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APPLICATIONS OF INFRARED THERMOGRAPHY IN VETERINARY SURGERY: REVIEW ARTICLE

N. R. Padaliya*, S. H. Talekar, D.T. Fefar, A. A. Vagh, J. V. Vadaliya and R. H. Bhatt

Assistant Professor, Department of Veterinary Surgery & Radiology, College of Veterinary Science and Animal husbandry, Kamdhenu University, Junagadh-362001.

***Corresponding Author: N. R. Padaliya**
Assistant Professor, Department of Veterinary Surgery & Radiology, College of Veterinary Science and Animal husbandry, Kamdhenu University, Junagadh-362001.

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ABSTRACT
This review article describes the application and use of Infrared Thermography (IRT) in the field of veterinary surgery. Infrared Thermography (IRT) is a non-invasive, non harmful and non-contact heat detecting camera for diagnosis in clinical conditions. An infrared camera measures the emitted infrared radiation from an object and then uses this information to create images of objects or body parts. These thermograms are evaluated by a specially analyzing software program. Changes in vascular circulation resulted to an increase or decrease in tissue temperature, which is measured by this camera to evaluate the situation in that area. But some limitations and factors that must be considered before using IRT (sunlight, moisture, dirt, weather conditions etc). IRT has been mainly used in veterinary surgery, primarily for diagnostic purposes, especially in the diagnosis of various musculoskeletal disorders and tumors like conditions in animals. IRT helpful for early detection of various affections like myositis, tumour, arthritis and various conditions in which local area become warmer than normal body parts of animals. Periodic routine thermographic evaluation of cattle, buffalo, dog and horses could be helpful for early diagnosis of disease, design treatment and training protocol for animals. Needs to explore in larger clinical studies are required to demonstrate and practical utility of this technique with its interpretation. This technique can't replace other diagnostic technique or procedures; furthermore, it is unable to provide information about the origin or cause of the disease. In this perspective, sometime thermography alone is not helpful for the formulation of an appropriate therapy.

KEYWORDS: IRT, Equine, Cattle, Canine, Hot spot, Thermogram, Image.

1. INTRODUCTION
Field of diagnostic imaging is innovative and upgrading with new innovation in respect to the diagnostic methods, mainly in the veterinary surgery. This has considerably developed and directed towards on techniques increasingly sophisticated, modern and secure that allows the veterinarian aid and essential information for a more complete, secure and efficient diagnosis (Roberto and De Souza, 2014). IRT is a non-invasive diagnostic method, based on body surface temperature detection. The infrared radiation of body surface area is recorded and visualized in the form of a temperature distribution map in camera. Thermography can be used to measure and visualize superficial temperatures and temperature changes in the body (Stewart et al., 2007). It can be used to screen for early stages of disease, support physical exam findings and monitor response of therapy by measuring radiant heat emitted from the skin's surface (Turner et al., 2019).

Infrared radiation is emitted by all objects proportionate to their temperature as electromagnetic waves of varying wavelengths in the range from 0.7 to 1000 μm (Eddy et al., 2001; Redaelli et al., 2014). Thermal cameras detect differences in temperatures of the target and surroundings and generate images based on the amount of heat generated rather than reflected (Eddy et al., 2001). In correlation with Body Surface Temperature (BST), a colour image illustrating the appropriate temperature values is then displayed. Using this procedure, BST is measured without physical contact with the examined animal. The skin and hair coat play an important role in the process of heat exchange between the body and the environment. Skin also acts as a thermal perception organ, informing the animal about environmental conditions, including changes in temperature and humidity. Hence, the body surface temperature of animals as measured by thermography is the combined result of the heat produced by the body and the impact of environmental factors (Soroko and Morel 2016).

The resulting 'thermogram' can be used to determine physiological changes and reflect blood flow patterns and the speed of metabolism in the body of animals. It also reflects the impact of environmental factors during examination (Turner, 1991). The energy transferred from the body surface by infrared radiation depends on both the physiological processes occurring within the body and the environmental conditions, which in turn influence blood circulation under the skin. Infrared radiation measurement is useful therefore in monitoring physiological changes in animals that result in heat production such as exercise, injury, illness and environmental impact (Soroko et al., 2014).

IRT effectively identifies problems in bone as well as soft tissue and can assist in the detection of nerve damage and dysfunction. It objectively measures the extent of any issues and is highly effective for monitoring recovery progress (Anders, 2013). IRT was used to identify febrile individuals at airports and thereby prevented the transmission of disease by travel, In veterinary, IRT can be used to screen animals for abnormally increased body temperature, so pyrexic animals can be isolated, tested and treated (Rekant et al., 2015).

2. History

It was originally designed for military purposes and since the early applications, the development of infrared imaging as advanced considerably (Ring, 2006). In the early 1970s, thermography was begun to be used as a diagnostic tool, complementary to standard radiographic and ultra-sonography examinations in veterinary surgery. Most of the publications of this period were presented by Stromberg (1974).

The regular use of thermographic examination to monitor and potentially predict injuries was increasingly investigated after 2010. The regular examination of the distal limbs of racehorses during the racing season, identifying areas of past injury and the effect of training loads. This proved helpful in managing and monitoring treatments and training programmes as earlier reported by Soroko (2011a).

3. Principle and fundaments of thermography

Infrared radiation can be measured using either a simple pyrometer or a thermographic camera. A pyrometer measures infrared radiation energy from a specific area of the body surface, which is presented as an average temperature value. A thermographic camera, however, produces a thermogram illustrating a map of the radiation energy over a selected body surface area (Soroko and Morel, 2016).

The thermographic examination should be performed indoors, in a stable ambient temperature on an appropriately prepared horse. It is important to take measurements within a specific ambient temperature range, as this will have a significant influence on the body surface temperature distribution (Tunley and Henson, 2004). Artifacts such as heat sources from sunlight, lamps and heaters should be eliminated (Palmer, 1981). Air draughts should also be avoided, as even barely noticeable air movements are able to decrease the body surface temperature, particularly of the limbs (Westermann et al., 2013).

To obtain reliable images, factors such as movement of the subject matter, any extraneous radiation in the environment, ambient temperature, and artifacts need to be checked. For example, movement can be controlled by physical constrains, but containment by drug should not be used so that false thermographic patterns caused by the sedative principle on the peripheral circulation are avoided (Soroko and Morel, 2016).

Indoor thermography measurement standards have been established in equine veterinary practice. To enhance the diagnostic value of thermography, the room temperature should be stabilized, draught free and windows should be covered and the doors remain closed.

If there is no room that meets these requirements, thermography can be performed in a wide, shaded stable corridor with a clean and even floor, although this is not ideal. Outdoor thermographic examination is not recommended because of the direct impact of the external environment, which will result in unreliable thermograms (Purohit, 2009; American Academy of Thermology, 2013).

4. Preparation of animals for thermographic examination

Thermographic examination of the horse should be performed at rest and before training, to avoid changes in body heat balance and blood circulation due to working muscles. However, in specific cases, thermographic examinations after exercise are also performed. It is recommended that the horse be acclimatized for 20 min prior to imaging in the room where thermography will take place. A longer period of equilibration may be required in cases where the animal is transported from an extremely cold or hot environment.

Recommended distance between horse and camera for specific body areas of a horse like Distal limbs is 1-1.5 m, Back and croup of the horse from the dorsal aspect is 1.5–2 m, Head, neck, shoulder, chest and croup area from the lateral aspect is 2 m and Lateral aspect of the horse body is 7 m (Soroko and Morel, 2016).

Thermography was able to show circulatory modifications in the early phase of bone remodeling and adaptation to exercise. Increased exercise intensity possibly resulted in an augmented blood flow and an increased limb surface temperature, which was detected by thermographic examination with a high sensitivity (Michelotto et al., 2016).

The dogs were placed in front of a uniform interior wall to minimize background artifact that may have been created by temperature differences in exterior walls. The camera was positioned approximately 1.5 to 4.6 m from the dogs, depending on the ROI. The protocol for imaging included cranial and caudal views of the body, full left and right lateral body views, and full-limb views of all limbs. Additionally, images of each limb were obtained to provide views of each joint region (Loughin and Marino, 2007).

Empirical use of thermographic imaging in dogs has suggested that thermographic imaging could be adopted in monitoring trauma patients during rehabilitation, such as physiotherapy, acupuncture and laser treatments; in neurologic and soft tissue injury diagnostics; in assessing gait abnormalities; and in monitoring working and competition dogs (Vainionpaa, 2014). It could also be utilized for the prevention of cruelty against animals by revealing the use of local anaesthetics in animal shows and competitions. Additionally, since normal testicular temperature patterns in various animals are known (Purohit et al., 2009).

5. CLINICAL APPLICATIONS

IRT has been used in veterinary surgery for the evaluation of soft tissue injury and superficial bone lesions as an imaging modality complementary to ultrasonographic and radiographic examinations (Turner, 2001).

Various scientists used thermography for diagnosis of various affections or abnormalities as a sole diagnostic technique or used with other diagnostic modalities like USG, Radiography and nuclear scintigraphy for pin point diagnosis, like Horn cancer in bullock can be very accurately diagnosed with thermography without contact in few seconds as compare to radiography. The effectiveness of thermography and ultrasonography are in combination for detecting back abnormalities, Fonseca et al. (2006). Thermography findings correlate with other diagnostic tools in a group of 64 horses affected by lameness. Thermography correlated with ultrasound examination in 10 of 15 cases (66.7%), with nuclear scintigraphy in 15 of 20 cases (75%), but with radiography in only15 of 29 cases (51.7%). This may be explained by thermography being less effective in the detection of chronic bone injuries or degenerative joint disease with minimal alteration of the vascular supply to the area (Eddy et al., 2001).

Thermography is also useful tool for detection of illegal performance-enhancing procedures during equestrian competition. The International Equestrian Federation (FEI) currently approves thermography as a method for detection of hypersensitization, but the guidelines for use are somewhat nonspecific, which has probably limited the uptake of the technique for this purpose (FEI).

5.1 Long bone injury

Thermography has limited use in evaluating bone abnormalities because the majority of bone is separated from the skin by soft tissues. However, thermography is very useful in the diagnosis of' dorsal metacarpal disease and ring bone like conditions (Michelotto et al., 2016).

5.2 Hind limb myopathy

Myositis can be detected as a generalized increased thermal pattern over the affected gluteal region. Inflammation in the cranial thigh appears as hot spots associated with the quadriceps proximal to their insertion of the patella. The loin, sacroiliac region, body of the gluteal muscle, and the biceps femoris appear hot when the croup region is injured. Once areas of inflammation have been observed, It can be used to evaluate progress in the convalescence period (Turner, 1991 and Turner, 1996).

5.3 Trauma

Traumatic injury of bone, muscle and soft tissue can be easily diagnosed with hotspots in thermography when radiographic and USG findings are inconclusive. Trauma with swelling of muscles within confined compartments, such as in the legs, can lead to elevated pressure in the compressed area, causing ischaemia which leads to compartment syndrome. Early detection of compartment syndrome is essential in order to avoid amputation or death and, therefore, it could be used as a supportive tool for early detection of acute compartment syndrome in trauma patients (Katz et al., 2008).

5.4 Surgery

Thermography has been utilized intraoperatively to monitor blood flow, such as cerebral blood flow in the cortex during brain tumour surgery (Gorbach et al., 2004) and the restoration of blood supply to the heart in coronary bypass surgery (Iwahashi et al., 2007) in humans. A study conducted on rats suggested, this tools can be used postoperatively for the early detection of free flap failure and to aid in the salvage of the flap, since early recognition of perfusion failure is essential for flap salvage (Tenorio et al., 2009).

5.5 Tumours

Canine mammary tumour and large animal tumours can be easily identifies in early stage with help of IRT with less time consuming and without any harmful effect as compare to other diagnostic modalities, Like mammary tumour in canine and horn cancer in large animals. Initial stage of tumours in animals can be diagnosed with help of IRT by increase temperature at affected area that can be useful for upcoming era of practice as earlier described by many scientists (Fig. 1 to 3).

Initial studies conducted on mice and humans have indicated that it could be useful in cancer detection, especially if the cancerous process involves a release of nitric oxide in dilating blood vessels and enhancing heat emission (Button et al., 2004). If the tumour has an impaired blood supply due to smaller size, poor organisation and hyper permeability of the blood vessels, it can appear colder than the surrounding tissues in the thermographic images, as suggested with Song et al. (2007).

Using an advanced integrated technique, thermographic imaging has been found to have an accuracy of 80.95 %, with100 % sensitivity and 70 % specificity, in identifying breast cancer, whereas a clinical examination conducted by an experienced radiologist has an accuracy rate of 60%–70 % (Ng and Kee, 2008).

5.6 Tendons and ligaments

Tendinitis is detected as a increased area of heat in the normally elliptical isothermic zone. As lesions heal, the pattern becomes more normal, but the overall temperature of the tendon remains elevated. 'Hot spots' can be detected thermographically up to two weeks before clinical symtoms arise of swelling, injury or pain. This permits early detection of lesions and appropriate changes in training routines. Ligament injuries such as suspensory desmitis can also produce 'hotspots', and thermography can be used in conjunction with the physical examination to detect and or confirm areas of palpable pain (Turner, 1991).

5.7 Foot and Joint disease

IRT is useful for detection of various diseases/ affections of the foot including laminitis, navicular disease, abscesses, ringbone, seedy toe and corns. It may helpful in the early phase or when physical and radiographic findings are in conclusive. Temperature differences greater than 1°C between any of the hooves are abnormal. If all four feet are involved, the temperature of the feet between the heel bulbs should be measured. A difference of more than 1°C between the feet is significant. Laminitis is detected as an increased temperature change between the warmer coronary band and the hoof wall. Normally this difference is between l °C and 2°C. It can be useful in detecting laminitis before clinical signs appear and can be used to monitor patients at high risk of becoming laminitis (Turner, 1991).

Moist inflamed joints exhibit an oval area of increased heat centered over the joint when viewed from lateral to medial. IRT of joints can reveal alteration in thermal patterns weeks prior to onset of clinical signs. This permits alteration in training and close observation to prevent more serious disease (Turner, 1996).

In veterinary practice this tool can be helpful for diagnosis of musculoskeletal disorders like early stage of laminitis, periostetis, navicular disease, and various foot affections in equine are commonly found, many time with lack of knowledge or diagnostic facilities sometime undiagnosed or misdiagnosed in field conditions. In such conditions this tool can be helpful for field veterinarians to remote diagnosis and to prevent further advancement of cases (Fig. 4 to 10).

5.8 Wild animals

There should be need to more explore to use of IRT in wild animals because as the roaming movement and habitat difficult to use other diagnostic modalities in wild animals, in such conditions this technique can be useful to diagnose from distance many conditions like wound on body, traumatic injury of musculoskeletal parts like fracture and also useful for movement of nocturnal animals and mammals.

6. Advantages of thermography

- Technique cannot cause any damage to either the patient or the operator.
- It does not use any penetrating radiation, as in radiography or computed tomography, and the anatomical part that is examined does not receive ultrasound waves, like in ultrasonography, and is not placed in an electromagnetic field as in MRI.
- It does not use any radioactive substances, as in scintigraphy.
- It is certainly the least invasive for both the patient and the operator among all diagnostic imaging techniques.
- It can be considered a physiological method, because it provides a real-time evaluation of changes over time, creating a dynamic image of the object: this characteristic represents a considerable advantage over other imaging techniques that offer only static representations, such as radiography, tomography, and MRI.
- It can detect surface temperature in a much more objective and sensitive way than clinical palpation.
- It appears to be a highly sensitive technique as it detects the radiation emitted by the object, turning it into a temperature rating, and for the physical laws on emission of heat, even for small changes in temperature, there are large variations in energy.
- Another key advantage of this technique is its ability to be used as a preventive method in the sense that it can highlight variations that do not yet lead to clinical signs.
- Detection of temperature changes in a clinically healthy subject is a helpful tool to estimate the possible development of future disease and can give early warning signals, allowing the health provider to make decisions about the animal's sports program or management.
- It is also a useful method to monitor the response to therapy without interfering with the treatment.

7. Disadvantages of Thermography

- Good quality thermographic cameras are very expensive.
- It can locate the pathological area and is able to provide information about the physiological and pathophysiological status thus allowing considerable diagnostic support.
- The technique cannot replace other diagnostic procedures; furthermore, it is unable to provide

information about the origin or cause of the disease. In this perspective, thermography alone is not helpful in the formulation of an appropriate therapy.

Figures

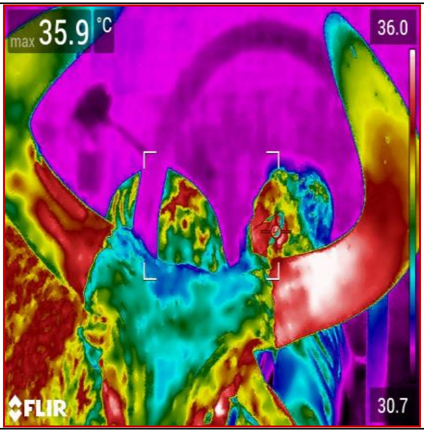

Fig. 1 Lefthorn showing higher temperature

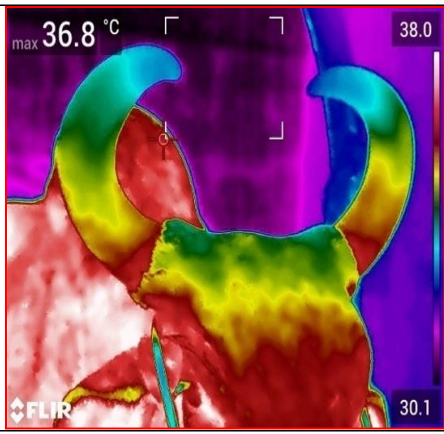

Fig.2.Both horn showing symmetrical temperature

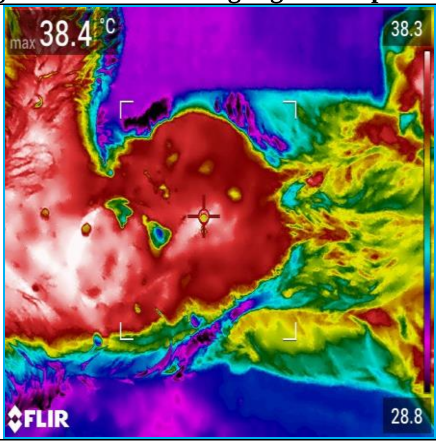

Fig. 3. Ventral abdomen showing higher temp. in case of pyrexic canine mammary tumour case.

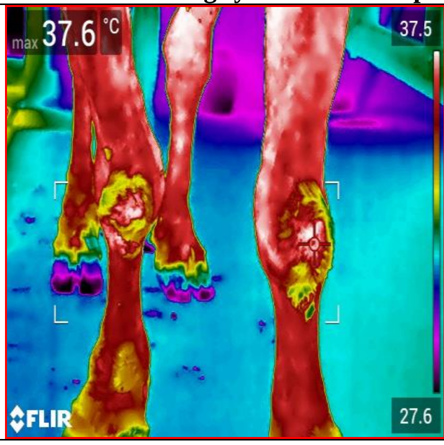

Fig. 4. Both carpal joint of bullock showed increased heat over center of joint.

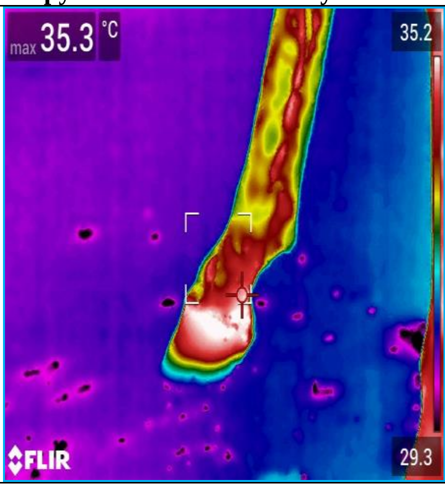

Fig. 5. Distal limb of equine foot showing higher temp at coronary band and pasteran area.

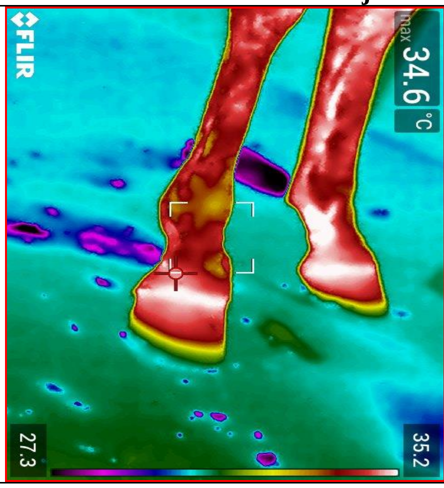

Fig. 6. Distal limb of equine foot showing higher temp at coronary band, pasteran and tarsal area.

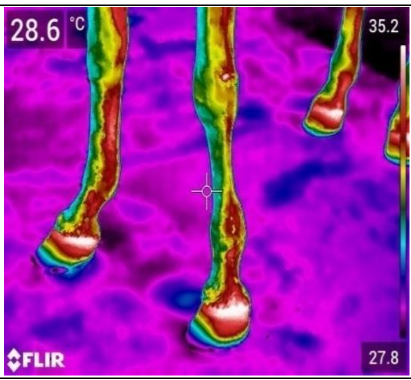

Fig. 7. Increase heat at coronary band in all limbs oflaminitic horse.

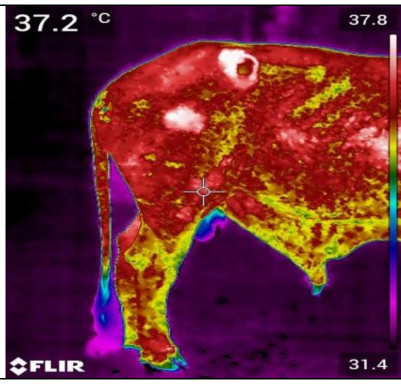

Fig. 8. Gir bull showed gonitis and coxitis in lateral thermogram

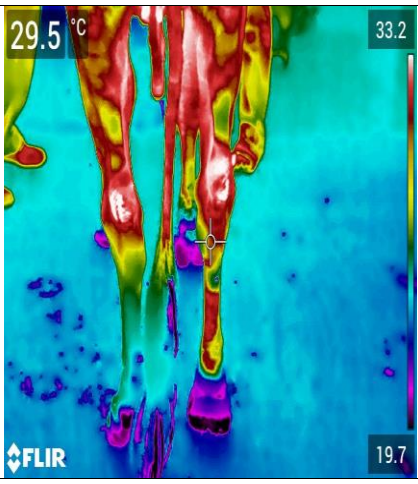

Fig. 9. Thermogram showed both point of hock is gettiing higher temp.

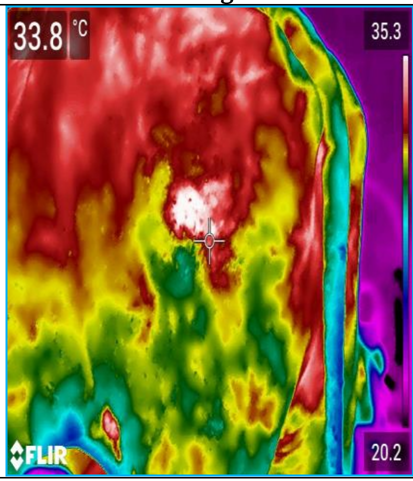

Fig. 10. Lateral thermogram showed coxitis in working bullock.

8. CONCLUSIONS

IRT is a rapid, remote method for assessing surface temperature that has many diagnostic and screening applications in veterinary surgery. It is also useful for evaluating the effects of various topical treatments (such as cold, biomagnets, and ultrasound) on skin temperature. A combination of thermography image analysis with clinical examination would be a helpful technique for preventing lameness. Therefore, IRT may be used in the future to help veterinarians and herd managers detect hoof lesions associated with lameness in dairy cows.

9. Future Prospects

Need to explore the use of IRT in different clinical conditions in ruminants, canine, feline including wild animals. Study of pathophysiology of ocular diseases and drug interactions of topical medications should be explore by ocular thermography. Further works are require for use of thermography as a screening tool for joint affections like osteoarthritis, meniscal tears, osteochondrosis, patellar diseases, cruciate and collateral ligament damage. More studies are also needed to assess whether there is a positive correlation between the temperature and tumor histopathological grade, and to check the temperature difference between benign and malignant mammary neoplasms in dogs.

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