Extracorporeal Shock Wave Therapy: Clinical Applications and Regulation

Scott McClure, DVM, PhD, DACVS, and Thomas Weinberger, Dr.med.vet, FTA fuer Pferde

Shock wave therapy is a relatively new modality for use in equine practice. The application of shock waves is dependent on an accurate diagnosis and localization of the lesion. At this time we are still gaining knowledge on proper application and what musculoskeletal problems will respond to treatment. This chapter describes how we use shock wave therapy and what we currently treat with shock wave therapy.

Key Words: Extracorporeal shock wave therapy; equine; musculoskeletal disease.

History

Equine focused shock wave therapy started in Germany in 1996. The following 5 standard indications used in human medicine were initially adapted for use in horses: (1) calcifying tendonitis of the shoulder (tendinosis calcarea), (2) tennis elbow (lateral epicondylitis), (3) golfer's elbow (medial epicondylitis), (4) heel spurs (plantar fasciitis), and (5) pseudarthrosis. Because of positive experiences treating people with insertional desmopathies and the large size of the machines and probes, the first equine disease to be treated was proximal suspensory desmitis. Initial clinical responses were positive. The company High Medical Technologies (HMT) developed the first machine designed specifically for equine use. The Equitron (HMT, Lengwil, Switzerland) was a modified machine originally used in people. It had a solid frame, a probe on a flexible cord, and a maximum energy flux density (EFD) of 0.15 mJ/mm^2. This machine made it possible to reach nearly every part of a standing horse. Since promising results were achieved in horses with proximal suspensory desmitis, shock wave therapy was attempted in numerous locations. In 1997, horses with navicular syndrome were first treated. Initially, the probe was positioned behind the navicular bone from the heel, but when ultrasonographic imaging showed the distal impar ligament could be seen through the frog, this location was then used to administer shock wave therapy to the distal part of the navicular area.

In 1998, horses with distal hock joint and navicular pain were first treated in the United States with shock wave therapy.[1,2] The first equipment was rather large, requiring water cycling and degassing. Its use was limited to anesthetized horses. Shock wave therapy became more cost effective and popular once a modified machine for use in the standing horse became available.

Over the last 5 years much has been learned about use in horses with extracorporeal shock wave therapy (ESWT) use in horses for orthopedic disease. Experimental data are lacking and only now becoming available. As with any new therapeutic modality, clinical use precedes objective data. There are often claims of effectiveness that are later modified. As with many new therapies, case selection can be a problem since horses refractory to other methods are managed with the "new kid on the block" therapeutic approach. Below, we have included data currently available and our personal experiences and opinions. We fully expect that ESWT will continue to evolve quickly over the next several years.

How to Use Focused Shock Waves

There is a continual debate on how best to focus shock waves to manage a lesion. Some clinicians use direct ultrasound guidance and some just estimate an area of interest. Since focused shock waves are a locally concentrated therapy without regional or systemic effects, it is absolutely necessary to have a clear and concrete diagnosis to define the treatment area. Diagnosis is limited by resolution of imaging equipment. For instance, Weiler and coworkers[3] found histopathological evidence of desmitis in horses judged healthy, based on clinical lameness inspection and an ultrasonographic examination. The clinical relevance of this finding is unknown, but diagnostic imaging may be still a limiting factor[4,5] One of us defined a three-dimensional method of treating lesions with focused shock waves. The approximate location is identified using ultrasonographic and radiographic examinations and a probe is positioned on the area without ultrasonographic guidance. The probe is then moved to treat an area larger than that viewed ultrasonographically or radiographically. The depth is also varied for complete treatment. The equipment will dictate how the depth is varied; however, for suspensory ligament we would use 20-mm and 35-mm probes. No negative side effects (energy level up to 0.15 mJ/mm^2) have been observed after 3500 treatments in horses.

The other concept of treatment is to treat just a very small defined area with parallel ultrasonographic guidance during the treatment to maintain the probe strictly on the previously identified lesion. Further experience will hopefully show if there are differences between the 2 techniques. Both authors use the three-dimensional approach to treatment. If high energy levels are used, it may be best to use ultrasonographic guidance and concentrate ESWT on the specific lesion, rather than the surrounding tissue since damage to healthy soft tissue structures

From the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Iowa State University, Ames, IA; and Pferdeklinik Burg Mueggenhausen, Burg Mueggenhausen, D-53919 Weilerswist-Mueggenhausen, Germany.

Address reprint requests to Dr. Scott R. McClure, Dept. of Veterinary Clinical Sciences, College of Veterinary Medicine, Iowa State University, Ames, IA 50010-1250.

1534-7516/04/0204-0000$35.00/0
doi:10.1053/j.ctep.2004.04.007

could occur. Magnetic resonance imaging (MRI) may better define lesion size and volume, but is currently only of limited value.

At the time of this writing, both authors are using similar electrohydraulic shock wave generators (Equitron/HMT); where energy levels and pulse numbers are discussed, they pertain to this equipment. Veterinarians using different shock wave generators with different energy density and focal sizes should consult with others using the same shock wave generator to achieve the best results.

Bone Spavin

In one of the first reports of use of ESWT in horses, Dr. McCarroll treated 74 horses with lameness ranging from grade 1 to 3 (0 being sound and 5 being nonweight bearing) that had distal hock joint pain refractory to traditional therapy.[2] Each joint was administered 2000 pulses at 0.89 mJ/mm^2 with the primary focus point at the site or sites of radiographically apparent lesions. In the 74 horses, a total of 139 joints were treated. At the time of follow-up examination 90 days after treatment, 80% had improved at least 1 lameness grade. Of the 15 horses with no improvement, 8 returned for a second treatment and 4 of these horses improved. Follow-up radiographs taken at 90 days after treatment showed no consistent changes when compared with radiographs taken before treatment. Horses with osteophyte formation on the dorsal or dorsomedial aspect of the tarsometatarsal joint were most likely to improve. Following treatment there does not appear to be an accelerated ankylosis of the joints. Subsequent to the 90-day follow-up period the horses that responded to treatment have continued to perform as expected without the lameness worsening to the pretreatment grade.

Shock wave therapy is most commonly used as an adjunct to intraarticular therapy. In horses that do not have adequate resolution with medical therapy alone, they can be treated with intraarticular medication and ESWT simultaneously. There appears to be an additive effect of the 2 therapies. The horse is sedated, clipped, and restrained in stocks. Eight hundred to 1000 pulses at 0.15 mJ/mm^2 are delivered to the affected joints, usually split between the 5-mm and 20-mm probes. The probe is moved around the joint medially, laterally, and dorsally and positioning is done by palpation. Horses that previously required the combination treatment may have both ESWT and intraarticular medication at the same visit. Horses that do not respond adequately to injections alone may be treated at another visit.

Navicular Syndrome

The chronic debilitating nature of navicular syndrome has led to the investigation of ESWT as a potential therapeutic modality. In 16 horses, blinded evaluators graded lameness before and 6 months after ESWT was administered with an electrohydraulic shock wave generator while the horses were under general anesthesia in lateral recumbency (McClure SR, unpublished data, 2002). ESWT was directed at each affected navicular bone, and a total of 2000 pulses (1000 pulses through the frog and 1000 through the heel) at 0.89 mJ/mm^2 were administered. After treatment, horses were given stall rest for 1 week, then given limited hand walking and ground work for an additional 5 weeks before resuming full work.

Before treatment, mean lameness grade was 1.8 (range 0 to 5) when trotted in a straight line on a hard surface. Lameness scores were consistently worse when the affected forelimb was on the inside of a circle (mean 2.6, range 1 to 4). After treatment, score ranges from 0 to 3 in a straight line and 0 to 4 when circled. Mean lameness score while trotting in a straight line and when circled decreased 0.7 and 0.9, respectively. When trotted in a straight line 9 of the 16 horses (56%) were improved, 2 had no change, and in 5 horses, lameness worsened. Similarly when evaluated in a circle 9 of 16 (56%) were improved, 1 had no change, and in 4 horses lameness had progressed.

Case selection criteria may improve these results. It appears that horses with radiographically visible enthesopathy of the navicular suspensory ligament do not respond well to ESWT. Perhaps this region is difficult to target. Horses with erosions on the flexor cortex of the navicular bone do not improve after ESWT likely because of the presence of the adhesions between the deep digital flexor tendon and navicular bone and DDF tendonitis (Fig 1).

To treat the navicular region it is important to prepare the foot. After the foot is trimmed and the frog pared, we prefer to soak the foot in a bandage for 8 to 12 hours. This softens the frog and improves the transmission of the shock waves. To treat the entire navicular region, we aim from 2 directions, from the frog and from between the heel bulbs (Fig 2). This can be easily done in the standing, lightly sedated horse. The veterinarian can sit on a short stool, flex the carpus, and rest the metacarpus on the veterinarian's leg. One hand can hold the shock wave probe and the other stabilizes the leg.

The energy setting and pulse number will vary between generators. Foot conformation makes a big difference in depth. The lateral radiograph can be taken with a metallic marker or the ultrasound can be used to direct the shock waves to the correct depth and location.

Tendonitis

ESWT is used to treat numerous tendon diseases in people. When compared with bone, tendons and ligaments are at risk of damage from excess energy or number of pulses.[6] While the results of laboratory studies in rabbits cannot be directly extrapolated to horses, some early treatments with high energy equipment set at 0.89 mJ/mm^2 resulted in increased inflammation in tendons and ligaments. Similar problems have not been seen with the portable HMT generators.

People with dystrophic mineralization of the Achilles, patellar, and rotator cuff tendons are managed successfully with ESWT. Pain relief and dissolution of calcified areas of tendon were reported.[7] Our experiences in horses are similar. We have observed dissolution of areas of dystrophic mineralization in horses using ESWT, similar to that seen in people with calcification of the rotator cuff tendons. Small areas of mineralization seen ultrasonographically can be resolved with ESWT, but large areas of mineralization seen radiographically are not altered. Excessive treatment may result in worsening of tendonitis/desmitis.

Eight Thoroughbred race horses with superficial digital flexor (SDF) tendonitis sustained during racing or race training were treated with ESWT (Hunter J, McClure SR, Merritt DK, unpublished data, 2003). All horses had core lesions (type 3) and were treated using an electrohydraulic generator. Approx-

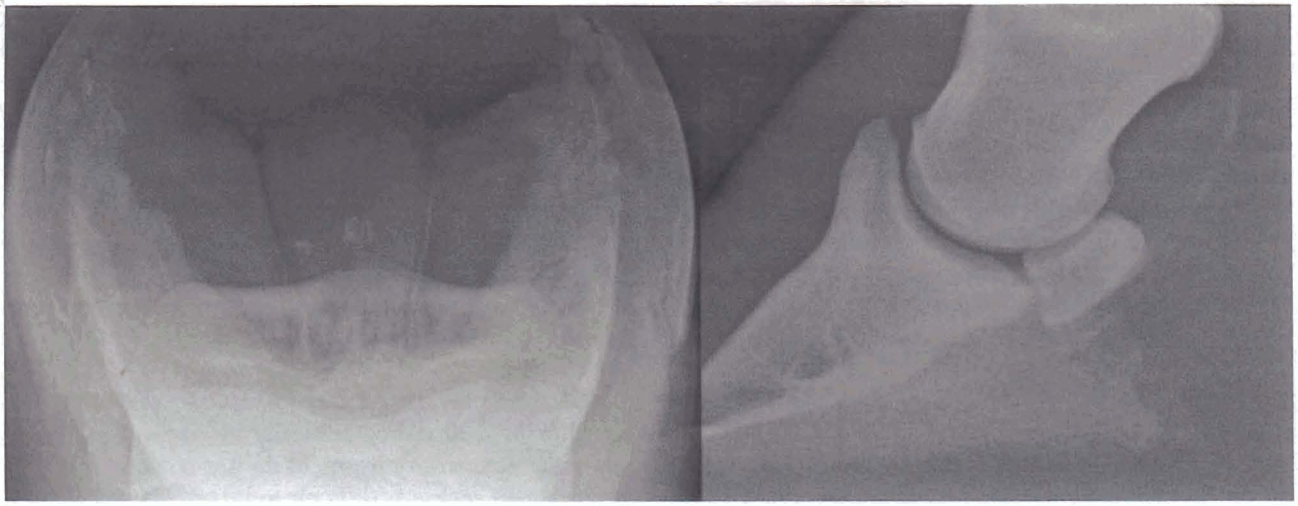

Fig 1. Radiographs of an 11-year-old German Warmblood. This horse was grade 3 to 4/5 lame with this limb on the inside of a circle on hard ground and was confirmed to have palmar heel pain during the lameness examination. There is calcification of the deep digital flexor tendon and radiolucency of the flexor cortex of the navicular bone. The horse was treated 3 times at 0.15 mJ/mm^2 with no improvement. Four weeks after the last treatment lameness was still at baseline levels. Calcification or adhesions involving the deep digital flexor tendon result in a poor outcome.

imately 150 shocks/cm lesion were administered between 0.13 and 0.15 mJ/mm^2 3 times at 3-week intervals. The healing and repair phases of each lesion were evaluated ultrasonographically (Fig 3). All tendons showed clinical and ultrasonographic evidence of improvement after treatment. After treatment, 4 of the 8 horses raced successfully, 1 returned to training after 1 year of rest, 2 reinjured the SDF tendon during retraining, and 1 horse was retired before retraining. Subjectively, ESWT appeared to speed the rate of healing as assessed by ultrasonographic examination. A blinded, controlled study is under way to support or refute these earlier findings. One of us (TW) uses a lower energy treatment protocol, 0.09 mJ/mm^2, 200 to 300 pulses, every 7 days, for 3 to 4 treatments starting within days of the injury. We both believe treatment of tendons with core lesions improves the rate of healing.

We have seen dramatic response to ESWT in horses with diffuse, type 1 tendonitis. Ultrasonographic evaluation of these tendons after ESWT reveals notable decrease in the fluid within

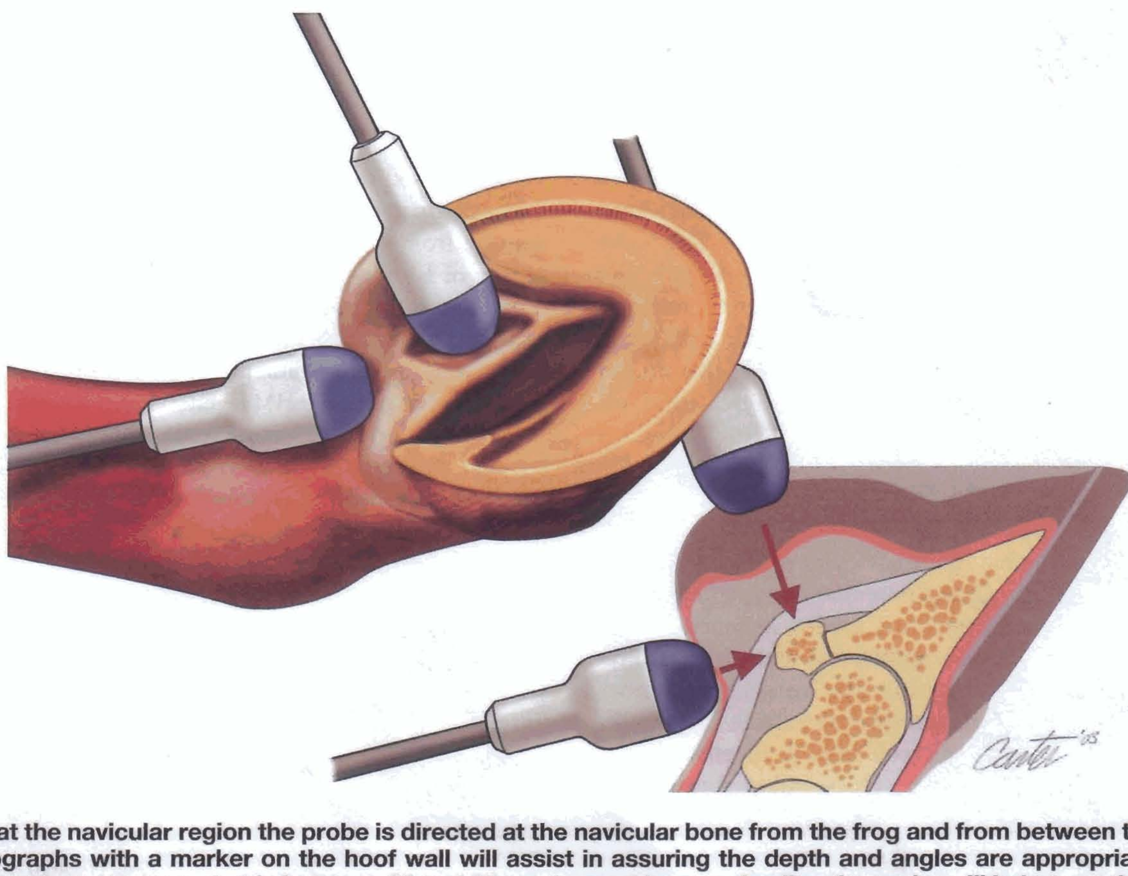

Fig 2. To treat the navicular region the probe is directed at the navicular bone from the frog and from between the heel bulbs. Lateral radiographs with a marker on the hoof wall will assist in assuring the depth and angles are appropriate. The depth varies based on foot structure, but is between 20 and 35 mm in most horses. Angling the probe will help treat the parasagittal region. The foot is pared to moist pliable tissue and soaked in water if possible before treatment.

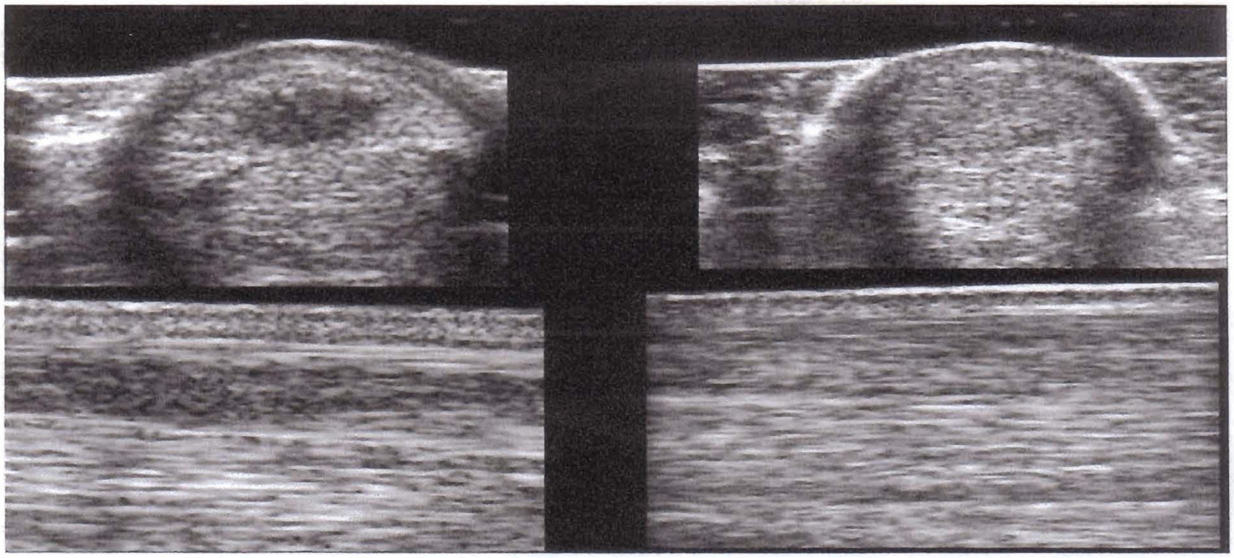

Fig 3. Transverse ultrasonographic images 16 cm distal to the accessory carpal bone of the right forelimb of a 2-year-old Thoroughbred filly before (left) and 78 days after (right) treatment (3 times, 1200 pulses at 0.13 mJ/mm^2, at 3-week intervals). A gradual increase in exercise was given and the horse raced successfully 5 months from the time of the initial injury.

the tendon (increased echogenicity) within days. Similarly, clinical parameters such as heat and painful response to deep palpation improve soon after ESWT. There is obvious concern about the potential for clinical improvement of a structurally weakened tendon and continued race training.

When should you treat a tendon, during the acute or chronic stage? There are differences of opinion on when it is best to start treatment. Because shock waves travel readily through fluid, which lacks an acoustic interface, it may be difficult to focus the shock wave in an anechogenic or hypoechogenic area. The result could be the deposition of the shock wave into normal tissue and cavitation-induced damage to healthy nearby tissue. These concerns have led some clinicians to recommend ESWT in early treatment of horses with chronic tendonitis or those with calcification within the tendon.[8] We have found that early treatment of horses with acute, diffuse tendonitis improves the rate at which the fluid within the tendon resolves. We feel that horses with acute and chronic tendonitis can be treated. When the injury is over 4 weeks old, the EFD is increased to 0.15 mJ/mm^2 from the 0.09 mJ/mm^2 used in acute cases and a larger number of pulses are used. Exercise is gradually increased based on the severity of the lesion.

Insertional Desmopathy

An insertional unit of a tendon or ligament is comprised of bone, mineralized cartilage, nonmineralized cartilage, and collagenous tissue. As a result of single or repetitive mechanical overloading, structural change of the insertional unit occur. In horses with chronic desmopathies, chondroid and osseous metaplasia occur. This has been demonstrated histologically in chronic insertional desmopathy of the suspensory ligament (interosseous medius).[9] In a 15-year-old Warmblood mare, one forelimb was treated with 1500 pulses from an electrohydraulic generator at 0.14 mJ/mm^2 and one hindlimb was treated with 1500 pulses at 0.15 mJ/mm^2 and the opposite limbs used as controls.[3] The histologist who was blinded to the treatments found destruction of metaplastic areas in the treated limb. We assume that decreased metaplasia may relieve tissue pressure and contribute to improvement in horses with clinical disease. Since ESWT has been beneficial in people with insertional desmopathies, it stands to reason that it would be beneficial in horses with similar injuries.

Suspensory Desmitis (Interosseous Medius)

Suspensory desmitis was one of the first equine injuries managed using ESWT. We reasoned that since ESWT appeared to work in people with insertional desmopathy, it should be useful in the horse. Since treatment options in horses with chronic pain from suspensory desmitis are limited, ESWT was considered.

To evaluate our clinical impression we have now completed a controlled study to measure the healing effect of ESWT on collagenase-induced suspensory desmitis.[10] Suspensory desmitis was induced in both forelimbs of 4 horses with ultrasonographically normal suspensory ligaments using a collagenase (4000 IU/site) model. Three weeks after injection of collagenase, ESWT was started. In each horse a single forelimb was treated and the opposite one served as a control. The Equitron (0.13 mJ/mm^2) machine was used, 3 treatments at 3-week intervals. Using a 35-mm probe 500 pulses were administered from the palmar aspect, and with a 5-mm probe 500 pulses were administered in both the palmar-lateral and palmar-medial direction for a total of 1500 pulses. Ultrasonographic evaluation was performed at 3-week intervals from the time of induction of lesions to the completion of the project, 12 weeks later. The percent cross-sectional area of ligament damage decreased significantly faster in treated limbs. Subsequently, over a 12-week period the treated limbs healed faster with a subjective assessment of better fiber alignment than control ligaments.

Numerous investigators reported positive results using ESWT to manage proximal suspensory desmitis.[11,12] Since there can be ligament and/or bone injury it is important to have an accurate diagnosis. To target the origin of the suspensory ligament, the probe is applied at 3 different angles (Fig 4). Energy settings are low (0.1 mJ/mm^2) in horses with acute desmitis and increase in those with chronic desmitis or when an avulsion fracture of the third metacarpal bone is present (0.15 mJ/mm^2).

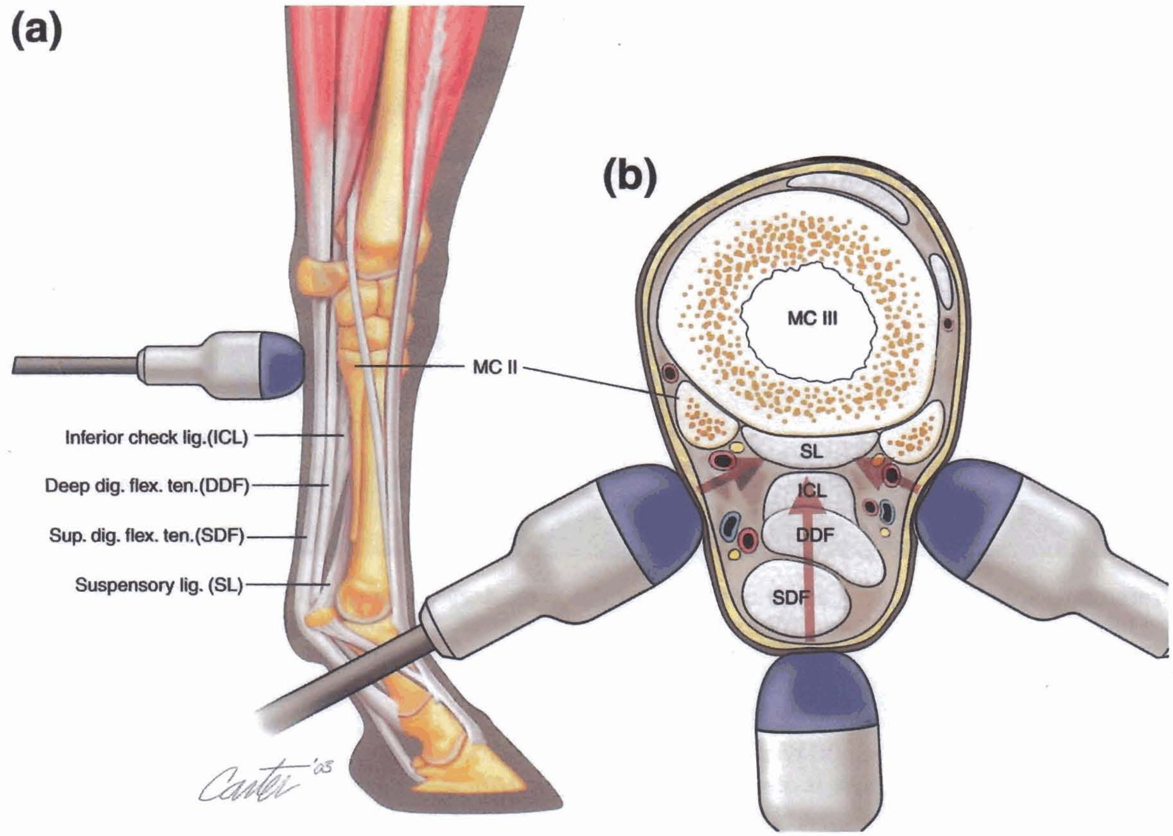

Fig 4. To treat the proximal suspensory ligament the 35-mm probe (a) is used from the palmar/plantar aspect and the 5- or 20-mm probe (b), depending on depth that can be determined ultrasonographically, is used from each oblique angle just behind the splint bone. The probes are moved proximal and distal to treat the entire region.

Insertional Desmopathy of the Ligamentum Nuchae

European Warmblood horses often suffer from problems that are evident when the riders try to maintain the head flexed at the pole in the correct dressage position. It is often difficult to obtain a definitive diagnosis, but in some horses there are clearly radiographic and/or scintigraphic changes associated with the attachment of the nuchal ligament (Fig 5). Horses often respond well to 2 or 3 administrations of ESWT at 14-day intervals, followed by 4 weeks of training without requiring flexion of the poll. After each treatment, the horses are given 1 g of phenylbutazone a day for 8 days. In 22 horses receiving therapy clinical signs resolved in 12 horses, improved in 6 horses, and in 4 horses there was no response to therapy. Two of the 12 horses that initially responded well and 4 of the 6 that were initially improved returned for a second series of treatments 6 to 12 months later and responded favorably.

In a published report of insertional desmopathy of the ligamentum nuchae 12 horses were reluctant to bend the head or neck or had head shaking when under saddle. Scintigraphic and radiographic changes of the protuberantia ossis occipitalis or of the ligamentum nuchae were documented.[13] Horses were treated with ESWT 3 times with an electromagnetic generator. After 20 weeks, 10 horses were being ridden normally, 1 showed partial improvement, and 1 did not improve.[13]

Stress Fractures/Nonunions

One of the first orthopedic applications of ESWT in people was to treat nonunions; ESWT consistently induces union in over 75% of human patients.[14] Nonunions are not common in horses but there are many potential orthopedic applications. A pilot study has shown that ESWT can increase activated osteons throughout the width of the dorsal cortex of MCIII, including a notable endosteal response.[15]

Dorsal Metacarpal Disease

Fifty Thoroughbred racehorses with dorsal metacarpal disease had clinical signs ranging from only pain on palpation of the dorsal cortex of MCIII to radiographically apparent dorsal cortical fractures. These racehorses were treated with a radial generator and a modified training program.[16] All horses had been treated previously by several modalities without a satisfactory outcome. At the completion of the treatment period 40 horses (80%) resumed breezing and racing without recurrence of lameness. In 20 horses with a single oblique dorsal cortical stress fracture, the mean time from the last treatment to the first race was 5 months. Shock wave therapy may be beneficial as an adjunct to training modification.

Similar results have been seen with focused shock wave therapy. We manage horses with periostitis with ESWT (0.14 mJ/mm^2, 800 pulses), give 1 week of walking, then resume training for 2 weeks; the cycle is repeated 2 more times. When horses are treated early in the disease process most can continue in training. Our initial concerns that these horses would be more likely to develop a dorsal cortical fracture have been unfounded. We are not aware of a 3-year-old that developed a cortical fracture after it was treated in this manner as a 2-year-old.

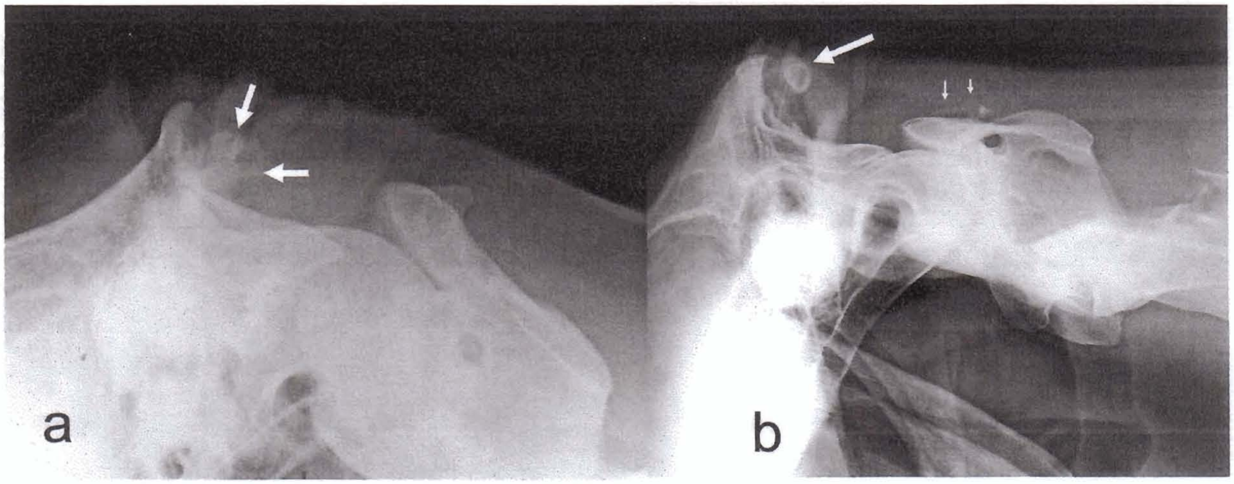

Fig 5. (a) Lateral 30° ventral-dorsal medial radiographic projection of an 8-year-old German Warmblood jumper that had an abnormal head carriage. An enthesophyte secondary to chronic insertional desmopathy at the attachment of the ligamentum nuchae on the occipital bone is radiographically evident (arrows). After ultrasonographic examination to determine the depth and lesion area, the horse was treated 3 times at 2-week intervals at 0.15 mJ/mm^2, with 400 pulses from a 20-mm probe and 400 pulses from a 35-mm probe. The horse was ridden for 5 weeks in a "long neck" position (the head is straight forward, no forced flexion in the neck). Before treatment, the horse was not able to train or compete, and after, the horse came back to normal competition standards. (b) Lateralmedial radiographic view showing an avulsion fracture of the occipital bone (large arrow) and calcification within the supraspinous bursa (small arrows) in a 7-year-old Hanovarian × Warmblood gelding used for dressage. Both areas were treated at 0.15 mJ/mm^2. The region of the avulsion fracture was treated with a total of 1000 pulses with the 20- and 35-mm probes. The bursa was treated with a total of 500 pulses with the 35- and 80-mm probes. After 3 treatments at 2-week intervals, the horse was trained for 5 weeks in long-neck position and returned to its previous level of activity. In general, horses with pain associated with the occipital bone and insertion of the ligamentum nuchae respond well to shock wave therapy, but those with chronic bursitis do not.

Incomplete/Stress Fractures

Horses with stress fractures of the tibia, humerus, and MCIII can be managed with ESWT. Without a controlled study it would be difficult to compare healing of treated horses to those with nontreated fractures or those in which osteostixis was performed. It is our impression that TB racehorses with dorsal cortical fractures of the MCIII can return to training in a similar time period as those that have received osteostixis. Similarly, 6 of 10 horses with metacarpal stress fractures were pain free and/or showed radiographic healing by 90 days.[11] Two horses took over 120 days and 2 were retired for other reasons.

Proximal Splint Bone Fractures

Surgical management of horses with proximal splint bone fractures is often complicated by the presence of infection. Four horses with closed and 3 with open, infected, comminuted fractures of the proximal splint bones were managed with focused ESWT (Weinberger T, unpublished data, 2003) (Fig 6). Infected horses were first treated locally and systemically with antibiotics, local wound curettage, and ostectomy of small loose fragments. ESWT began when signs of infection resolved and the skin healed. The horses were treated with 3 treatments at 10- to 14-day intervals with the 5- and 20-mm, or the 20- and 35-mm probes. They were administered 600 to 900 pulses, depending on the size of the lesion, at an EFD of 0.15 mJ/mm^2. Radiographs were taken after the third treatment and about 4 weeks later. The horses were started hand walking after the second or third treatment. In horses without infection, training began 10 to 12 weeks after fracture, whereas in those with infected fractures training began 13 to 16 weeks after fracture. All the horses were sound and in normal use.

Back Pain

Diagnosis of the origin of back pain and assigning clinical relevance can be complicated. Complete clinical examination including diagnostic analgesia, radiographs, ultrasonography, and scintigraphy are needed for definitive diagnosis. With focused shock waves there are two opportunities for treating back problems. The treatment can be focused on the visible lesions such as insertional desmitis or bone sclerosis as identified by scintigraphy, radiography, or ultrasonography. Alternatively, in some horses painful regions on the dorsal musculature can be located and treated.[4]

Horses with "kissing spines" usually respond well to treatment. Clinical response depends on the severity of changes and the physical or muscular conformation of the horse. A well-muscled horse with mild pain as determined by palpation and the rider's experience will usually respond to 1 to 2 treatments at 0.15 mJ/mm^2. Shock waves are directed at the radiographically visible lesions and the palpable painful points. Number of pulses is directly related to lesion size. For each 1-cm length of bone sclerosis of the dorsal spinous processes, 50 pulses from each side are necessary. Horses are lightly sedated since they may become painful when shock waves are directed at the site of pain. The choice of the probe depends on the depth of the lesion, but most commonly the 35- and 80-mm probes are used. Some horses are more painful on the day after treatment and we recommend they be rested 1 day, then lunged 1 week before returning to normal work. Horses with severe pain and poor muscling require additional treatment sessions. Training changes are recommended to rehabilitate poorly muscled regions. Up to 5 treatments at 2- to 4-week intervals over 1 to 3 months are used. Horses with mild clinical signs (not always corresponding to radiographic findings) respond well (nearly 100% improvement), whereas severely affected horses have a

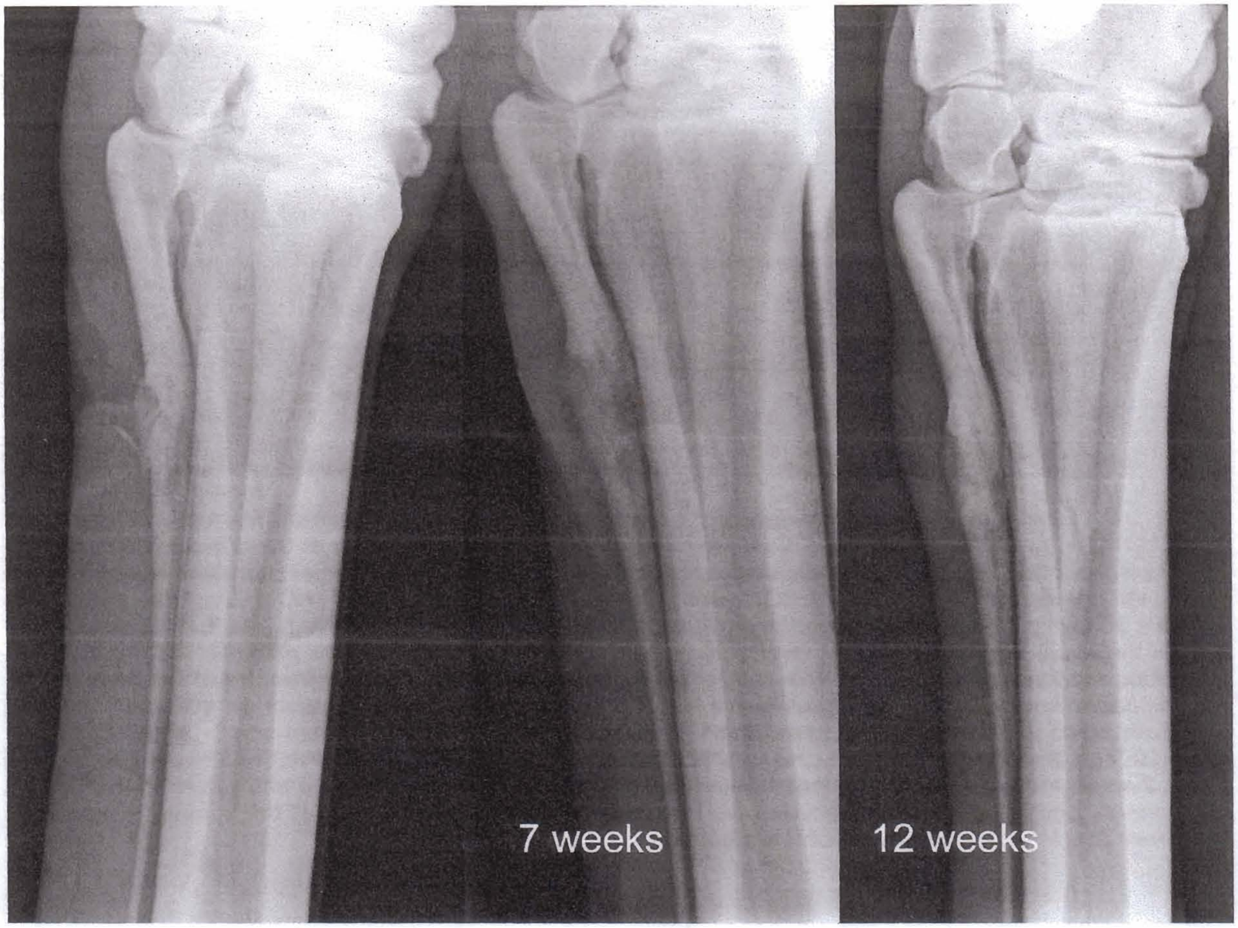

Fig 6. Dorsolateral-plantaromedial radiographic views of the metatarsal region of a 9-year-old Oldenburg × German Warmblood mare that suffered an open comminuted fracture of the 4th metatarsal bone as a result of a kick wound. The fracture site was cleaned and debrided. ESWT was started after the skin wound was closed (18 days). Three treatments (18, 40, and 60 days after injury) were done at 0.15 mJ/mm^2. The first treatment was 250 pulses with each the 5- and 20-mm probes, and the second and third treatments were 400 pulses with each probe. The horse was sound and returned to full work after 16 weeks.

guarded prognosis (65% improvement). Management of these horses often includes other treatment modalities and is complex.

Performance horses may have back problems as determined by the rider's experience and may lack radiographic, scintigraphic, or ultrasonographic abnormalities. They respond very well to treatment of the soft tissues with ESWT. The back is prepared by wetting with hot water or alcohol. In horses with long hair the hair is clipped from midline laterally for 8 cm on both sides. With an energy level up to 0.15 mJ/mm^2, probes between 20 and 80 mm are used. During treatment the probes are moved over the back until the horse reacts with a short muscle fasciculation. When the fasciculation is identified, the probe is kept in that area for about 80 pulses before moving on. Probes of different depths will get reactions at different points. A total treatment of 2000 pulses is necessary. Horses with a positive reaction (muscle fasciculation) showed nearly 100% improvement, as judged by the rider's opinion, for up to 10 months. Horses without a visible muscle reaction may also improve. The reason for the muscle reactions and improved movement is not clear.

Other Indications

ESWT has been used to manage numerous conditions in the horse but clinical studies are lacking. ESWT may be a good adjunct to internal fixation in the horse. Hardware fatigue and contralateral limb complications can occur in horses before bone healing is complete so any mechanism to speed healing would be indicated. Initiation of ESWT in the immediate postoperative period following internal fixation may be of benefit. This has been demonstrated in dogs with a plate spanning a fracture gap.[17] In horses, fractures of the distal phalanx may heal slowly with fibrous unions. We have managed a limited number of horses with fractures of the distal phalanx and have seen favorable results (Fig 7). The distal phalanx must be targeted through the frog or other soft tissues of the foot and not through the hoof wall.

The indications and applications will change as more data become available. There are numerous other orthopedic applications being tried clinically including subchondral bone cysts of distal MCIII/MTIII and femur, carpal and tarsal bone sclerosis, proximal sesamoid bone disease, and potential applications for the management of osteoarthritis. There is much more to be learned about mechanisms of action of ESWT. For instance, it is difficult to understand why radiolucent defects in the proximal sesamoid bone abate in one horse when a periosteal proliferation subsides in another, both of which were treated with similar ESWT.

Potential Complications

In people and small animals skin petechiation at the treatment site has been reported, but it is not commonly seen in the horse.

Fig 7. Dorsoproximal-palmarodistal radiographic views of a 5-year-old Standardbred horse with a distal phalanx fracture. The horse was treated conservatively with nonsteroidal antiinflammatory drugs and a bar shoe for 3 months before the first shock wave treatment. The horse was treated with 0.15 mJ/mm², 3 times at 2-week intervals through the frog. The bar shoe was maintained for another 10 weeks from the start of shock wave therapy. After 10 weeks the horse was sound and resumed race training. The radiographs were taken at the first (left), the second (middle), and 2 weeks after the third treatment (right).

Excessive energy or pulse numbers may lead to tissue necrosis. Since there is a dose-dependent relationship of ESWT, it is therefore important to keep in mind that "more is not necessarily better." Gas/tissue interfaces should be avoided because of the potential damage to lung and intestinal tissue. Major blood vessels should not be in the focal zone since intimal damage in arteries may be seen following ESWT. Effects on nerve tissue have not been fully evaluated so important nerves should be avoided. Active physes should be avoided as studies have demonstrated premature closure of the physis in laboratory animals following ESWT. When considering complications there are differences in the type of generator (electrohydraulic, piezoelectric, or electromagnetic) and wave type (focused versus radial waves) in addition to the energy and pulse numbers.

Safety Issues for Performance Horses

Important safety issues have been raised about both ESWT and radial pressure wave therapy (RPWT). Shock waves induced dose-responsive micro and macro fractures in formalin-fixed rabbit bones.[18] This result caused speculation that ESWT affected bone in vivo similarly by creating fractures that would weaken the bone and make it subject to acute failure. Microfractures of bone after ESWT were thought to be the stimulus for healing after ESWT. In people a period of pain relief (analgesia) after ESWT has been reported. Obviously, there is potential for injury to both horse and rider if a horse performs without recognition of pain.

Material Effects

If ESWT or RPWT could alter the material properties such as the modulus of elasticity of equine cortical bone, this would increase the risk of structural failure. To evaluate the potential for microfracture formation 4 horses were treated while under general anesthesia; the bones were then harvested and processed. After 1000 pulses at 1.8 mJ/mm^2 (5 to 10 times what is used clinically) were delivered to MCIII, microfractures were not found.[12] A more complete study was done on bone specimens harvested from the proximal, dorsal cortex of MCIII in healthy horses.[19] The modulus of elasticity (E) was determined by the measured density (ρ) and unidirectional transmission ultrasound speed (ν) of each specimen according to the equation $E = \rho\nu^2$. Eight specimens were then treated with 500 pulses of 0.15 mJ/mm^2 of ESWT and 8 specimens were treated with 500 pulses of 0.15 mJ/mm^2 of RPWT. After treatment ν was again determined and this sequence was executed 3 more times resulting in 2000 pulses being delivered to each specimen. The modules of elasticity was calculated 4 times for each group. There was no significant effect of treatment group (ESWT or RPWT) or number of pulses. No histological changes were attributed to either treatment modality. ESWT and RPWT do not influence at this treatment regime equine cortical bone breaking strength.

In a similar study the speed of sound was used in vivo to measure the potential changes in material properties of MCIII after RPWT.[20] A single MCIII was treated in all horses with 1000 pulses at 0.9 mJ/mm^2 and the contralateral MCIII served as a control. Measurements were made after a single treatment in 1 group of 6 horses and after a series of 3 treatments at 2-week intervals in another group of 6 horses. There were no differences between treated and control limb in speed of sound. Based on this study RPWT had no direct effect on the material properties of MCIII.

In an in vitro study 2000 pulses of RPWT were delivered to numerous locations in the distal equine limb.[21] The bone was harvested and evaluated histologically using both basic fuchsin staining and three-dimensional microscopy. There were no differences seen between treatment and control groups.

ESWT could potentially weaken tendons and ligaments. High energy, high doses were shown to damage and weaken calcified tendons in turkeys.[22] To date a similar study has not been performed in the horse.

Analgesic Effects

In human medicine, a posttreatment analgesic effect is well known. Pain relief for 3 to 4 days after treatment is common and may be partially explained by destruction of nerves, nerve receptors, and change in central control of sensory input (gate control theory). The exact mechanism is not known. The possibility exists that after ESWT or RPWT a horse may be at risk of incurring additional injury. One of us (TW) has data in 100 horses (jumpers, dressage horses, and Thoroughbred racehorses) treated directly before competitions that fails to reveal any substantial risk of additional injury.

Two studies have been done in rats to investigate the potential for a central effect of ESWT.[23,24] Paws of rats were treated with variable energy densities with either 1 or multiple treatments and spinal cords were examined histologically with stains for opioid and nonopioid neurotransmitters. No significant effect after ESWT was found.

Shock waves induced nearly complete degeneration of epidermal nerve fibers in rat skin as determined by measuring immunoreactivity of substance P and calcitonin gene-related peptide, 2 neuropeptides. Normal histologic staining did not return for 14 days.[25]

We studied nerves and neurotransmitter substances serially following shock wave therapy in a sheep model. RPWT and ESWT were used to treat the mid metacarpal/metatarsal regions in 30 sheep.[26] Nerve, skin, and periosteum were collected from each leg from 2 sheep immediately after treatment and at daily intervals for 14 days in the remaining 28 sheep. The treatment consisted of 1000 pulses of ESWT at 0.15 mJ/mm^2 or 1000 pulses of RPWT at 0.16 mJ/mm^2. The skin and periosteum were evaluated for concentrations of substance P and CGRP. The nerves were fixed and evaluated histologically. There were no differences between treated and untreated limbs in neuropeptide concentrations. However, the effect of time after treatment was significant for perineural inflammation and axonal swelling; there was more inflammation after treatment for both ESWT and RPWT. Nerve inflammation may contribute to the analgesic effect.

Analgesia after ESWT is evident in some horses. All horses are not affected similarly since some have a notable decrease while some have an increase in lameness for a few days after treatment. Pain relief after shock wave therapy in horses with proximal suspensory desmitis was studied by using a force plate instrumented treadmill. At 24 hours after shock wave treatment, analgesia was similar to that induced by local or perineural analgesia, and the duration was 3 days.[27]

The effect of shock waves on cutaneous sensation in the horse was investigated in 2 ways.[26] Skin sensation in the treatment area of the mid metacarpal/metatarsal region and the skin sensation distal to a treatment site on the palmar digital nerve were measured. Horses were equipped with small electrodes taped to the skin surface and a constant current stimulator was used to pass a small wave of electrical current through the electrodes. The milliamperes were gradually increased until the horse first responded to stimulation. In the mid metacarpal region there was a difference from baseline for both ESWT and RPWT for the first 4 days after treatment. This indicated that skin sensation was attenuated directly under the treatment site for 4 days after treatment. Skin distal to the nerve treatment site was unaffected.

The palmar digital nerves in horses were evaluated by nerve conduction velocity and histology after RPWT in the pastern region.[28] The conduction velocities were slower in treated nerves at 3 and 7 days after treatment. Histologically, there were segmental areas of demyelination and axonal swelling in all treated nerves as well as disruption of myelin sheaths of large-diameter axons.

At the time of this writing the analgesic effects have led to regulations governing the use of shock wave therapy in performance horses. Three of the major racing states, California, Florida, and New York, have declared that horses may not race within 10 days of treatment with shock wave therapy. There are no regulations governing German Thoroughbred racing. The USA Equestrian organization has remained silent on the use of shock waves. In Europe the Federal Equestrian International limits the use of shock wave therapy 5 days before competition.

References

1. McCarroll GD, Hague B, Smitherman S, et al: The use of extracorporal shock wave lithotripsy for treatment of distal tarsal arthropathies of the horse. Proc Assoc Equine Sports Med 19:40-41, 1999
2. McCarroll GD, McClure SR: Initial experiences with extracorporeal shock wave therapy for treatment of bone spavin in horses. Vet Comp Orthop Traumatol 3:184-186, 2002
3. Weiler, H, Haugstetter, H, Jacobi, R, et al: Effects of extracorporeal shock wave therapy (ESWT). Symposium of Extracorporeal Shock Wave Users in Veterinary Medicine, Pferdeklinik Barkhof, Sottrum, Germany, 2002, pp 39-40 (abstr)
4. Weinberger T: The use of focused shock wave therapy in back problems of the horse. Symposium of Extracorporeal Shock Wave Users in Veterinary Medicine, Pferdeklinik Barkhof, Sottrum, Germany, 2002, p 41 (abstr)
5. Weinberger T: Shock wave therapy for back problems in the horse. First Symposium of Extracorporeal Shock Wave Users in Veterinary Medicine, Pferdeklinik Burg Mueggenhausen, Weilerswist, Germany, 2000
6. Rompe JD, Kirkpatrick CJ, Kullmer K, et al: Dose-related effects of shock waves on rabbit tendo Achillis. J Bone Joint Surg Br 80:546-552, 1998
7. Loew M, Daecke W, Kusnierczak D, et al: Shock-wave therapy is effective for chronic calcifying tendinitis of the shoulder. J Bone Joint Surg Br 81:863-867, 1999
8. Kreling K: ESWT in tendon treatment in sports horses. Symposium of Extracorporeal Shock Wave Users in Veterinary Medicine, Pferdeklinik Barkhof, Sottrum, Germany, 2002, pp 13-14 (abstr)
9. Weiler H: Insertionsdesmopathien beim Pferd. Waredorf, Germany, Deutschen Reiterliche Vereinigung, 2001
10. McClure S, Evans RB: In vivo evaluation of extracorporeal shock-wave therapy for collagenase induced suspensory ligament desmitis. Proc Am Assoc Equine Pract 48:378-380, 2002
11. Scheuch B, Whitcomb MB, Galuppo L, et al: Clinical evaluation of high-energy extracorporeal shock waves on equine orthopedic injuries. Proc Assoc Equine Sports Med 19:18-22, 1999
12. McClure, SR, VanSickle, D, Blevins, WE. Extracorporeal shock wave therapy for equine musculoskeletal disease: research update and clinical applications. Proc Assoc Equine Sports Med 19:14-16, 1999
13. Brems R, Weiss D: Extracorporal shock wave therapy at the insertion desmopathy of the nuchal ligament in horses. Symposium of Extracorporeal Shock Wave Users in Veterinary Medicine, Pferdeklinik Barkhof, Sottrum, Germany, 2002, pp 11-12 (abstr)
14. Schaden W, Fischer A, Sailler A: Extracorporeal shock wave therapy of nonunion or delayed osseous union. Clin Orthop Rel Res 387:90-94, 2001
15. McClure SR, VanSickle D, White MR: Extracorporeal shock wave therapy: what is it? what does it do to equine bone. Proc Am Assoc Equine Pract 47:197-199, 2001
16. Palmer SE: Treatment of dorsal metacarpal disease in the thoroughbred racehorse with radial extracorporeal shock wave therapy. Proc Am Assoc Equine Pract 48:318-322, 2002
17. Wang CJ, Huang HY, Chen HH, et al: Effect of shock wave therapy on acute fractures of the tibia: a study in a dog model. Clin Orthop Rel Res 387:112-118, 2001
18. Kaulesar Sukul DMKS, Johannes EJ, Pierik EGJM, et al: The effect of high energy shock waves focused on cortical bone: an in vitro study. J Surg Res 54:46-51, 1993
19. McClure SR, Pauwels F, Evans RB, et al. The effects of extracorporeal shock wave therapy and radial pressure wave therapy on the elasticity and microstructure of equine cortical bone. Proc Int Soc Musculoskel Shockwave Ther XXX:68, 2003 (abstr)
20. Hubert JD, Burbe DJ, Bolt DM, et al: Changes in bone properties after extracorporeal shockwave application to the third metacarpus of horses. Vet Orthop Soc 30:70(abstr), 2003
21. Bathe AP, Collings A, Boyde A. Ex-vivo study into the microstructural

effects of extracorporeal shock wave therapy on equine bone. Proc Eur Coll Vet Surg XXX:165-170, 2002
22. Maier M, Saisu T, Beckmann J, et al: Impaired tensile strength after shock-wave application in an animal model of tendon calcification. Ultrasound Med Biol 27:665-671, 2001
23. Haake M, Thon A, Bette M: No influence of low-energy extracorporeal shock wave therapy (ESWT) on spinal nociceptive systems. J Orthop Sci 7:97-101, 2002
24. Haake M, Thon A, Bette M: Abscence of spinal response to extracorporeal shock waves on the endogenous opioid systems in the rat. Ultrasound Med Biol 29:279-284, 2001
25. Ohtori S, Inoue G, Mannoji C, et al: Shock wave application to rat skin induces degeneration and reinnervation of sensory nerve fibers. Neurosci Lett 315:57-60, 2001
26. McClure S, Sonea IM, Yeager M: The safety of shock wave therapy in performance horses. Proc Int Soc Musculoskel Shockwave Ther XXX:62, 2003 (abstr)
27. Lischer Ch. J, Ringer S, Schnewlin M, et al. Extracorporeal shock wave therapy (ESWT) in the management of chronic musculoskeletal disorders. Proc Eur Coll Vet Surg XXX:137-142, 2002
28. Bolt DM, Burba DJ, Hubert JD, et al: Functional and morphological changes in palmar digital nerves following extracorporeal shock wave application in horses. Vet Orthop Soc 30:67(abstr), 2003