Short-Term Effects of Non-Focused Extracorporeal Shockwave Therapy on the Palmar Digital Vasculature

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1. Introduction
Extracorporeal shockwave therapy (ESWT) is used by veterinarians to treat several musculoskeletal conditions in horses, including suspensory ligament desmitis, osteoarthritis of the low-motion joints of the tarsus, and dorsal metacarpal disease. Recent literature in the human and veterinary field suggests that ESWT has analgesic properties. A study that exposed the sciatic nerves of frogs to shockwaves showed hyperpolarization of nerves. During this hyperpolarization period, a higher threshold is necessary to stimulate the targeted nerve. A different study showed that there is a significant decrease in sensory-nerve conduction velocity of the equine digital nerves when treated with 2000 impulses of non-focused extracorporeal shockwaves (ESW). The same study found that extensive disruption of myelin sheaths in large-diameter axons occurred, but there was no traumatic damage to the axonal cytoplasm or Schwann cells. This reduced ability of the nerve to transmit the sensory impulse may have contributed to the improvement or resolution of lameness that was reported by other researchers.

Previously described studies of non-focused ESWT in horses was limited to the functional and morphologic changes in the treated palmar digital nerves. The vasculature adjacent to the digital nerves was not evaluated. It has been recommended by some that ESWT treatment protocols should avoid large nerves and blood vessels within the focal zone of the shockwaves. This is partly because previous studies on the effect of focused high-energy shockwaves on a human umbilical model showed vessel-wall necrosis and rupture with complete detachment of endothelial cells.

Our hypothesis was that a catastrophic disruption of the digital blood supply may occur if a horse is
treated with non-focused ESWT at the level of the digital neurovascular bundle. The purpose of this study was to describe the acute macroscopic and histological changes found in the equine palmar and plantar digital vasculature after exposure to non-focused ESWT.

2. Materials and Methods

The horses in the study were used in conjunction with a previously approved protocol by the Institutional Animal Care and Use Committee of the University of Minnesota. Five adult non-lame ponies (mean age = 3 yr; age range = 2–3.5 yr; mean weight = 150 kg; weight range = 137–160 kg, with no palpable abnormalities in the pastern region) were used for the study.

The ponies were under general anesthesia for use in a student surgical laboratory. The medial and lateral digital neurovascular bundle of one forelimb pastern area and one hindlimb pastern area per pony was treated with non-focused ESWT. The treated legs (right or left and fore or hind) were randomly assigned using a coin toss. The exact area to be treated was determined by measuring one-half the distance between the base of the proximal sesamoid bone and the collateral cartilage of the hoof over the digital neurovascular bundle. For use as a control for each treated area, a neurovascular bundle sample was taken from 5 cm proximal to the ipsilateral proximal sesamoid bone from the point of treatment (contralateral limbs were not available to serve as controls because of their use in an unrelated concurrent study).

The pneumatic shockwave generator was used to generate and apply the non-focused ESW. The system consists of a control unit, an air compressor, and a hand piece. The compressor creates pneumatic energy that is used to accelerate a projectile inside the hand piece. When the projectile strikes the applicator, a shock wave is created and distributed from the tip of the applicator to the desired area.

Before each treatment, the treated and control areas were clipped, shaved, and prepared with coupling gel to obtain maximum skin contact and to minimize the loss of shockwave energy at the applicator tip/skin interface. Each session consisted of 2000 impulses/treatment at a pressure of 2.5 bars and a frequency of 8 Hz (energy density = 0.105 mJ/mm²). The coupling gel was removed after treatment.

After the non-focused ESWT, the horses were stabilized and monitored for evidence of discomfort. After 24 h, the ponies were humanely euthanized; then, the palmar/plantar digital neurovascular bundle was harvested from the treated and control areas. All samples were identified and fixed in a 10% neutral buffered-formalin solution. After fixation, the neurovascular bundles were trimmed and embedded in paraffin. A total of 20 treated sections and 20 control sections were stained with hematoxylin and eosin. They were evaluated microscopically (≤60 times magnification) by comparing cross-sectional and longitudinal views of the treated specimens with the control sections obtained from the same pony.

The slides were histologically evaluated by one author (Hayden) who was unaware of the treatment status of each neurovascular bundle. The slides were evaluated for evidence of abnormalities in the vessel lumen, intima, tunica media, and tunica adventitia. The lumen was evaluated for evidence of clot formation. The integrity of the intima was evaluated by observing the degree of endothelial cell detachment and endothelial cell swelling. The tunica media was evaluated for evidence of disruption of the elastic fibers and vascular smooth-muscle cells. All layers, including the tunica adventitia, were evaluated for the infiltration of inflammatory cells.

3. Results

There were no significant lesions identified macroscopically in the neurovascular structures in the treated or control specimens. No gross evidence of skin ulceration was observed 24 h post-treatment. Light microscopic examination did not reveal any evidence of clot formation, tissue damage, or infiltration of inflammatory cells in any of the tunics. No evidence of endothelial swelling or detachment was noted in any of the treated or control slides.

4. Discussion

The results of this study suggest that non-focused ESWT (evaluated by gross examination and histopathology in adult ponies) does not have any appreciable anatomic or gross functional effect on the digital blood vessels in the short-term period.

In human trials, vessel-wall necrosis, vessel-wall rupture, and complete detachment of endothelial cells of human umbilical vessels were observed after treatment with high-energy ESWT; however, none of these changes or acute vasculitis were observed in the current study. The difference in results may be caused by the type of generator used (non-focused ESWT in the current study compared with focused high-energy ESWT used more commonly in human medicine). There are two major categories of shockwave-therapy generators used in veterinary medicine: focused and non-focused generators (also known as radial pressure wave). The focused-shockwave generators initiate a pressure wave within a fluid medium; the fluid is displaced, and it creates a shockwave that can be focused into the patient’s body. Non-focused ESWT is pneumatically generated by compressed air pulses that move a projectile within a hand piece and generate the radial shockwaves through concussion. Because the axonal degeneration in the equine digital nerves was induced by the application of non-focused ESWT, we elected to study the effects of this generator on the vasculature.
A comparison of the ability of focused and non-focused shockwaves to generate cavitations in an in vitro model has been reported. Cavitation is the generation of gas bubbles in the tissues as a result of the rapid interaction between compression and shear loads that occurs when the shockwaves reach an interface of tissues with different impedance. These bubbles accumulate large amounts of energy, which is released when the bubble implodes, resulting in high-energy water jets and high temperatures. It is this effect that may generate damage to the adjacent surface. Focused shockwaves have been shown to produce measurable cavitation formation, whereas there has been no evidence of detectable cavitations from the non-focused shockwaves.

The idea that cavitation has a prominent role in shockwave trauma has been suggested in recent human literature. When shockwaves are generated in an environment in which cavitations are created, they are able to produce significantly more damage to endothelial and renal cells compared with shockwaves generated in a medium without cavitation.

This lack of cavitation formation by the non-focused ESWT used in the present study may explain the lack of damage to the blood vessels. Further comparison between the effects of focused and non-focused ESWT on equine blood vessels is recommended. Two limitations of this study are that the number of horses used was small and that the site of collection of control samples was in close proximity to the treatment area; however, because none of the treatment areas showed evidence of vascular alterations, the chance of interference with the control specimens is very unlikely.

5. Conclusion

Non-focused ESWT using the protocol described above may be applied directly over the digital vascular bundle without the risk of inducing acute vascular abnormalities.

References and Footnotes

Swiss DolorClast Vet, EMS Corporation, Dallas, TX 75243.
ESWT Contact Gel, EMS Corporation, Dallas, TX 75243.