ganjam V. K., Moore L. A., Kreeger J. M. and *Messer N. T.* (1998) Activation of extracellular matrix metalloproteinases in equine laminitis. Vet. Rec. 142, 392-396

Kohro S., Yamakage M., Arakawa J., Kotaki M., Omote T. and *Namiki A.* (1998) Surgical/tourniquet pain accelerates blood coagulability but not fibrinolysis. Br. J. Anaesth. 80, 460-463

Levine D. G. and *Richardson D. W.* (2007) Clinical use of the locking compression plate (LCP) in horses: a retrospective study of 31 cases (2004-2006). Equine Vet. J. 39, 401-406

Muir W. W. 3rd and *Woolf C. J.* (2001) Mechanisms of pain and their therapeutic implications. J. Am. Vet. Med. Assoc. 219, 1346-1356

Mungall B. A., Kyaw-Tanner M. and *Pollitt C. C.* (2001) In vitro evidence for a bacterial pathogenesis of equine laminitis. Vet. Microbiol. 79, 209-223

Parsons C. S., Orsini J. A., Krafty R., Capewell L. and *Boston R.* (2007) Risk factors for development of acute laminitis in horses during hospitalization: 73 cases (1997-2004). J. Am. Vet. Med. Assoc. 230, 885-889

Peloso J. G., Cohen N. D., Walker M. A., Watkins J. P., Gayle J. M. and *Moyer W.* (1996) Case-control study of risk factors for the development of laminitis in the contralateral limb in Equidae with unilateral lameness. J. Am. Vet. Med. Assoc. 209, 1746-1749

Peroni J. F., Moore J. N., Noschka E., Grafton M. E., Aceves-Avila M., Lewis S. J. and *Robertson T. P.* (2006) Predisposition for venoconstriction in the equine laminar dermis: implications in equine laminitis. J. Appl. Physiol. 100, 759-763

Robertson S. A., Sanchez L. C., Merritt A. M. and *Doherty T. J.* (2005) Effect of systemic lidocaine on visceral and somatic nociception in conscious horses. Equine Vet. J. 37, 122-127

Sammarco J. L., Conzemius M. G., Perkowski S. Z., Weinstein M. J., Gregor T. P. and *Smith G. K.* (1996) Postoperative analgesia for stifle surgery: a comparison of intra-articular bupivacaine, morphine, or saline. Vet. Surg. 25, 59-69

Shannon O., Hertzen E., Norrby-Teglund A., Morgelin M., Sjobring U. and *Bjorck L.* (2007) Severe streptococcal infection is associated with M protein-induced platelet activation and thrombus formation. Mol. Microbiol. 65, 1147-1157

Sheehy J. G., Hellyer P. W., Sammonds G. E., Mama K. R., Powers B. E., Hendrickson D. A. and *Magnusson K. R.* (2001) Evaluation of opioid receptors in synovial membranes of horses. Am. J. Vet. Res. 62, 1408-1412

Sprayberry K. A., Madigan J., LeCouteur R. A. and *Valentine B. A.* (1998) Renal failure, laminitis, and colitis following severe rhabdomyolysis in a draft horse-cross with polysaccharide storage myopathy. Can. Vet. J. 39, 500-503

Stashak T. S. (2002) The Foot. In: Adams Lameness in Horses, 5th edn., Ed: D. Troy, Lippincott Williams and Wilkins, Baltimore. pp 645-680

Valverde A., Little C. B., Dyson D. H. and *Motter C. H.* (1990) Use of epidural morphine to relieve pain in a horse. Can. Vet. J. 31, 211-212

Wagner A. E., Walton J. A., Hellyer P. W., Gaynor J. S. and *Mama K. R.* (2002) Use of low doses of ketamine administered by constant rate infusion as an adjunct for postoperative analgesia in dogs. J Am. Vet. Med. Assoc. 221, 72-75

Weiss D. J., Evanson O. A., McClenahan D., Fagliari J. J., Dunnwiddie C. T. and *Wells R. E.* (1998) Effect of a competitive inhibitor of platelet aggregation on experimentally induced laminitis in ponies. Am. J. Vet. Res. 59, 814-817

Weiss D. J., Evanson O. A., McClenahan D., Fagliari J. J. and *Jenkins K.* (1997) Evaluation of platelet activation and platelet-neutrophil aggregates in ponies with alimentary laminitis. Am. J. Vet. Res. 58, 1376-1380

Weiss D. J., Geor R. J., Johnston G. and *Trent A. M.* (1994) Microvascular thrombosis associated with onset of acute laminitis in ponies. Am. J. Vet. Res. 55, 606-612

Weiss D. J., Trent A. M. and *Johnston G.* (1995) Prothrombotic events in the prodromal stages of acute laminitis in horses. Am. J. Vet. Res. 56, 986-991

Dr. med. vet. Annina Widmer
Equine Department, Vetsuisse-Faculty Zurich
Winterthurerstr. 260
8057 Zurich, Switzerland
awidmer@vetclinics.uzh.ch