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Instrumentation of Thermography and its Applications in Horses

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Abstract: Thermography is the noninvasive technique that measures emitted heat and displays this temperature as a picture. Inflammation can be determined by using a medical thermogram. The techniques involve contacting and noncontacting device; noncontacting thermography is very accurate for detecting infrared radiation. Thermography is a useful imaging tool to evaluate diagnosis of certain lameness conditions in the horse and also to allow appropriate treatment that can be applied before some clinical signs occur. This review is intended to present instrumentation and applications of thermography in equine medicine.

Key words: Thermography, inflammation, infrared, lameness, horse

INTRODUCTION

Thermography provides graphic images of the temperature gradients over anatomic regions. Emitted heat is measured noninvasively by thermography. A medical thermogram gives visual thermographic patterns of the skin and also is useful for the detection of inflammation. Because inflammatory changes have been detected by thermography, certain lameness conditions in the horse can be diagnosed (Head and Dyson, 2001).

Infrared electronic sensors were firstly used for military purposes in 1950 andthen used in medicine. Thermography was introduced to veterinary medicine in 1966. Since then, it has been practiced in equine medicine (Godwin *et al*., 2004).

INSTRUMENTATION OF THERMOGRAPHY

Contacting and noncontacting thermography are used in thermography. Both have advantages and disadvantages.

Contacting thermography: This device uses liquid crystals in a deformable base. The crystals change the shape according to the temperature and reflect different colors of the light. For this reason, the color of a crystal shows a specific temperature. To utilize this technology for medical intentions, the liquid crystals are first embedded into a latex base. The base is made into a flexible and durable sheet so that can be easily performed to various skin conditions. When performed in direct contact with the skin, the crystals change the shape, reflect a specific color of light andform a colored thermal picture (Turner, 1996).

This equipment is comparatively easy to use and durable and provides immediate results. One of the major disadvantages of this equipment is that it must contact skin. Because the latex sheets could either cause heating or cooling the skin, the false thermograms may be produced when contacts skin (Turner, 1991).

Noncontacting thermography: This device uses a detector of infrared radiation to measure temperature. The infrared thermometer detects a point temperature on the skin (Turner, 1996). Today, there are some handheld models that detect the temperature difference between two adjacent symmetric areas rather than indicating specific temperature (Shevelev, 1998). Thus, a significant difference in temperature can be easily detected (Turner, 2001) (Fig. 1).

Fig. 1: Handheld model

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The thermographic camera is a more complex device than handheld models. Thermographic camera also includes an infrared detector, scanning and focusing mirrors. The camera is made of a couple cathode-ray tubes. Intensity of the detected radiation is converted to an electrical signal. This signal is displayed on the cathode-ray tube as a black and white image of the object. Through the use of microchips, the black and white image can be made into a colored image of the thermal picture (Turner, 1991).

PRINCIPLES OF THERMOGRAPHY

Body consistently produces heat. It is emitted through the skin by radiation, convection, conduction, or evaporation. Thus, body core temperature is usually 5°C warmer than skin temperature. Sources of heat the skin are tissue metabolism and local circulation. Because veins are draining metabolically to active areas, arteries are cooler than veins. The skin is more heated superficial veins than superficial arteries. Venous drainage from tissues or organs with a high metabolic rate is warmer than venous drainage from normal tissues. Local circulation and the relative blood flow determine the thermal pattern. Surface contour and vascularity of the organ can be visualized by thermography. Temperature of the skin increases during muscle activity (Turner, 1996). One of the major signs of inflammation is heat. If there is a hot spot associated with the localized inflammation, it is seen in the skin directly overlying the injury (Se-wook *et al*., 2005). However, if there is a thrombosis of vessels, a reduced blood supply resulting from swelling or infarction of tissues, the area of decreased heat is generally surrounded by increased thermal emissions, probably due to shunting of blood (Turner, 2001).

Motion: Motion can be controlled by appropriate equipment or immobilizing the horse in stocks. To keep the horse from moving, chemical agents should not be used because these drugs affect the peripheral circulation and cardiovascular systems. This could produce false thermal patterns (Turner, 1991).

Extraneous radiant energy: Thermography should be performed under cover shielded from the sun due to the reduction effects of extraneous radiant energy (Coulter *et al*., 1997). Darkness or low-level lighting is ideal for thermography (Benington *et al*., 1996).

Ambient temperature: 17°C is suitable for thermography, but any temperature below 30°C is acceptable. Thermographic area ideally should have a steady and uniform airflow so that erroneous cooling does not occur. The horse should be kept from drafts. Similarly, the horse should be 10-20 min to acclimate to the environment or room where the thermography is performed (Turner, 1996).

Artifacts: Artifacts are extraneous sources on the skin that can cause false images. These are debris, scar tissue, hair length, leg wraps, liniments and equipment. To avoid artifacts, all subjects are groomed and freed leg wraps and equipment 2 h before thermography whenever possible. As long as the hair is short and in uniform length, the thermal image is accurate. If there is a suspicion area, multiple thermographic images should be made. The area should be evaluated from at least two directions approximately 90° apart so as to detect if a hot spot is consistently present. Extremities should be examined from four directions (Turner, 2001).

THERMOGRAPHY IN EQUINE MEDICINE

Infrared thermography has been used to diagnose inflammatory conditions such as sole abscesses and laminitis in the horses (Eddy *et al*., 2001), predict changes in udder temperature in dairy cows (Berry *et al*., 2003) anddetect inflammation associated with hot-iron and freeze branding in cattle (Schwartzkopf-Genswein and Stookey, 1997) andbovine viral diarrhea infection in calves (Schaefer *et al*., 2004). Soles of hooves affected by subclinical laminitis commonly appear soft and warm long before the appearance of yellowish discoloration, lesions andulcers (Nocek, 1997). For this reason, thermography can be useful for early detection of laminitis, allowing interventions that could prevent or attenuate subsequent lameness (Nikkhah *et al*., 2005).

Thermography has been used to determine illegal procedures in show horses such as application of irritants to the peritoneal region to enhance tail elevation andalso detect illegally enhanced performance in horses (Hoogmoed and Snyder, 2002).

Thermography can be used in equine practice for three ways: Thermography can be used as a diagnostic tool. In these cases, thermography is a physiologic imaging method. If there is a 1°C difference between 2 anatomically symmetric regions, it indicates inflammation in this region, Thermography can be used to enhance the physical examination. In these cases thermography can be determine suspicion areas where the heat increase or decrease and Thermography can be used in wellness program. In this method, horses are followed on a routine care once weekly. Because clinical changes occur 2 weeks after thermographic changes, thermography can be used to detect subclinical problems (Head and Dyson, 2001).

Generalizations of normal thermograms in horses:

- The midline, the back, the chest, between the hind legs andalong the ventral midline will be usually warmer (Turner, 2001).
- Heat over the legs tends to follow the routes of the major vessels such as cephalic vein in front and sephaneous vein in the rear (Holmes *et al*., 2003).
- Because on the dorsal view of the distal limb, the metacarpus, fetlock and pastern are away from the major blood supply, the image recorded is relatively cool (Turner, 1996).
- Around of the rich arteriovenous plexus of the coronary and laminar corium located proximally on the hoof wall is the warmest area in the distal limb (Turner, 2001).
- There is increased warmth between the third metacarpus and flexor tendons; this follows the route of the metatarsal vein in the hind leg and the median palmar vein in the foreleg (Turner, 1991).
- Coronary band is the warmest area over the foot (Turner, 2001) (Fig. 2).
- Tendons are relatively cool at plantar aspect; between the bulbs of the heel along the midline is the warmest area (Turner, 2001).

Specific applications

The foot: The diagnosis and evaluation of several conditions of the foot can be detected by thermography. Thermography provides valuable information about some diseases such as laminitis, navicular syndrome, subsolar or submural abscesses, corns and any other inflammatory conditions of the hoof. Definitive diagnose of these problems are not obtained via thermography. However, thermography provides additional information about localization of the problem, evaluating the degree of associated inflammation anddeciding the best course of treatment. When the physical or radiographic examination findings are inconclusive, thermography is particularly helpful for early or occult conditions of the foot (Turner, 2001).

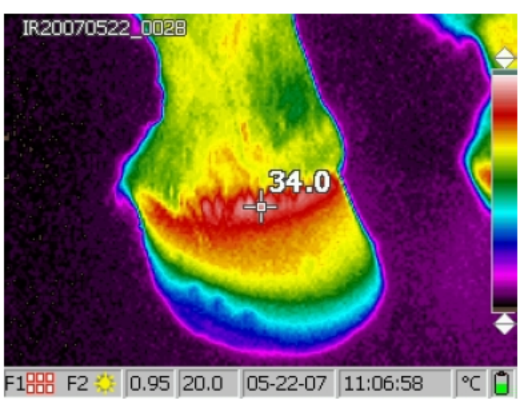

Fig. 2: Coronary band of horse

Laminitis is an inflammation of the sensitive laminae of the foot, the area of the hoof that contains nerves and blood vessels. If the laminitis occurs, the blood flow through the hoof may be increased which is detected via thermography. The coronary band is usually 1-2°C warmer than the remainder of the hoof. If there is an inflammatory problem, hooves begin to approach temperature of the coronary band. Using thermography, inflammation in the contralateral foot can be detected well before lameness, which allows preventative therapy before the laminitis becoming irreversible (Turner, 1991).

Navicular syndrome also can be evaluated via thermography. Navicular syndrome is characterized by a reduced blood flow to the caudal hoof. Thermography determines the relative blood flow to the navicular area. If there is a suspicion of the navicular syndrome, the foot is thermographically evaluated before and after exercise. In normal horses, there is a 0.5°C increase in temperature of the foot after exercise. However, most horses with navicular syndrome do not sustain increase in the caudal foot because of the low blood flow. Other focal inflammatory conditions of the hoof such as abscesses, bruises or fractures that are characterized by focal areas of increased temperature are differed from navicular syndrome. In these cases, exercise intensifies the hot spot (Turner, 2001).

The joint: If there is a joint inflammation, characteristic thermal patterns can be observed. The best view to study most joints is the dorsal aspect. Surrounding structures are warm in comparing with the normal joint, with the exception of hock because it has a vertical hot spot along the medial aspect that corresponds to the sephaneous vein. When joints become inflamed, the thermal patterns change to an oval area of increased temperature that is centered over the joint. However, if pastern joint inflames, there is a circular area of decreased temperature surrounded by areas of increased heat (Turner, 2001).

If there is a problem associated with joints, thermal patterns have been shown to change 2 weeks before the onset of clinical signs of lameness. For this reason, thermography can be useful to assist training and help preventing serious injuries. Before clinical signs occur, training programs can be changed, thereby preventing serious injury (Turner, 1991).

Long bones: Most of long bone problems are rarely evaluated by thermography. Because a bone needs to be in relatively close contact with the skin to affect its temperature, thermography provides limited information about most of long bone problems. Eventually, bones that are heavily covered with muscle cannot be evaluated accurately via thermography (Turner, 2001).

One of the major applications of thermography in long bone problems is dorsal metacarpal disease, which is also called bucked shin complex. Dorsal metacarpal disease is a common source of lameness in the racehorse. Dorsal metacarpal disease is categorized into 6 grades. Grade 1 is characterized as a horse with varying degree of lameness and shins that are painful to palpation with normal radiographic findings. Grade 2 is characterized as a horse with varying degrees of lameness and shins that are painful to palpation and radiographic evidence of thickening of the dorsal cortex of MC3. Grade 3 is characterized as a horse with varying degrees of lameness andshins that are painful to palpation and radiographic evidence of radiolucent lines in the dorsal cortex of MC3 that ran parallel to the long axis of the bone. Grade 4 is characterized as a horse with varying degrees of lameness and shins that are painful to palpation and radiographic evidence of a single oblique fracture line in the dorsal cortex of MC3. Grade 5 is characterized as a horse with varying degrees of lameness and shins that are painful to palpation and radiographic evidence of multiple oblique fracture lines in the dorsal cortex of MC3. Grade 6 is characterized as a horse with persistent lameness and a shin that is painful to palpation and radiographic evidence of a fracture line that extended through the dorsal cortex of MC3 into the shaft and/or palmar cortex of MC3. Grade 1 and 2 diseases are characterized by hot spots located midshaft over the dorsal cannon bone. The hot spot generally is 1-2°C warmer than the surrounding tissues. The Grade 3 has hot spots on bone lateral and medial views in addition to the dorsal view. These areas are 2-3°C warmer than the surrounding tissues. Thermographic changes are seen 2 weeks before radiographic changes occurs. With thermography, an appropriate treatment can be applied at an earlier time (Scott, 2002).

Tendon: Normal flexor tendons are seen bilaterally symmetric and consists of elliptical isothermic zones in thermograms. Palmar aspects of the tendons are seen as the lowest temperature andthe peripheral areas near the carpus and fetlock are approximately 1°C warmer than the surrounding tissues. If tendon becomes inflammed, a hot spot can be seen over the site of tendon lesion. Tendon lesions can be evaluated with thermography 2 weeks before physical evidence of swelling and pain around the tendon. With this enhanced ability of detection, tendon lesions can be identified and the training protocol can be adjusted to prevent further damage to the tendon. If a healing tendon and normal tendon are compared, it can be seen an increased thermal emission from the damaged tendon (Marr, 1992).

Ligament: Ligament injuries are seen thermographically very similar to tendon injuries. Hot spot can be seen centered over the injured area. If there is an inflammation associated with the suspensor ligament adjacent to the splint, thermography can detect this inflammation. These indications can also be valid for any ligament (Turner, 1996).

Muscle: If there is an inflammation associated with muscle, it can be seen thermographically as a hot spot in the skin overlying the affected muscle. Scarcely, swelling and edema in the affected muscle inhibit blood flow through the muscle. If this occurs, injured muscle is seen thermographically as a cold spot. Thermographic evaluation of muscle should be made from paired samples (comparison of right and left sides). These images must be nearly identical. Consistent variations from side to side indicate muscle damage located either the hot or cold spot (Turner, 2001).

Vertebral column: Vertebral column injuries such as luxations, subluxations and fractures can be evaluated through thermography. These injuries are usually undiagnosed or diagnosis is delayed because of difficulty of the equine spine radiography. If there is an inflammation associated with vertebral column, it can be seen thermographically as hot spots, cold spots or root signatures. If cold spots are seen thermographically, it is not associated with chronic injuries. Instead, cold spots suggest severe injuries associated with marked swelling that may affect the autonomic nerve supply. If local sympathetic nerves are irritated, root signatures can be seen thermographically (Turner, 1991).

THERMOGRAPHY AND OTHER IMAGING TECHNIQUES

Radiography usually evaluates changes in bone. On the other hand, thermography provides useful information about inflammation, which usually implies pain. In this respect, thermography can also be useful to determine if a radiographic change is associated with inflammation. Ultrasonography evaluates morphology of the injured structures and size and shape of the injury. Thermography however may be useful for location of injury. Moreover, thermography evaluates when the inflammatory process is resolved, whereas ultrasonography can be used to follow the healing. Finally, thermography and scintigraphy are complementary. Although thermography evaluates the overlying soft tissues, scintigraphy can be used selectively to evaluate bone (Denoix, 1994).

CONCLUSION

Recent advancements in biomedical technology emerge veterinary medicine to use sophisticated instrumentation for effective diagnosis and thereby treatments. Thermal camera is the new imaging technique that uses infrared radiation to determine inflammation. Thermography is noninvasive for the patient and also helpful to determine accurate diagnosis. In order to accurate diagnosis, care must be taken (sunlight, hair length, ambient temperature and area or room). Because of increased demand for early diagnosis and effective treatment, use of thermography in equine medicine would be extremely beneficial.

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