CHAPTER 3

Infrared Thermography in Zoo and Wild Animals

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Infrared (IR) thermography is a noninvasive diagnostic screening tool that does not require handling or restraint of an animal. Physiologic or pathologic processes involving changes in surface temperature may be evaluated using this technique. This modern method provides real-time, instantaneous visual images with measurements of surface temperatures over a greater distance.

The first medical application of "thermography" was by Hippocrates (ca. 460–375 BC), who used thin layers of mud for his temperature measurements, similar to modern thermography. An area of great heat emission caused an area of the mud to dry first, and thus a "hot spot" was detected.[29] It was not until the mid–eighteenth century, however, that temperature scales were developed by Fahrenheit, Réaumur, and Celsius, and not until 1800 that Sir William Herschel discovered infrared rays distinguishable from visible light. The first detector was constructed in 1830.[6]

Infrared thermography has been used for skin temperature measurement in human medicine since 1960 and for the early detection of diseases since 1980, mainly pathologic processes such as pain in the lumbosacral region, intervertebral disc prolapse, spinal cord lesion, traumatic lesions, fractures, neuropathology, cardiovascular diseases (especially impairment of blood supply), lateral effects of heat or frost burns, and long-term monitoring of skin transplants. In wildlife biology, IR thermography has been used since the mid-1940s for detecting and monitoring mammal and bird species. To some degree the method could even be used successfully in animal censuses. In veterinary medicine this technique has been used on farm and companion animals since the late 1950s.[9] The most advanced field is that of equine medicine.[24,28,29] Eulenberger and Kämpfer[3] first recommended the use of IR thermography in zoo and wild animal medicine.

Phillips[15] performed the first large-scale comparative studies on thermoregulation in zoo animals with the aid of infrared thermography. Both studies employed traditional, carbon dioxide (CO_2)–cooled systems, which proved to be difficult to use under routine zoo and wildlife conditions. Hilsberg[9] first used IR thermography extensively with modern equipment in zoo medicine.

METHOD

Infrared thermography makes use of the physical characteristic of bodies or materials to emit electromagnetic waves, and with the aid of a special detector, these rays are visible. Therefore, surface temperatures are measured over a greater distance.[6]

The advantages of IR thermography compared with other imaging techniques (e.g., ultrasonography, radiography, magnetic resonance imaging, endoscopy) are as follows:

1. Is completely noninvasive because no contact with the animal is necessary, and therefore no animal training, immobilization, or sedation is required.
2. Offers an ideal, instantaneous first screening method to help the veterinarian in decision making, monitoring, and determining whether other measures need to be taken.
3. Yields real-time visual imaging in gray or false-color coding.
4. Provides surface temperature imaging of a whole animal, or parts of the animal, as well as easy comparison with herd mates at the same time.
5. Permits examination of motion and direction (e.g., inflammation, reproductive evaluation).
6. Allows easy monitoring of a condition over time (e.g., lameness, inflammation, pregnancy).
7. Facilitates documentation and preservation of primary data.
8. Is portable and uses battery packs and thus is conducive to zoo and wildlife field conditions.

As with other techniques, however, IR thermography presents specific challenges in zoo and wildlife medicine that are not encountered as often in human medicine and classic veterinary medicine. For example, detailed knowledge of the morphology of many different species is required; no control exists over the animal under investigation (e.g., movement, position relative to the sun, muddy or wet surface parts, positioning of animal for best investigation); and no specific examination room in a veterinary clinic with controlled environmental parameters (e.g., temperature) is available.

TECHNIQUE

Using an IR camera or scanner, the heat emitted by every material or object may be detected and made visible through conversion into temperature-associated shades of gray. The warmer areas are colored white or light gray, and the cooler areas are darker gray or black. The system may also use several scales of false-color coding. This means that an image is created in which each temperature is assigned a specific color on a reference scale; the best scale for veterinary diagnostics is the rainbow color scale. The image created can be interpreted and used for diagnostic purposes in medical fields.

The IR camera works similar to a digital video camera, except the lenses possess specific attributes. Because glass hinders the transmission of heat waves, other materials are used as semiconductors, such as germanium-zinc, lead-selenium, or cadmium-mercury-telluride. Each specific mixture of half-metals measures a defined wavelength within the IR spectrum. Each of these wavelength windows possesses specific properties, but also disadvantages, so the industry has tried to optimize the materials used for the required purposes. Gaussorgues[6] provides detailed information on the physics behind these systems, with a shorter, more veterinary-oriented version by Hilsberg.[9] Before obtaining a system, the clinician must consider the lens specification.

An IR system should be certified by the regional authorities. Only such systems guarantee that the measured temperatures are accurate and that it is legal to use the system; specific regulations exist because of the military use of this technology. Recently, increasing numbers of systems are appearing on the market that are remakes or copies of earlier units. These systems, however, may not be certified and thus may yield false temperature readings. The potential thermographer should consult with engineers or local experts before acquiring such equipment. All the studies described by Hilsberg[9] have used the IR systems by the companies AGEMA and later FLIR Systems. With the enormous technical developments achieved in the last decade, this technique should be used throughout veterinary medicine, especially in zoo and wild animal medicine, as an aid in primary diagnostics.

The images captured by the IR detector may be saved and stored on a hard disc or other storage media and viewed and evaluated later on the computer with specialized software. Each false color or gray point in the image is still associated with the originally measured temperature, so the settings of each image may be optimized for evaluation on the computer.

When using this technique, it is important that investigators are aware of the influences on their readings. The animal should be acclimatized to the environment, preferably for 2 hours before thermal imaging. Furthermore, the animal should be clean, dry, and free of dirt; otherwise, artifacts may be created, which may require interpretation. Under certain circumstances it is more advantageous to have the animal wet and not acclimatized, as explained later under the species-specific investigation techniques.

ANIMALS AND ENVIRONMENT

Thermography is best used on animals, or parts of them, without long hair, such as elephants, rhinoceroses, hippopotami, giraffes, zebras/horses, and many larger antelopes. In longer-haired animals such as carnivores, camels with winter coats, and mountain animals, the interpretation of results is more difficult. In these cases the procedure is better done by an experienced thermographer, unless only joints, feet, or parts of the head are evaluated, although even these may create problems. The thermographer must be familiar with the normal skin surface, internal anatomy, and morphology of the animal under investigation. Regional hair length is an important factor for interpretation, as well as the location of blood vessels and the innervation of skin areas under investigation.

SOURCES OF ARTIFACTS

Clipped hair may increase temperature readings. Alcoholic ointments or other surface heat–producing materials also create artifacts in the form of increased heat emission. On the other hand, cold water, dirt, or mud may create an altered heat emission that shows lower temperatures, at least when first applied. Later, this foreign material emits the heat according to its composition. Additionally, uneven pelage creates uneven heat transmission. Strong physical activity of the animal will create local heat production at first, but heat emission from the whole-animal surface may occur later, depending on the type of animal and the type and duration of the activity.

High ambient temperature poses difficulties when looking for smaller temperature differences. Under high ambient temperatures the difference between the animal core and surface temperature decreases. This makes the use of IR thermography more challenging in field investigations than in zoo settings. A good way to address this problem is using the technique in a stable or, for wildlife at night, near a waterhole. The sun itself also creates significant artifacts, and therefore cloudy days are preferred. However, clouds still allow a certain quantity of infrared emission. The effect of the sun is especially visible in giraffes and zebras. In zebras the author found specific skin pattern–related heat radiation when the animals were in their stables at night.[1]

A brief introduction to these investigations is provided in the later discussion on thermoregulation. Again, the best place for an investigation of a zoo animal is the stable, or the investigations should take place on a cloudy day, after sunset, or before sunrise, if absolute temperatures are required. Otherwise, the investigator should try to lure the animal into a shady part of the enclosure. An experienced thermographer can cope with many artifacts or will do a follow-up investigation a few hours or days later. Artifacts may also result from sources of heat in the housing environment of zoo animals, such as heaters on walls, floor heating, or even heating from ceilings. If not accounted for, these sources may lead to gross misinterpretations, as in pregnancy diagnosis.

OPTIMAL SETTING

When starting to use IR thermography, as just discussed, the best time and place to investigate an animal is the animal's stable early in the morning. This animal is most likely acclimatized, dry, dirt free, and not stressed or physically exhausted. The investigator should look for signs of scratching on the skin. If the stable has floor heating, the animal must be allowed to stand for at least 1 to 2 hours to prevent false readings from that heat source. If the animal is dirty, hosing it down with medium-temperature to cool water may help. The thermographer can then follow up on the process of warming the skin to look for hot areas. This method is sometimes the best way of investigating elephants and hippopotami.

GENERAL FIELDS OF USE

Thermoregulation: the Basics for Medical Thermography

Before veterinarians can make good use of IR thermography in zoo and wildlife medicine, they must become familiar with the thermoregulatory patterns of each species. This is important because each species presents specific challenges for thermography: color patterns; hair length; thickness of the dermis; location of glands; size of ears, horns, or antlers; location of potential thermal windows on the body itself; and the anatomy of the legs. *Thermal windows* are areas of increased heat emission; some are facultative and some obligatory (see later discussion).

Because of the lack of hair, elephants (and most rhino species) display a relatively even surface temperature under normal conditions, with only the ears, horns, or tusks showing lesser heat radiation than the body and legs. Mammals with short hair and thin legs (e.g., giraffes, antelopes, zebras) display cooler legs than bodies under normal thermoregulatory conditions and in the shade. Animals with thick hair may display little radiation through the body surface, which may make the use of IR thermography almost impossible. However, some uses may still be possible, such as the diagnosis of inflammatory processes on the legs. The inside of mammalian legs shows a slightly greater heat radiation than the outside because of the more superficial location of blood vessels. When doing close-up views of the ears in both African and Asian elephants, the blood vessels may be located easily. Apart from the blood vessels, ears should display no other source of higher radiation, except at the opening of the ear canal. As an example, normal thermoregulation in elephants is judged by viewing cooler ears than body temperature, as well as measuring the overall average body and leg surface temperatures, which should be relatively constant within a limit of about 1° to 2° C.

The only exceptions from this uniform surface temperature are the obligatory or facultative thermal windows. In mammals the eyes are always *obligatory* thermal windows, as are the mouth, heart region, and the rectal and vaginal openings, as well as the penis during urination or erection. These are areas where function permits no insulation, or where an opening in the body is connected with the body core. *Facultative* thermal windows are much more difficult to judge because they may or may not be active, depending on the ambient conditions and the thermoregulatory needs of each animal. These are species specific and may also show individual variations.

Therefore, it is advisable to study many individuals over time before judging pathologic processes. When this is not possible, the investigator should make use of other individuals of the same species in the same environment, or if time permits, investigate the same individual on different occasions under similar conditions. This last approach yields the most accurate investigation technique for an individual. This is the technique used in equine preventive medicine or in racecourse training management, especially in Great Britain. Experienced trainers and veterinarians are able to identify potentially lame animals up to 2 weeks before the animal actually shows clinical signs.[13,22,27]

General indicators of altered thermoregulation can be physiologic or pathologic, as follows:

1. Exposure to strong sun
2. High ambient temperatures with simultaneous high humidity and no water access
3. Physical activity
4. Stress (psychologic)
5. Pregnancy (see Monitoring Reproductive Events)
6. Abrasions (see Diagnosing Inflammation)
7. Inflammation

Elephants

As animals without a notable amount of hair on the body, elephants display relatively even heat radiation over their entire body surface when in a thermoneutral zone. Only the ears show less heat radiation than the body, whereas the eyes, mouth, and anus are thermal windows (Figure 3-1). Any other source of heat should be investigated. A thermogram of an elephant feeding on branches may show the "hot" mouth, the hot distal trunk, and the warm tips of the front feet. Thermograms of an African *(Loxondonta africana)* and an Asian *(Elephas maximus)* elephant may show heat radiation with specific reference to their ears. In both animals the larger blood vessels are localized.

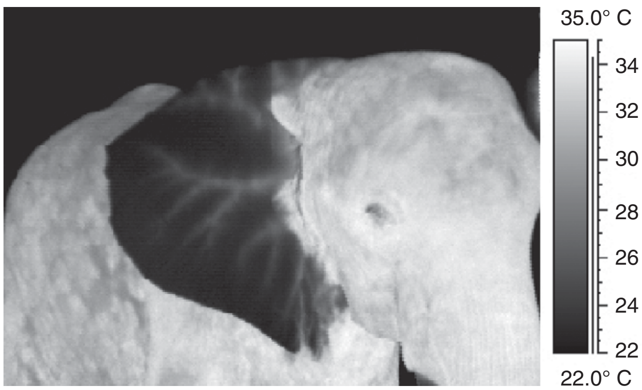

Fig 3-1 Normal thermogram of an elephant, with the ear showing less heat radiation than the body.

Intense sunshine creates high temperature readings on the body and outer surface of the ears, especially in African elephants. The underside of the large ears usually remains cool. Ear flapping results in increased convection and saves the ears from collecting further heat. More than 30% of excess heat may be radiated off the ears in African elephants.[16] In a group of Asian elephants in a newly built indoor enclosure, the keepers noted that the elephants did not display normal activity patterns but seemed somewhat lethargic. IR thermography revealed an altered thermoregulation, with ears that were the same high temperature as the body. This was noted in all members of the group. The ambient high humidity of 95% was reduced, and the animals were given more frequent access to cool water. Overheating poses a great stress and health risk to captive elephants, especially Asian elephants, and may even cause death during immobilization, if the thermoregulatory influence of a new enclosure is not evaluated; in this case the health of the animals improved.[9] Uhlemann[25,26] provides similar examples of recent investigations into thermoregulatory behavior of zoo animals involving insight into environmental heat stress caused by enclosure design.

Elephants may also display increased radiation from parts or whole ears caused by psychologic stress. When this occurs, at least some animals in the herd display normal ear radiation and serve as comparisons.[9]

Rhinoceroses

As another species with lack of a significant hair coat, except for the Sumatran rhinoceros *(Dicerorhinus sumatrensis)*, rhinoceroses kept at most zoos belong to one of three species: black *(Diceros bicornis)*, white *(Ceratotherium simum)*, or greater one-horned rhinoceroses *(Rhinoceros unicornis)*. As with elephants, rhinoceroses display an even radiation over their body surface and legs, with only their ears and horns showing less radiation under normal conditions (Figure 3-2). Juvenile or newborn rhinos display a higher radiation than adults. This contrasts with newborn horses, because foals have long hair, which insulates the small body. In the greater one-horned rhino the thicker skin plates are visible as areas with less radiation.

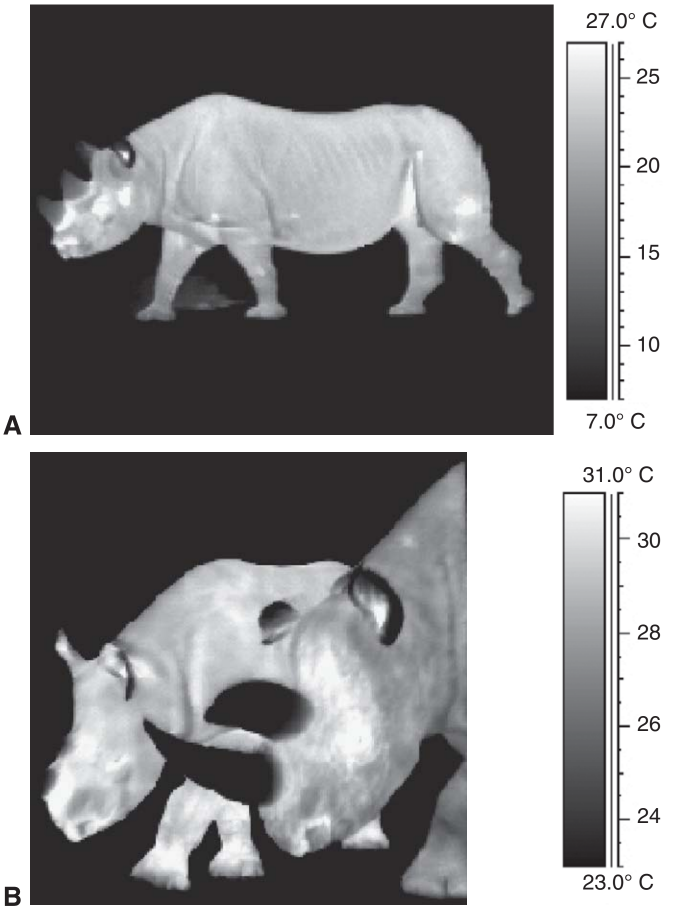

Fig 3-2 **A,** Normal thermogram of black rhinoceros. **B,** Ears and horns appear cooler than bodies of black rhinos.

Intense physical activity may create various forms of heat radiation in the animal under study. Activities such as mating in black rhinoceroses may cause the male partner to radiate intense heat over his whole body, whereas the female stays "cool" (Figure 3-3). Running creates heat in the shoulder and hip muscles, as well as in the legs. In animals with heavy heads, the head may also show increased radiation during running. In rhinos, only the head itself increases in radiation, whereas in deer the neck also shows increased radiation. Under normal circumstances the abdomen remains at the general body temperature and does not show increased radiation with a running activity, or only after prolonged activity. This is important for pregnancy diagnosis.[9]

Lions

The mane in adult male lions poses a specific challenge for thermography because it serves as an insulator. Only about 50% of the male lion's body surface is available for temperature regulation because of the mane. Therefore a male lion could experience a heat

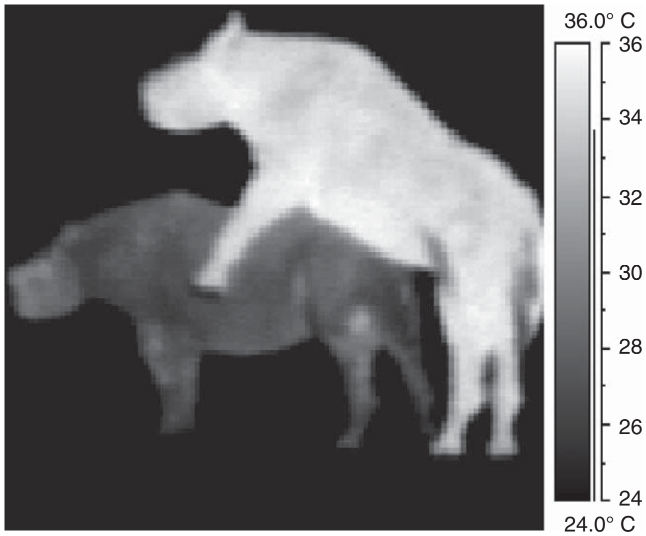

Fig 3-3 During mating, male rhinoceroses may be much warmer than female rhinos. (See Color Plate 3-3.)

stroke if hunting under intense sunlight.[9] This was verified and placed into an evolutionary context in an investigation on wild lions in East Africa,[30] as well as in historical perspective.[14]

Anesthesia. An interesting feature in lion thermoregulation is observed during anesthesia (Figure 3-4). When the animal is under full anesthesia using a combination of medetomidine and ketamine, the nose is cold compared with the body. A few minutes after the antidote atipamezole is administered, the nose starts to warm up. When the nose is much warmer than the body, the lion may raise its head and soon arise. Therefore the nose temperature serves as a good indicator of immobilization status, and thermography may be used to monitor anesthesia.

Giraffes

Again, species-specific skin coloring has an influence on thermographic investigations in giraffes. The sun heats up the darker skin parts more intensely than the lighter parts, but even during the night the giraffe may display this same skin radiation pattern, even though no sun was present for hours, and a new equilibrium should have been reached (Figure 3-5). Therefore I investigated this phenomenon further. In a Rothschild giraffe *(Giraffa camelopardalis rothschildi),* a subspecies with three different hair colorings, the black-haired areas showed a less dense hair covering and a thinner epidermis than the white areas. In the superficial blood vessels, we found no difference with reference to the skin color.[10] An earlier investigation suggests a skin color–related distribution of the slightly deeper

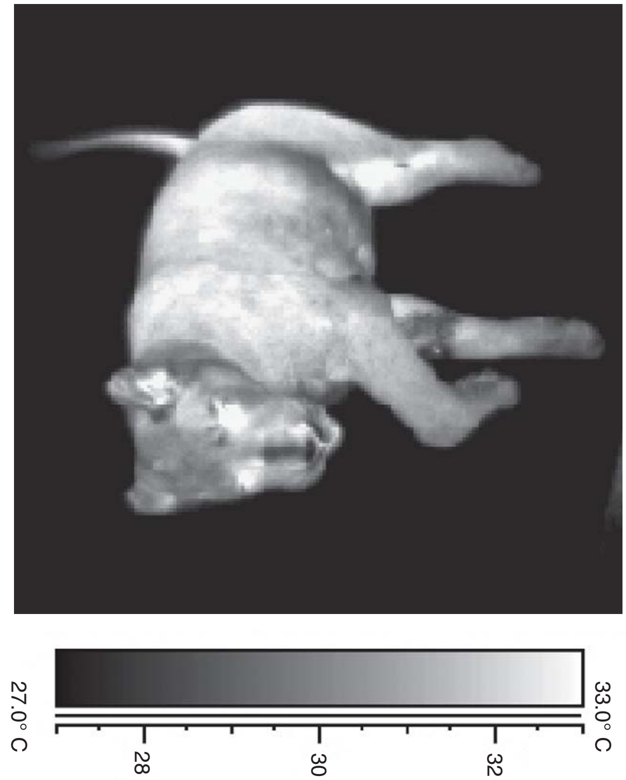

Fig 3-4 Thermogram of a female lion during anesthesia. Males show significant insulation in the mane region and little insulation on the remaining body surface.

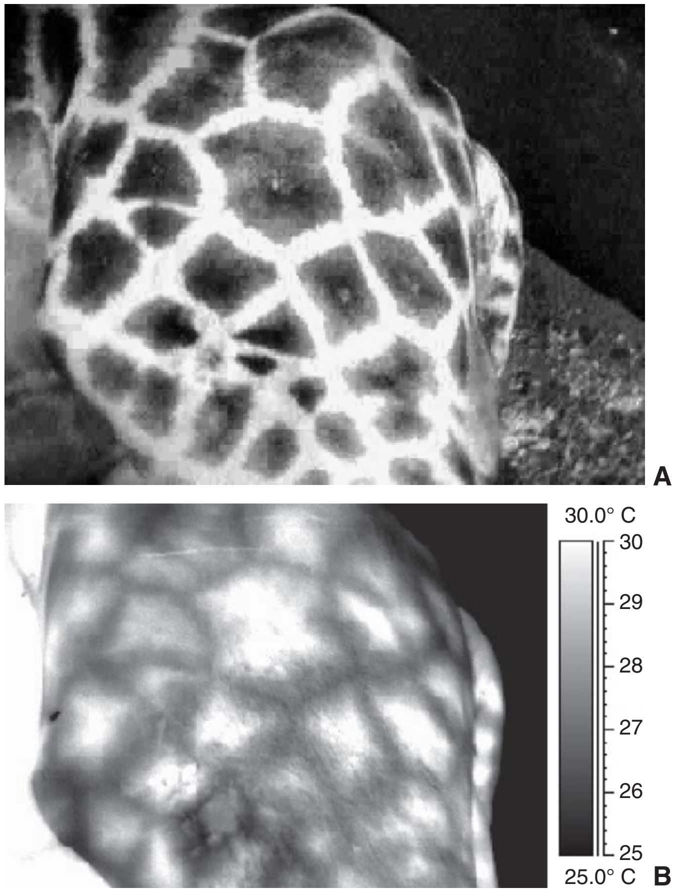

Fig 3-5 **A,** Thermoregulation in a giraffe during the day. **B,** Same individual during anesthesia. The dark spots radiated more heat than the white lines.

and larger blood vessels.[21] This thermographic, histologic study allows definition of the dark patches in giraffes as general, "predefined facultative thermal windows," which may be turned on or off, depending on local thermoregulatory needs.[10]

Zebras

Zebras show a different thermoregulation than giraffes in regard to the influence of the skin color. Zebras are similar to giraffes regarding influence of the sun. Under the bright sun a zebra shows higher radiation over the black stripes versus the white stripes, as well as a more intermediate radiation over brown stripes. Thus the hot black stripes show up in gray-coded thermograms as light areas, and the cooler white stripes appear as darker areas. In a Chapman zebra *(Equus quagga chapmani)* a maximum temperature of 71.9° C was measured on a sunny day of 22.8° C ambient temperature and 50% relative humidity. The average difference between black and white stripes was more than 20° C under these conditions. More surprising were the findings in the various zebra species at different zoos during night investigations. With no influence of the sun, the white stripes emitted more radiation than the black stripes[1] (Figure 3-6). This phenomenon is explained by Kingdom,[11] who found insulating fat layers under the black stripes in plains zebras *(Equus burchelli).*

Other Animals

During more general studies using IR thermography, housing conditions were investigated in regard to their influence on the behavior and well-being of zoo and wild animals. In one investigation, Uhlemann[26] found significant heat stress for Mishmi takin *(Budorcas taxicolor taxicolor),* a large ruminant, from the rock surface of its enclosure. Temperatures greater than 60° C on the rocks resulted in the animals crowding into a small part of the enclosure covered with wood chips. Because takins are normally found in cool mountain environments, this indicated suboptimal management for this species and could pose medical problems from overheating.[26]

In a study of wild greater mouse-eared bats *(Myotis myotis),* Sandel et al.[17] discovered a temperature-related movement pattern. As ambient temperature

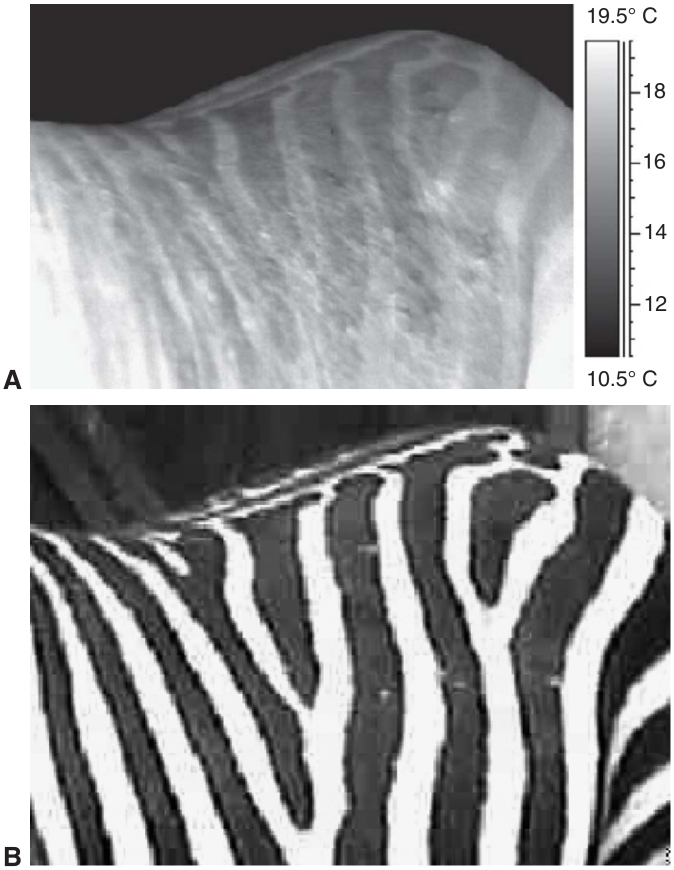

Fig 3-6 **A,** Thermoregulation in a zebra during the day. **B,** Same individual at night, when the zebra radiated more heat from white than from black stripes.

increased in the summer, the bats moved from positions under the tiles onto the wooden roof constructions, and with further temperature increase, onto the thick stone walls of the church roof. This choice of roosting places on a temperature gradient seemed essential for the temperature regulation in bats and is currently being investigated for zoo animals.

These examples illustrate that IR thermography may be a valuable tool in monitoring animals with regard to their health status and their surroundings in captivity, as well as in the wild. This technique helps veterinarians evaluate the habitats and welfare of the species in their care. The example of the herd of elephants revealed a true veterinary concern for monitoring enclosure design. For this more general application, however, one need not be a veterinarian to make sensible diagnoses. In the field of thermoregulation, a curator or technical personnel may be trained, or even an outside thermographer hired, to do an enclosure evaluation with the animals present. However, it is always advisable to have this done in cooperation with the zoo veterinarian.

Monitoring Reproductive Events

Unfortunately, not every zoo or park has the means to monitor reproductive events in elephants and rhinoceroses on a routine basis, and therefore reproductive output in these endangered species is suboptimal in some institutions. Researchers and zoo veterinarians have designed noninvasive methods for monitoring cycling activities, including fecal hormone analyses[18] and minimally invasive methods such as rectal ultrasonography.[7] However, both these techniques are labor and time intensive. Under field conditions, such methods often are impractical, too expensive, or against the philosophy of noninterference practiced in many national parks. In these cases, IR thermography may yield instant results with a noninvasive method and brief time commitment. Because no method is perfect, however, thermography has disadvantages, as mentioned earlier, as well as in the following examples.

Cycling Activities in Elephants

In my experience with IR thermography, female elephants with increased heat radiation over the vaginal sheath were noted. If a bull was nearby, he always followed the females with this presentation. A similar intense radiation through the vaginal folds in black rhinoceroses during estrus was also observed when they lifted their tail to present themselves to the bull. Especially in elephants, this finding should be pursued with scientific investigation in regard to its use in estrus determination. Once the method is established, inexpensive instruments could be used by keepers or park managers to assist reproductive management. For rhinos, however, this is not practical, unless the animal is easily accessible and the tail can be lifted by hand to give full access to the vaginal folds. Figure 3-7 illustrates a female Asian elephant with increased radiation over her vaginal sheath.[9]

Pregnancy Diagnosis

During pregnancy the female animal shows increased metabolism that allows for the growth of the fetus. When energy of one form is converted into another form, some energy is always lost in the form of heat. Depending on the ambient temperature and relative humidity, this metabolic heat, as well as the heat of the placenta and the body heat of the growing fetus, is channeled to the outside of the mother's skin by conductance, especially when the fetus is pressed against the mother's body wall. This sets two constraints for

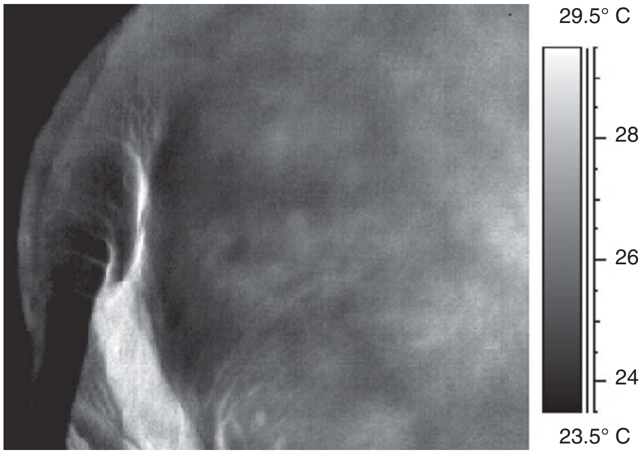

Fig 3-7 Estrus in an elephant. During presumed estrus in this Asian elephant, the vaginal sheath radiated more heat than the other body surface. The bull pursued this female intensely.

Fig 3-8 Late pregnancy in an Asian elephant. The abdomen bulged, and heat radiation increased both from that area and from the mammary glands. The heat radiation during late pregnancy was so great that the feet and trunk functioned as facultative thermal windows. In some individuals the feet may show swelling and increased radiation. (See Color Plate 3-8.)

the use of this method: (1) the fetus must be of a certain size so that enough heat is produced to become visible through conductance, and (2) the ambient temperature and relative humidity must be in a range that allows conductance of excess heat. Ambient temperature is optimal between 15° and 18° C.[9]

To date, the best species for pregnancy diagnosis using IR thermography are the black and white rhinoceroses. In rhinos we diagnosed a pregnancy at the end of the first trimester. These animals possess a tough skin that shows little expansion during pregnancy and therefore allows localized heat areas to be visualized with sharp edges. This is not the case in elephants or giraffes. Even so, their skin also contains keratin and tough fiber, their skin is more elastic, and their abdomen bulges greatly during pregnancy. This creates a more diffuse picture without sharp edges around the increased-radiation areas.[8] Experience has shown that providing a sound diagnosis of pregnancy in a multiparous giraffe is difficult. For primiparous giraffes the method works well for experienced thermographers. However, as previously noted, the predefined facultative thermal windows in giraffes pose a problem. Figures 3-8 and 3-9 show late pregnancy in a multiparous Asian elephant and in a multiparous black rhinoceros, respectively.

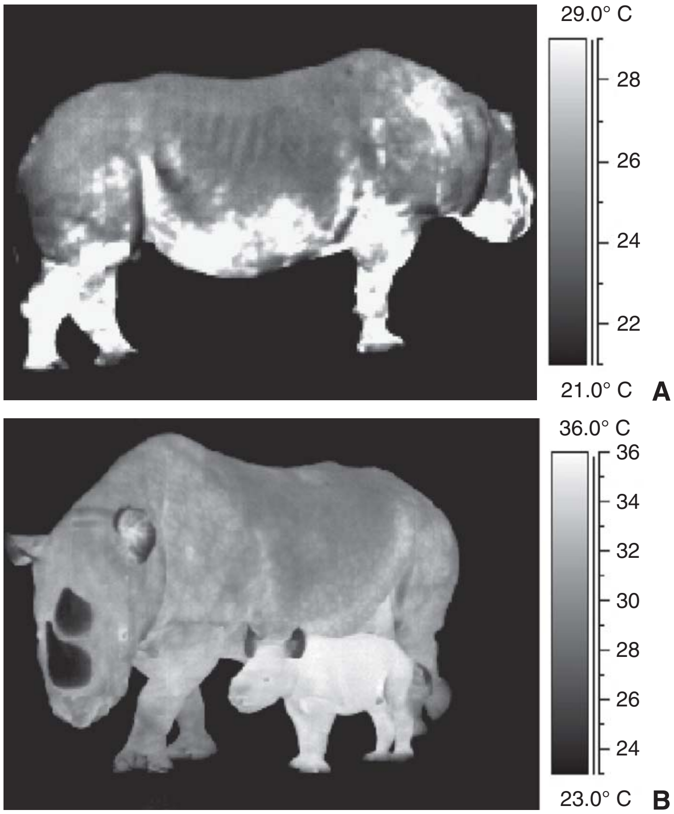

Fig 3-9 **A,** Reproductive evaluation in a black rhinoceros. Late pregnancy with increased heat radiation from the abdomen and legs. **B,** After the calf was born, the increased radiation disappeared in the mother but was shown by the newborn calf.

Diagnosing Inflammation

Heat production in inflammatory processes is one of the cardinal symptoms of inflammation. IR thermography picks up this heat if the process is located close to the body surface. The diagnosis of an inflammatory process in a leg or ear is a good way to gain experience with this method. Figures 3-10 to 13-13 provide some examples.

Elephants

Elephants and giraffes have been major species for the use of IR thermography in inflammation diagnosis. Many problems are only visible using this new technology; even though some animals seem healthy under visual inspection, thermography may reveal a different picture. The following examples should encourage zoo veterinarians to employ this technology for their patients. Zoo animals are not domesticated, and thus they try to hide pain and illness when possible.

In the first case an Asian elephant displayed unsynchronized walking behavior, but no single leg or joint could be identified as the source of the abnormal gait (Figure 3-10). IR thermography revealed the problem to be the right foreleg, specifically the elbow. On the left side, no area of increased radiation could be found in the forelimb.

A major challenge for veterinarians and keepers remains the management of elephants in zoos because of the problems associated with their feet.[2,5,12,20] Studies are ongoing to determine the prevalence of foot conditions in wild elephants.[23] Even though elephant management has greatly improved, *pododermatitis* in elephants is still seen. New approaches to therapy have been presented.[4,19]

In less severe cases of pododermatitis, only one nail shows increased radiation (Figure 3-11). If the therapy is effective, the inflammation will be reduced, and the nail will lose its increased radiation, as monitored by thermography. In more severe cases the whole foot emits increased radiation: the nails, interdigital glands, and the connecting tissues above the nail (Figure 3-12). From this stage the inflammation may quickly move to more proximal parts of the leg. The healing process usually takes years, so continuous,

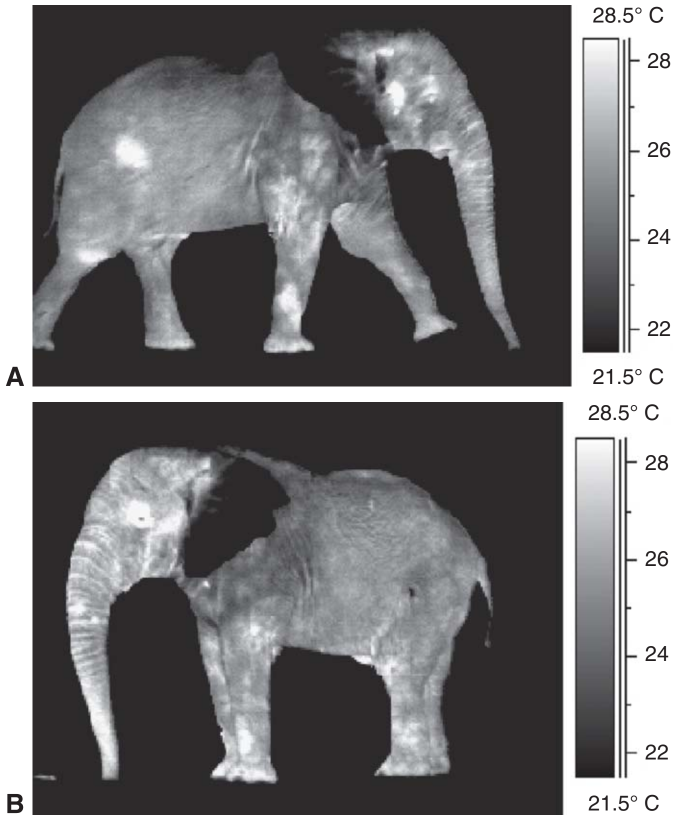

Fig 3-10 **A,** Inflammation in an Asian elephant. After an accident with the outside enclosure, this elephant went lame, but no location was found on normal diagnosis. Infrared thermography revealed that the location was on the right shoulder over the elbow joint. **B,** Left side showed no site of increased radiation.

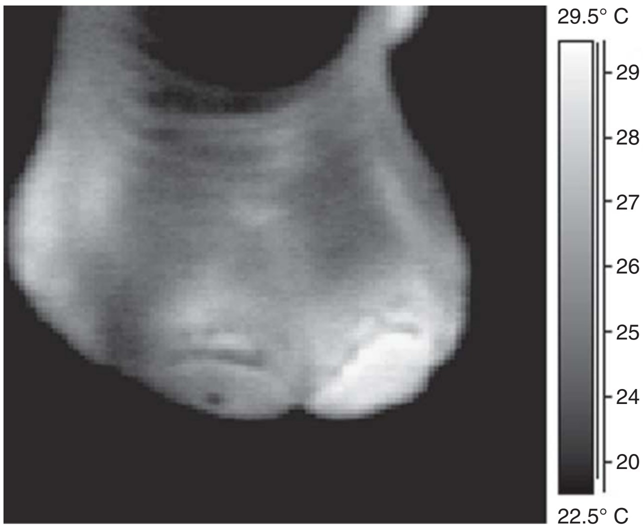

Fig 3-11 Chronic septic pododermatitis in an Asian elephant. The middle toenail in the front foot showed increased heat radiation. (See Color Plate 3-11.)

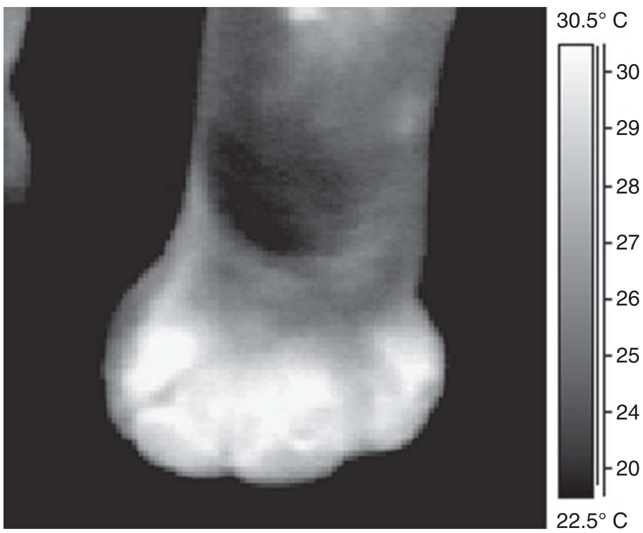

Fig 3-12 Chronic septic pododermatitis in an Asian elephant. The complete phalangeal region of the front foot displayed increased heat radiation.

regular treatment must be undertaken. In the patients, IR thermography helps to monitor the effects of the therapy.[9]

On rare occasions a completely different radiation pattern is found, as when an elephant's nails display greatly reduced radiation (Figure 3-13). This may indicate a severe necrosis of the nail, connective tissues, and even bone material, including osteomalacia and osteolysis. Shortly after finding this radiation pattern, one zoo decided to euthanize the elephant because it no longer used the foot and was therapy resistant. Pathologists found extensive necrosis up to the radius. All bones in the distal phalanges were completely lysed. Therefore, reduced radiation in an elephant's foot is a serious concern, and the foot should be radiographed immediately and the nail surgically explored. In another case the purulent exudates were found after thermography. (For the complete thermographic evaluation of Asian elephant leg and foot health, consult the website www.wildlife-thermography.com.)

Fig 3-13 Nail abscesses in an Asian elephant. This elephant displayed severely reduced radiation in two nails of the right front foot and severe lameness. On opening of the nail base, large quantities of purulent material emerged. Euthanasia was performed after therapy resistance. Postmortem examination revealed lysis of all phalangeal bones in both nails.

Fig 3-14 This Asian elephant showed moderate lameness after a fight. Thermography revealed a bruise above the right carpal joint.

In another example, an Asian elephant group had to fight for a new hierarchy. One female was limping with her right foreleg, but the severity of the injury was unclear. Thermography showed increased heat radiation just above the carpal joint, apparently the result of bruising from the metal stable dividers (Figure 3-14). The animal had been observed sticking her feet through the bars to strike at another animal. Subsequently, the animal was successfully treated locally with antiinflammatory ointments.

Hippopotami

In hippopotami the normal diagnostic technique is altered. The animal should be in the water for at least 1 hour before thermo-diagnosis is performed. To obtain an optimal reading, the thermographer should measure the body surface temperature immediately after the animal emerges from the water. Hippopotami have a thick skin (~4-5 cm) that is penetrated by many fine blood vessels. Past experience has shown many individually placed, facultative thermal windows in this species, which may hide the true inflammatory site. This altered approach yielded the best results to overcome this problem.

As in other species, a thermogram of the healthy individual is the best reference for later diagnoses. The example given here shows a hippopotamus with severe lameness of unknown origin (Figure 3-15). Within 3 minutes of leaving the water and simultaneous thermal imaging, the right carpal joint showed a 3°-C higher temperature than the left side. The animal was

Fig 3-15 Hippopotamus with severe lameness. Infrared-thermography found that the location of the injured area was the right carpal joint. Within 2 minutes out of the pool, the animal displayed an increase in radiation of more than 3° C over the medial side of the right carpal joint. A hairline fracture was presumed after healing and reduction of the heat radiation took almost 2 years.

to be medicated as well as "stall rested" in the pool until the temperature difference was 1° C or less; this took 2 years. A hairline fracture or chip fracture in the carpal joint was suspected. Therefore, continuous surveillance of the animal allowed for informed decisions and constant evaluation of the efficacy of therapy.

Rhinoceroses

Rhinoceroses are usually not in direct contact with their keepers, so diagnosing lameness may be difficult. A black rhinoceros was presented with lameness in the left foreleg. Using the IR camera, however, the area of concern was the tarsus and stifle of the right hind leg (Figure 3-16). The lameness and elevated radiation observed in the front leg were compensatory. No superficial skin changes were visible, and the reason for this inflammation remained unclear. Because the animal was old, it was decided not to anesthetize it for further investigations, but rather try conservative treatment with local antiinflammatory ointments, and the lameness resolved.

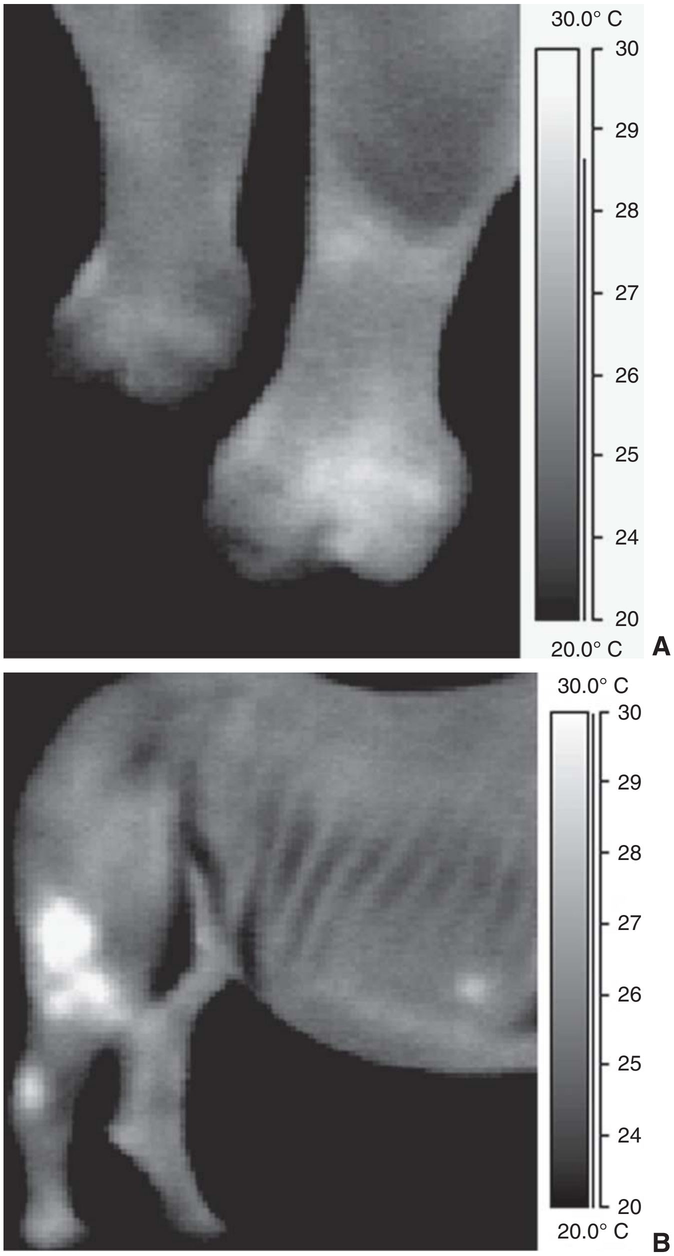

Fig 3-16 Lameness in a black rhinoceros. This animal was presented with lameness of the left front foot. **A,** The foot showed only a slight increase in heat radiation. **B,** The right knee/thigh area, however, showed an intense increase in radiation. A severe thigh bruise was the presumed cause of compensatory lameness in the front foot. (See Color Plate 3-16, *B*.)

Giraffes

In giraffes, hoof alterations are a common problem of animal management. Giraffes are challenging candidates for anesthesia, so they less frequently receive close examinations for leg or hoof problems than other hoofed mammals. With IR thermography, a surveillance program for giraffes may be installed with no risk and may assist in decision making for further procedures. Zoo veterinarians may start such programs by collecting routine thermograms of each individual in the herd. When alterations are visible, the surveillance may be intensified or other diagnostic tools utilized. Figure 3-17 illustrates leg problems in a giraffe observed at Frankfurt Zoo in which IR thermography assisted the evaluation of and surveillance for an inflammatory process.

In captivity, giraffes often develop hoof overgrowth, or alterations of the relative positions of the hoofs to each other. This results from inadequate hoof wear, which can be secondary to enclosure design (e.g., soft material such as loose sand), too little physical activity on hard surfaces, genetic predisposition, or nutritional factors. A recurrent, progressive, therapy-resistant lameness is often the reason for euthanasia of zoo giraffes. Postmortem, animals are diagnosed with arthritis and arthrosis.[9]

As a first measure, a surveillance program was installed at Frankfurt Zoo using thermography. The activity patterns of each member of a giraffe herd *(Giraffa camelopardalis reticulata)* in relation to the enclosure were measured after it was discovered that several individuals showed increased heat radiation, with or without clinical lameness. A slight alteration in the enclosure had reduced the hoof overgrowth during the last few years but did not completely eliminate the problem. Figure 3-17 illustrates a giraffe breeding bull that became lame after pursuing two young bulls and tripping over a rock. On inspection the fetlock showed

A

B

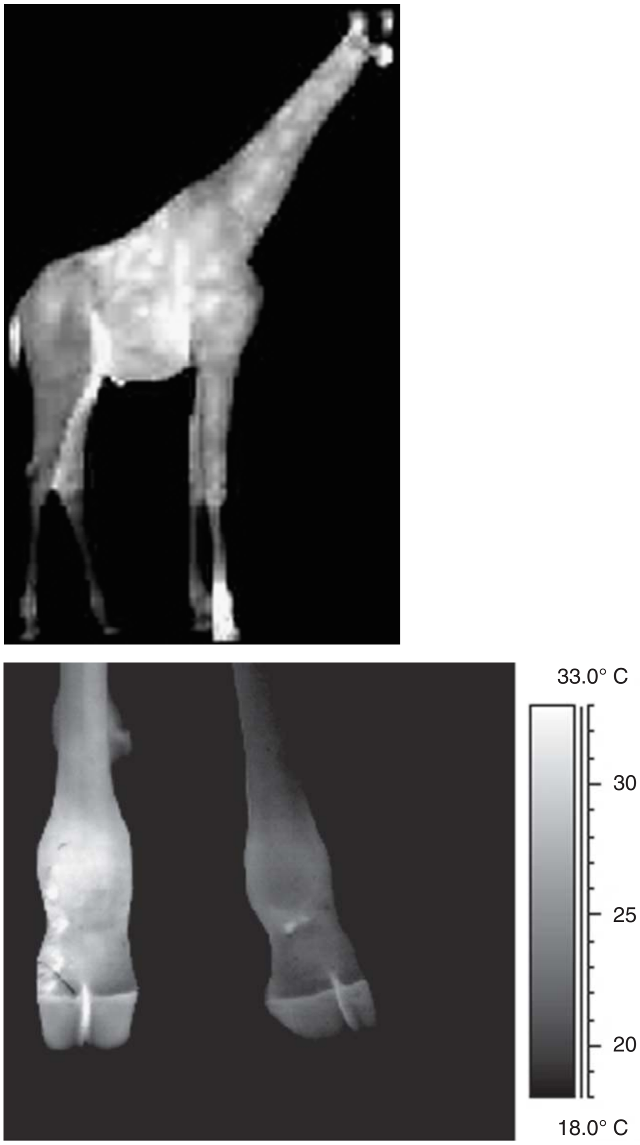

Fig 3-17 **A,** Giraffe bull after an injury to right fetlock. This bull had tripped over a stone in the enclosure and fell on his right side, causing abrasion and swelling on the fetlock. **B,** Only the fetlock and hoof area displayed increased heat radiation.

abrasions in three places; one surrounded a deep skin cut directly over the joint from which blood was seeping. Immediate immobilization of the animal seemed unwarranted because of the local facilities, so a simple external treatment was tried. The animal was sprayed with 20 mL of 3% hydrogen peroxide (H_2O_2) directly on the abrasions. The bull showed intermediate-degree lameness and swelling of the fetlock. IR thermography showed no further increase of heat radiation, and the swelling went down on day 3. In this case, thermography confirmed that other measures, including the risks of immobilization, were not warranted.

Other Animals

The method of IR thermography may be used for inflammatory investigations on other, smaller mammals as well. For example, observations have been made of a southern pudu *(Pudu puda)* with a lameness over a distance of 5 m in its enclosure; a musk deer *(Moschus moschiferus)* with a second hairline fracture next to the primary fracture in the metatarsus observed in the x-ray film; a pygmy hippopotamus (*Hexaprotodon liberiensis,* formerly *Choeropsis liberiensis*) with tenosynovitis; Grevy's zebras *(Equus grevyi)* with various inflamed joints, hooves, or multiple inflammatory processes on the legs, even on wild animals under African conditions[9]; marine mammals with flipper problems; and a dolphin *(Tursiops truncatus)* with an abscess.

In birds, penguins have been the species of most intense use of thermography. In one exhibit a rockhopper penguin *(Eudyptes crestatus)* was observed with severely increased radiation over the right foot. Clinical investigation showed a small, infected wound under the foot.

Descriptions of many other cases can be found elsewhere.[9] The official website (www.wildlife-thermography.com) is being constantly updated to provide a place to share information among zoo veterinarians.

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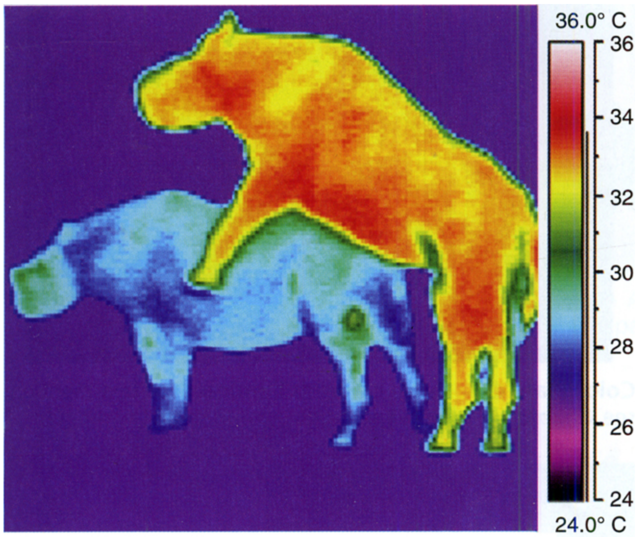
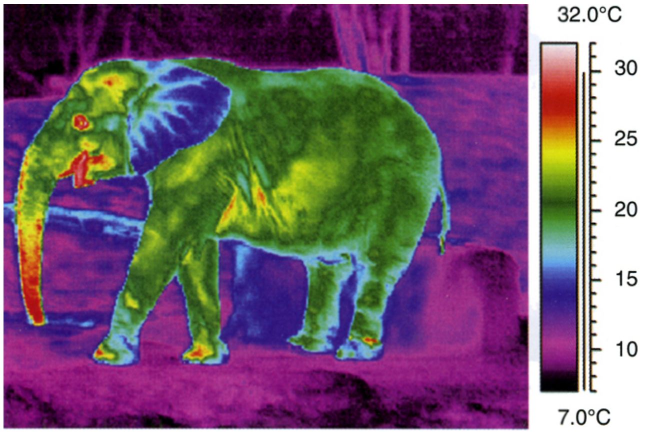
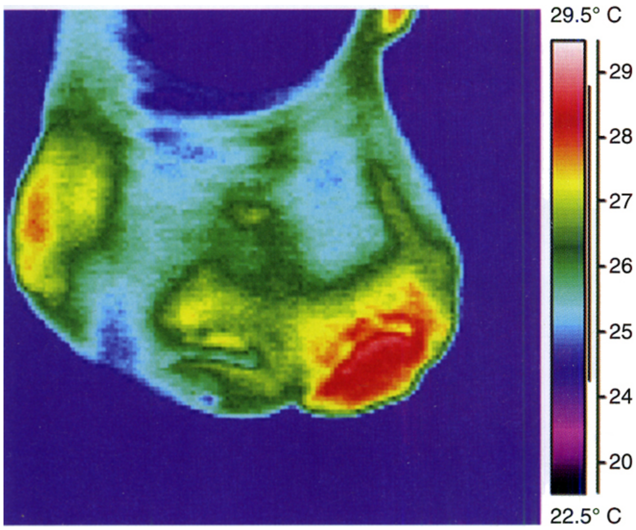


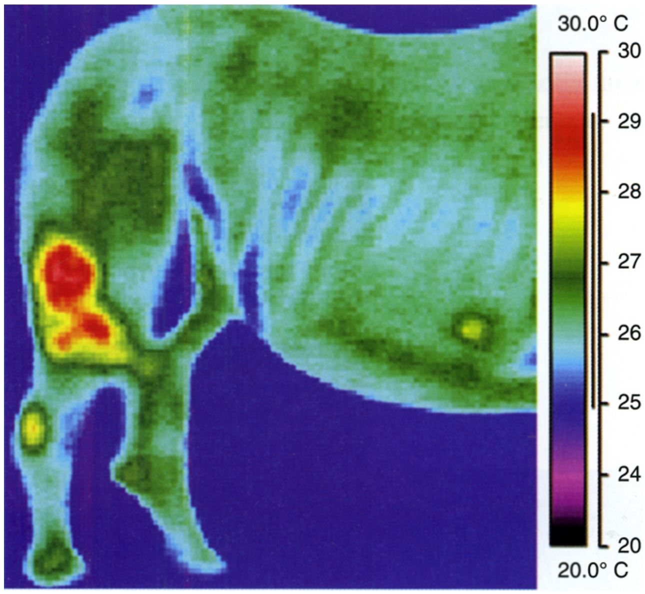
Color Plate 3-3 During mating, male rhinoceroses may be much warmer than female rhinos. (For text mention, see Chapter 3, p. 24.)



Color Plate 3-8 Late pregnancy in an Asian elephant. The abdomen bulged, and heat radiation increased both from that area and from the mammary glands. The heat radiation during late pregnancy was so great that the feet and trunk functioned as facultative thermal windows. In some individuals the feet may show swelling and increased radiation. (For text mention, see Chapter 3, p. 27.)



Color Plate 3-11 Chronic septic pododermatitis in an Asian elephant. The middle toenail in the front foot showed increased heat radiation. (For text mention, see Chapter 3, p. 28.)



Color Plate 3-16, B Lameness in a black rhinoceros. The right knee/thigh area showed an intense increase in radiation. A severe thigh bruise was the presumed cause of compensatory lameness in the front foot. (For text mention, see Chapter 3, p. 30.)