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THE USE OF INFRARED THERMOGRAPHY TO DIAGNOSE EFFECTS OF ELECTRIC SHOCK ON THE BROWN HOWLER MONKEY (*ALOUATTA GUARIBA*)

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Abstract

The brown howler monkey (*Alouatta guariba*) is a platyrrhine primate classified as Vulnerable (VU) due to threats such as habitat loss, fragmentation, hunting and diseases. This species often persists in urbanized environments. Three free-living brown howler monkeys were treated in the veterinary hospital of Sorocaba Zoo, São Paulo state, Brazil after being subject to electrocution from electrical wires. Each individual presented different degrees of severity of electric shock. Here we describe the utility of infrared thermography to evaluate lesions and blood perfusion of tissues in monkeys affected by electric shock. Infrared thermography is a non-invasive and non-radioactive detection method that captures images of a specific body region at a distance. It has the advantage that users can avoid handling or restraint of an animal and, in some cases, it provides early detection of physiological problems. It has been widely used as a tool for examination of free-living wild animals as well as those kept under human care. In this report, infrared thermography was decisive for improving decision-making in the prognosis of the howler monkeys that initially survived electric shock.

Key-words: Electrocution, image, platyrrhine primates, temperature, zoological park

Resumo

O bugio-ruivo (*Alouatta guariba*) é um primata platirrino classificada como Vulnerável (VU) devido à ameaças como a perda e fragmentação de habitat, caça e doenças. Essa espécie frequentemente vive em ambientes urbanizados. Três indivíduos de bugio-ruivo de vida livre foram atendidos no hospital veterinário do Zoológico de Sorocaba, São Paulo, Brasil, após sofrerem eletrocussão por fios elétricos. Cada indivíduo apresentou diferentes graus de severidade do choque elétrico. Neste estudo, descrevemos a utilidade da termografia infravermelha para a avaliação de lesões e da perfusão sanguínea dos tecidos em primatas acometidos por choque elétrico. A termografia infravermelha é um método de detecção não invasivo e não radioativo, capaz de capturar imagens de uma região corporal específica à distância. Apresenta a vantagem de dispensar a contenção ou o manejo direto do animal e, em alguns casos, possibilita a detecção precoce de alterações fisiológicas. Essa técnica tem sido amplamente utilizada como ferramenta de exame em animais silvestres de vida livre, bem como naqueles mantidos sob cuidados humanos. Neste relato, a termografia infravermelha foi decisiva na tomada de decisão prognóstica em bugios que sobreviveram inicialmente à eletrocussão.

Palavras-chave: Eletrocussão, imagem, primatas platirrinos, temperatura, zoológico

Introduction

The brown howler monkey (*Alouatta guariba*) is a platyrrhine primate endemic to the Atlantic Forest, and in Brazil it has a wide distribution, from Espírito Santo to Rio Grande do Sul (Fortes, 2008). It is classified as Vulnerable (VU) on the Official National List of Endangered Fauna Species of the Brazilian Institute of the Environment and Renewable Resources (IBAMA) and the International Union for Conservation of Nature (IUCN) due to threats such as habitat loss, fragmentation, hunting and disease (Jerusalinsky et al., 2021; Brasil, 2022). After major outbreaks of yellow fever that occurred in Brazil during 2007–2009 and 2016–2018, this species had a great population decline; it has been classified as one of the world's 25 most endangered primates (Mittermeier et al., 2022).

Platyrrhine primates have morphological and functional adaptations to arboreal life. Some of these characteristics include great skill with the hands and feet, greater rotational movement in the arms, and in some species, a prehensile tail (Verona and Pissinatti, 2014). Forest fragmentation affects biodiversity as it modifies the distribution patterns of forest space and reduces areas of

continuous forest to smaller isolated fragments (Maués and Oliveira, 2010). Arboreal species are more vulnerable to the effects of fragmentation in places where there is no canopy connectivity, as in many species and populations arboreal animals avoid descending to the ground and moving through an open area. Arboreal species that do tolerate descending to the ground to move through open areas are susceptible to being run over by cars or killed by terrestrial predators (Weston, 2003; Monticelli and Morais, 2015).

Electrocution is an additional risk that primate species are exposed to when living in forest fragments in proximity to urban areas. Electric shocks are caused by exposed wiring and transmission lines on poles (Petrucci et al., 2009; Souza et al., 2018). Anthropized areas and forest edges where the vegetation comes into contact with electrical wiring are the main sites of electrocution. When primate groups are moving along the boundaries between vegetation and urban environments, they often make use of the electrical wires to travel (Monticelli and Morais, 2015).

Electric shock occurs when an electric current passes through the body, causing a rapid stimulus (Fundacentro, 2005). When the electric current contacts the body it may cause several types of tissue damage and organic imbalances. The vast majority of animals die after electric shock. Survivors, may present sequelae such as burns, neurological deficiencies, and circulatory issues (Botelho, 2017).

Infrared thermography (IRT) is a noninvasive and nonradioactive detection method that captures images of a specific body region at a distance. It is able to analyze physiological and pathological conditions related to skin temperature control (Hilsberg-Merz, 2008). IRT detects the infrared light that the body emits and shows changes in body temperature related to blood flow alterations (Corte and Hernandez, 2016). It has the advantage that caretakers can avoid handling or restraining an animal and, in some cases, it can detect physiological problems relatively early (Mikail, 2010). It has been widely used as a diagnostic healthcare tool for both free-living wild animals and those kept under human care (Costa et al., 2020; Mota-Rojas, 2022).

The aim of this study was to evaluate how well infrared thermography could help in the diagnosis of physiological problems, management of treatment, and prognosis in three cases of free-living howler monkeys that had undergone electrocution in an urban environment and were treated at the Sorocaba Zoo.

Materials and methods

Study site

The Sorocaba Zoo, in São Paulo state, Brazil, is located in a secondary forest area of 128,339 m² (Figure 1A). This area is inhabited by brown howler monkeys (Prefeitura de Sorocaba, 2023). The howlers are often in direct contact with urban life and sometimes electricity cables (Figure 1B).

Electrocution

We evaluated three cases of electric shock in free-living *Alouatta guariba* referred to the veterinary hospital of Sorocaba Zoo. Each individual presented a different degree of severity, assessed based on their state of consciousness, and the extent and depth of the lesions. After prompt care

Figure 1. A) Satellite image of Sorocaba Zoo area, São Paulo state, Brazil. **B)** Free-living brown howler monkey walking along a non-energized electric cable in an urban area adjacent to the forested Sorocaba Zoo.

and clinic stabilization, the animals were photographed using an infrared thermography device as an aid in determining treatment and prognosis.

For infrared thermographic image capture, we used a Forward-Looking InfraRed (FLIR)® device, model T420, with thermal sensitivity of 0.04ºC and fourth generation detector with 76,800 pixels (320 x 480 pixels). We used the "rainbow" color pattern, with multicolored images, in which the shades of blue indicate that the temperature is low, while colors in warmer tones, ranging from white to red, indicate higher temperatures. The average temperature for each color varies according to the range of temperatures detected in each image.

Results

Case studies of treatment after electrocution

Case 1: Adult male with moderate electric shock severity

A 5.7 kg adult male *Alouatta guariba* was referred to Sorocaba Zoo presenting lack of coordination, absence of reflexes and poor response to stimuli. During physical examination, we observed mild burns in the fur and abrasions on the limbs and on the face, the latter suggestive of head trauma. The initial treatment performed included oxygen therapy, Meloxicam (0.2mg/kg, intramuscularly, once daily), Mannitol 20% (2g/kg, intravenously, once daily), Tramadol (2mg/kg, intramuscularly, twice daily), and NaCl 0.9% (60m, subcutaneously, once daily), during three days.

After the animal was stabilized, IRT was used to evaluate the temperature of different affected body regions. The right hand presented an average of 37.5°C (max 40.8 and min 29.9°C) while the left hand had an average temperature of 36.3°C (max 39.8 and min 32.6°C). The right foot had an average temperature of 37.9°C (max 40.1 and min 36.3°C) and the average left foot temperature was 37.5°C (max 40.0 and min 35.1°C) (Figure 2A).

On the fourth day, the clinical signs improved. The animal was alert and responsive, his reflexes and coordination had also improved, and he was able to drink and eat by himself.

IRT now showed the right hand with an average temperature of 36°C (max 39.3 and min 28.2°C), the left hand with 36.7°C (max 40.5 and min 27.2°C), the right foot 37.5°C (max 39.3 and min 34.5°C) and the left foot 37.4°C (max 39.4 and min 34.2°C) (Figure 2B).

After the three-day treatment, the animal presented normal behaviors for the species. He fed and drank normally and did not present any new lesions on the body. He was discharged from the veterinary hospital and monitored for another five days until he was released back into his natural environment.

Case 2: Adult male with extreme electric shock severity

A 6.4 kg adult male presented an absence of reflexes and no response to stimuli. During physical examination, burns were observed all over the animal's fur. There were abrasions on the limbs and face, blood inside the oral cavity with a wound on the tongue. The exam suggested that traumatic brain injury had occurred.

First aid included airway clearance and oxygen therapy. Meloxicam 0.2mg/kg IM, Mannitol 20% 2g/kg IV, Tramadol 2mg/kg IM and NaCl 0.9% 60ml SC were given. After animal stabilization, IRT indicated a maximum body temperature of 42.0°C in the abdominal region and low temperatures in the extremities. The right hand had an average temperature of 29.9°C (max 33.9 and min 27.2°C), the left hand 25.2°C (max 32.3 and min 21.0°C),

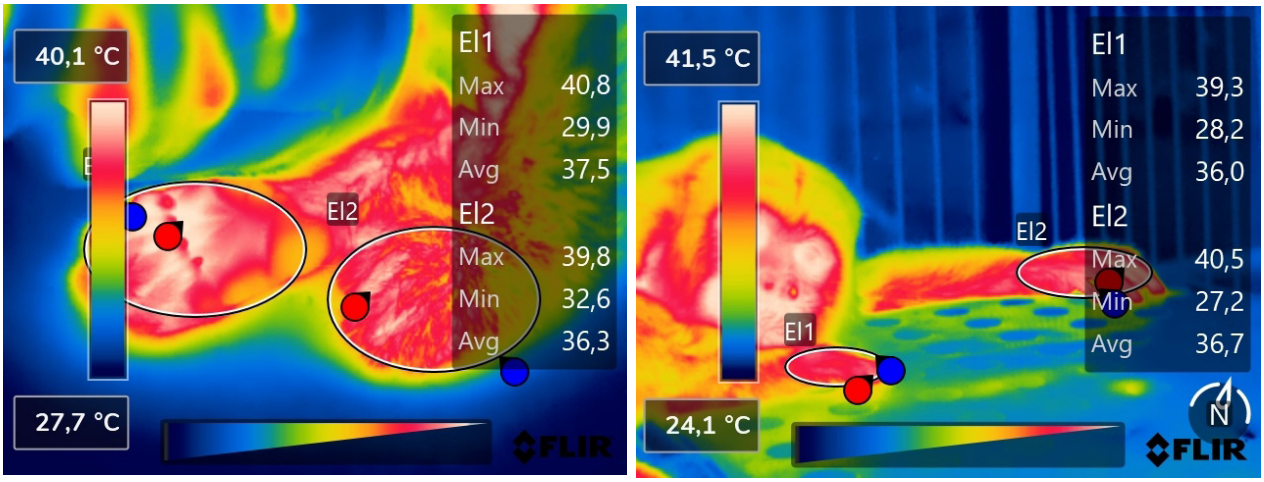

Figure 2. A) IRT of both hands of adult male *Alouatta guariba* (Case 1) on the day of admission. **B)** IRT at the next day, showing the same average temperature for the hands as on the admission day.

the right foot 30.0°C (max 31.9 and min 27.1°C) and the left foot, 29.0°C (max 31.2 and min 25.7°C) (Figure 3A).

The animal's clinical condition progressed very poorly the next day. He was apathetic and did not ingest food or water. Generalized edema and several new skin lesions appeared throughout the body. IRT showed maximum body temperature of 41.0°C and even lower temperatures in the extremities. The right hand had an average temperature of 23.8°C (max 25.5 and min 21.3°C), the right foot 31.6°C (max 33.8 and min 27.4°C) and left foot 25.3°C (max 27.0 and min 23.5°C) (Figure 3B). As the animal was in acute pain and IRT images showed limb ischemia, the prognosis was poor and to prioritize the animal's welfare, he was euthanised.

Case 3: Another adult male with extreme electric shock severity

An adult male weighing 6.1 kg was in a stupor, non-responsive to environmental stimuli and, at the same time, vocalized excessively and showed dyspnea (shortness of breath). He was promptly anesthetized for accurate evaluation and analgesia. The physical examination revealed lesions on the face, hind limbs and tail, and that the fur was burnt over his entire body. IRT showed maximum body temperature of 40.6°C and lower temperatures in the extremities. The right hand had an average temperature of 34.6°C (max 39.8°C on the arm and min 28.1°C on the fingers) and the left hand 33.8°C (max 39.6°C on the arm and min 21.3°on the fingers) (Figure 4).

The IRT revealed a large temperature difference between the limbs and the body, reaching up to 19.3°C difference between the hand and fingers; this pointed to ischemia, possibly resulting in necrosis. Due to the clinical presentation of acute pain associated with the images showing limb ischemia, the prognosis was poor and the animal was euthanized.

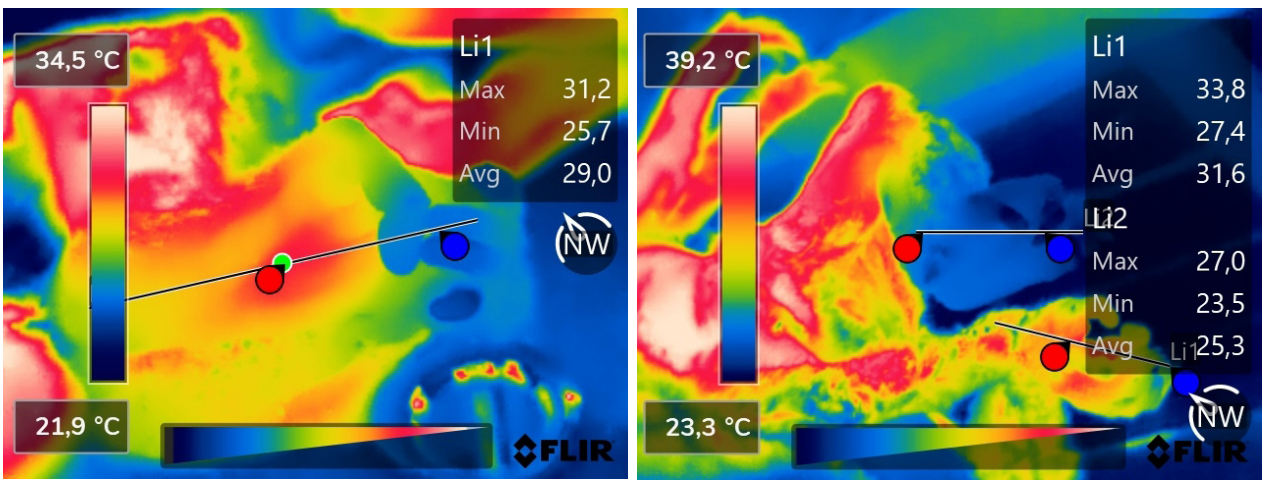

Figure 3. A) Left foot of adult male *Alouatta guariba* (Case 2) presenting an average temperature of 29.0°C on the admission day. B) Left foot showing an average temperature of 25.3° the following day.

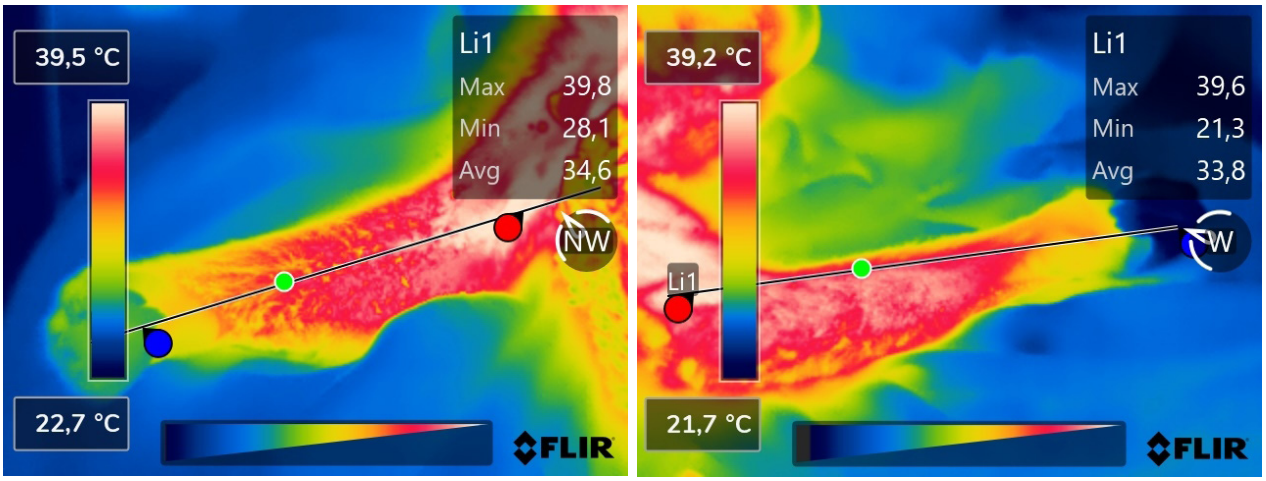

Figure 4. Right hand (A) and left hand (B) of adult male *Alouatta guariba* (Case 3). The IRT shows less heat radiation on the fingers than on the arms.

Discussion

Electric shock is reported in the literature for at least 31 species of primates (Cunneyworth and Slade, 2021). Electrocution in howler monkeys in areas close to urban developments has been reported in Porto Alegre, RS, Brazil (Lokschin et al., 2007). Media and conservation organizations describe additional species that have been injured or killed by the electrical infrastructure, though they remain undescribed in the scientific literature (Cunneyworth and Slade, 2021).

The injury severity caused by electrical energy depends on factors such as: voltage, intensity and frequency of the electric current, duration of contact, path taken by the electric current in the body and the structure and resistance of the tissues (Lee, 1997; Botelho, 2017). Injuries may vary from no visible marks to first to fourth degree burns or even completely carbonized tissues. These lesions may develop at any time after the accident, even after several weeks. This occurs due to the strong electricity conductivity of blood, so current tends to flow along the blood vessels, causing damage to endothelial cells and myocytes, resulting in thrombosis and ischemia (Schulze et al., 2016).

In addition, the flow disturbs physiologic electric processes of the body, including brain and heart activity, leading to respiratory and cardiac complications, organ damage and systemic infections (Schulze et al., 2016). Most of the power lines in Brazil are aerial and when the howlers suffer an electric shock, their fall results in secondary trauma (Kumar and Kumar, 2015). In this study, head trauma was observed in all the three of the treated animals. The reduced tissue temperature caused by thrombosis and ischemia can be visualized by IRT. As such, the use of this equipment in these cases not only allowed the detection of visually inapparent lesions but was also decisive in determining the prognosis and choosing the course of treatment in severe cases (Melero et al., 2013).

In Case 1, the average body and limb temperature oscillated little, showing normal temperatures both at admission and the following day. No lesions appeared in the following days. The animal fully recovered and was released back into his natural habitat. In cases 2 and 3, the howlers showed no apparent skin injury on the body or limbs on the day of admission. However, infrared thermography showed low temperatures on the limb's extremities reaching up to 17.2°C degrees difference in Case 2 and 19.9°C in Case 3, suggesting necrosis of those areas. In both cases, thermography was decisive for making the prognosis and choosing the option of euthanasia.

Previous reports state that for birds that have suffered electrocution, thermography can assist in predicting tissue damage and in guiding rehabilitation efforts (Melero et al., 2013). In thermography, the injured tissues appeared cooler than their corresponding healthy ones, and the thermal pattern was altered (Melero et al., 2013). Thermal symmetry and thermal distribution are more important parameters than absolute temperature, as also observed in the primates in this study.

Conclusion

Electric shock caused by electrical wiring can be very damaging to howler monkeys and other primates, causing serious injuries and potential death. The use of infrared thermography in this study proved to be useful in the identification of lesions caused by electrocution. It allowed veterinarians to access non-visible lesions, as well to determine their degree of severity, helping to direct the treatment and clinical prognosis of the animals.

Conflict of interest

The authors have no conflict of interests related to this manuscript.

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