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Case Report

Wildfire-related lesions in a free-ranging Paraguayan Hairy Dwarf Porcupine (*Coendou spinosus*) in Brazil

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Abstract
The impacts of wildfire smoke on the health and behavior of wildlife are largely unknown and a few studies have explicitly considered the impact of wildfire smoke inhalation on the health of wildlife. Veterinarians should be aware of how animals behave during forest fires and the lesions are most common in different groups of animals. We describe here the injuries found in a porcupine that was a victim of wildfire, in a State Park, after a balloon crash. Despite the care provided, the animal died. At necropsy, it showed singed fur, erythema on the skin, swollen lungs, and congestion in the kidney. Microscopic examination revealed pulmonary edema, carbon pigmentation in the alveoli, liver degeneration, acute tubular injury in the kidney, and cardiac hemorrhage. The cardiorespiratory lesions were the most significant finding and were associated with the cause of death. These findings are a warning sign, since rescue veterinarians are often concerned primarily with providing support for burns visible on physical examination, neglecting cardiorespiratory function and metabolic changes that may be present. Necropsy of an animal killed by a forest fire should always be encouraged, as it can help clarify the events that occurred, allows comparative pathology and develop intensive care protocols, reducing the loss of life.

Keywords: burns, conservation, pathology, intensive care.

Introduction

Intensification of wildfire driven by climate and land-use change threatens the existence of forests (4) and more than 4400 vertebrate species (19, 31). In Brazil, every year, between June and November, there is an increase in the number of hotspots recorded by the National Institute for Space Research (INPE) and forest fires and burnings have been increasing, as have deforestation indicators (3). Causes of wildfires are commonly grouped into categories, including lightning, arson, clearing fires, forestry operations, smokers, recreational fires, and railroads (26). The most frequent causes of this type of fire are those of anthropogenic origin (22), and arsonists are commonly recorded as the main in conservation units (26).

The impacts of wildfire smoke inhalation on the health and behavior of wildlife are largely unknown (11), and a few studies have explicitly considered the impact of wildfire smoke on the health of wildlife (25). Healthcare professionals need to better understand the health impacts of a warming planet (12). Veterinarians should be aware of how animals behave during forest fires and what thermal lesions are most common in different groups of animals. This information could be essential to provide a faster and more efficient response to this catastrophe. Even though forest

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fire is a common and recurrent problem worldwide, it is often neglected, especially regarding wildlife (10). To inform the study and conservation of wildlife in a rapidly warming world, it is imperative that we expand our knowledge of wildfire smoke impacts on wildlife (25). Fire victims should always be necropsied, and detailed information from the scene may be extremely helpful for the interpretation of findings (32).

Coendou spinosus is a mammal that occurs in Brazilian territory, belonging to the Order Rodentia, family Erethizontidae (23). The most common name for *C. spinosus* is "Paraguayan Hairy Dwarf Porcupine" (30). These animals are arboreal herbivores (6, 7), found mainly in forest environments (20) and close to human communities (24). With crepuscular and nocturnal habits, porcupines search for food in the tree canopy (17), and rest during the day in the treetops. They are extremely elusive and move slowly when on the ground (2). Their lethargic habits make them susceptible to hunting, being run over (15), predation (8) and greatly limit the porcupine's ability to escape during large fires in forest fragments or reserves (8), making fires also a threat factor. Recent studies have observed a significant increase in the number of road accidents on stretches of road near or within burned areas, and porcupines are common victims (16). According to the IUCN Red List, *Coendou spinosus* is classified as "least concern" in terms of extinction risk (24). However, Wildlife Rehabilitation Center of the municipality of São Paulo reported a growing increase in the number of porcupines received in the years 2007 to 2022, and the causes include the expansion of deforestation and the fragmentation and reduction of natural habitats, which can bring significant impacts to the population in the long term (34).

Studies in veterinary burn victims are warranted and serve as a translational research opportunity for uncovering novel disease mechanisms and therapies (27). Since these cases do not occur frequently in diagnostic pathology, they represent a challenging task in general but also concerning forensic or criminal aspects (32). This study aimed to describe the lesions in a porcupine that was the victim of wildfire.

The activity of access to Genetic Heritage was registered in SisGen, in compliance with the provisions of Law No. 13,123/2015 and its regulations (registration number: A429CFC). This work has authorization for collection and laboratory analysis of biological materials from the following institutions: SISBIO (nº 79891-2); Ethic Committee on Animal Use of the School of Veterinary Medicine and Animal Science (University of São Paulo) (CEUA/FMVZ) (nº 1221260122-ID 009657) and Technical Committee for Scientific Assessment of the Secretariat for Green and the Environment of the City of São Paulo (nº 6027.2021/0012190-2).

Case description

In August 2021, a wildfire occurred in Juquery State Park (Latitude -23.3326; Longitude: -46.68655), a Full Protection Conservation Unit (UC), located in the municipalities of Caieiras and Franco da Rocha, metropolitan region of São Paulo, SP, Brazil. Date of this fire's occurrence coincides with religious or social celebrations, when the release of balloons is common, especially during the São João festival period, in June and July, which coincides with the dry season in the Center-Western Brazil (22).

The fire started on Sunday morning (the 22nd), after a balloon crashed; it lasted 4 days and consumed around 53% of the vegetation in the conservation unit, which is Cerrado and Atlantic Forest, totaling 1,175 hectares of area, which represented just over half of the park (Fig. 1) (28). Fire was extinguished through direct combat. Twenty-five animals were rescued by volunteer veterinarians (9), including a cub albino porcupine that was rehabilitated (5). Of the animals rescued, at least 14 died (9), including the porcupine in this report. It was the first report of macro or microscopic pathological changes in porcupines victimized by fires, in the authors' knowledge.

On August 23, 2021, the day after the fire started, a male adult Paraguayan Hairy Dwarf Porcupine (*Coendou spinosus*) rescued from the fire was admitted to the Wildlife Management and Conservation Center, Wildlife Division, Green and Environment Secretariat (23°25'17.3"S 46°47'13.4"W), a triage center of wildlife in São Paulo, Brazil. There is no information about the conditions at the time the animal was found and captured. The animal was clinically examined under physical restraint, and it was unresponsive, unconscious, had a good nutritional status (1.430 kg), pale mucous membranes, moderate dehydration and a slight presence of ticks (identified as a nymph and an adult male of *Amblyomma longirostre*) and lice (unidentified). The animal presented multifocal areas of singed hair throughout the body, with no additional macroscopic evidence of skin lesions besides a superficial erythema. There was a slight erythema around the nostrils. It was very dyspneic and alternated with moments of apnea. Fluid therapy, medication with tramadol and oxygen therapy were administered. Despite care and attempts at stabilization, the porcupine died a few hours after admission.

At necropsy, the animal's biometrics yielded the total length - 59 cm; tail length: 23 cm; right foot length: 6.5 cm, an adult male. The hairs modified into spines were singed, twisted in the distal region and with a brownish coloration, some of them broken at the ends (Fig. 2A,B). The undercoat was twisted and singed diffusely throughout the dorsal region. The same changes were observed in the guard hairs of the snout (Fig. 2C). The skin of these regions showed slight erythema. Hairs on the ventral surface and tail showed no changes. Upon cut, there was approximately 20 mL of serous fluid in the abdominal cavity. Discrete food content was observed in the stomach. Lungs were reddish, with a turgid consistency, draining foam upon cut (Fig. 2E,F). Kidneys showed congestion in the medullary region (Figure 2F). Dimensions of the heart was 3.7 x 3.0 cm. Spleen measured 3.0 x 1.5 cm. There were no gross lesions in the other organs.

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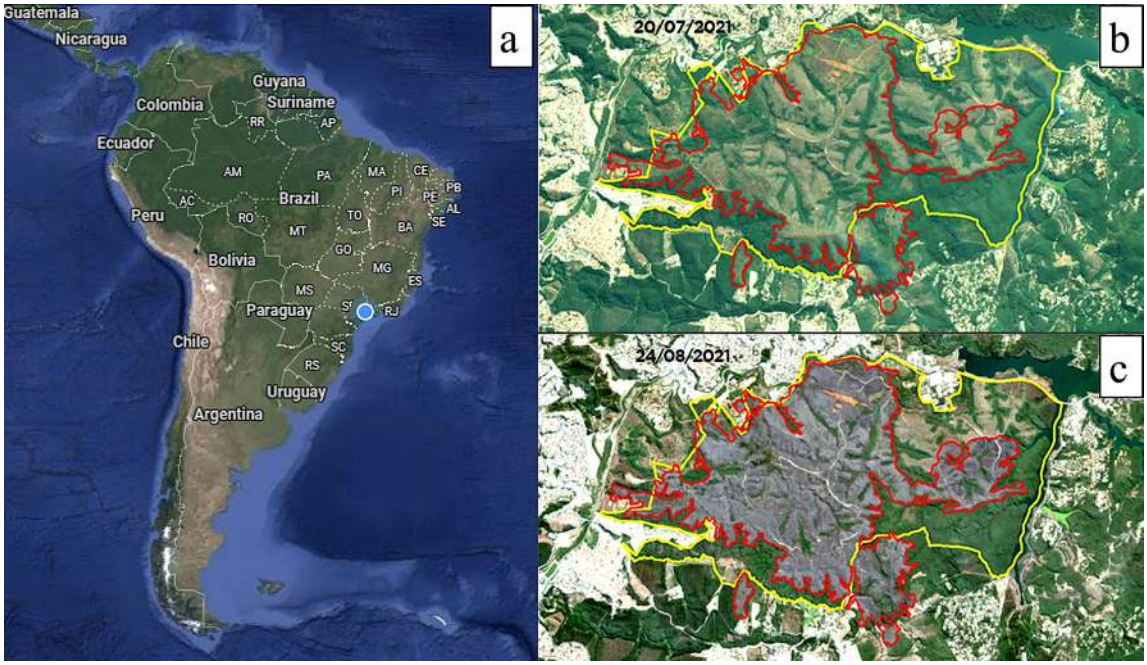

Figure 1. Juquery State Park location (A), next to São Paulo city. Satellite images show the Juquery Park fire, in Franco da Rocha. Comparative data were obtained on July 20, before the fire (B), and August 24, after the fire ended (C). The yellow line represents the total area of the park and the red line represents the area affected by the fire, consumed 53% of the area of the Conservation Unit (Biodiversity and Inspection Monitoring Center, linked to the Environment Secretariat of the state of São Paulo, 2024).

Tissue fragments were collected, fixed in 10% formalin and processed to obtain histological sections stained with hematoxylin-eosin. Trachea had a mild quantity of red blood cells in the lumen and epithelium with a slightly vacuolated appearance. Microscopic examination of the lungs revealed marked acute pulmonary edema (Fig. 3A). There was diffuse black to dark brown carbon pigment deposition in several macrophages in the alveoli and bronchi, with particles also in the alveoli lumen. There were also carbon particles in some alveoli, mild hemorrhage, and marked congestion, with vascular dilation. Many mast cells were present in the interstitial, peri bronchial, and perivascular spaces (up to 6/high power field) (Fig. 3B). There was mild focal dilation of the pleura and multifocal areas of emphysema. The pulmonary condition was characterized by marked acute pulmonary edema and emphysema.

In the liver, there was discrete, microgoticular vacuolar degeneration, in zones 1 and 2, and an increased volume of hepatocytes (Fig. 3C). There was individual necrosis of hepatocytes (Fig. 3D), with some moderate apoptosis figures. Binucleation figures were common in hepatocytes. In the kidney fragment, there was degeneration and protein casts in glomeruli and tubules and tubular necrosis in the cortex, indicating acute tubular injury (Fig. 3E,F). In the heart, discrete, multifocal areas of hemorrhage and necrosis were observed. Skin fragments were not sampled for microscopic analysis due to absence of gross skin lesions. No significant histological changes were observed in the spleen, stomach, urinary bladder, pancreas, testis, or brain. The death was due to cardiorespiratory failure related to acute wildfire smoke inhalation.

Discussion

Although injuries associated with wildfires can be understood from other species, fire-associated injuries have not yet been described in porcupines. Morphological findings in patients who died of acute burning disease or acute smoke inhalation may include lesions particularly in the heart, lung, liver, pancreas, and kidney (32). Burns to the face, eyes, ears, perineum, and feet are considered more severe than those to other body areas because they have the potential of serious disfigurement, loss of function, and severe pain (21). In this case, we found that the skin injuries caused by heat were superficial, but the effects of smoke inhalation had more damaging consequences.

According to the classification of burns proposed in literature (32), this porcupine had a superficial first-degree burn. In these cases, distension and hyperemia of blood vessels are less prominent compared to humans because the superficial dermal vascular plexus is lacking in animals (32), that explains in part the absence of gross skin lesions. First-degree burns are disregarded for the calculation of the affected body surface area unless they exceed 25% (13). To prevent organ fragments from being forgotten during the

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post-mortem examination of fire victims, we recommend systematic tissue collection, regardless of the presence or absence of macroscopic lesions in skin and upper respiratory tract, as recommended by literature (32).

Animals can suffer from carbon monoxide poisoning (mostly fatal), thermal and chemical burns in the respiratory tract (29). Wildfire smoke composition is influenced by the fire area, intensity, and materials burned (12) and animals are

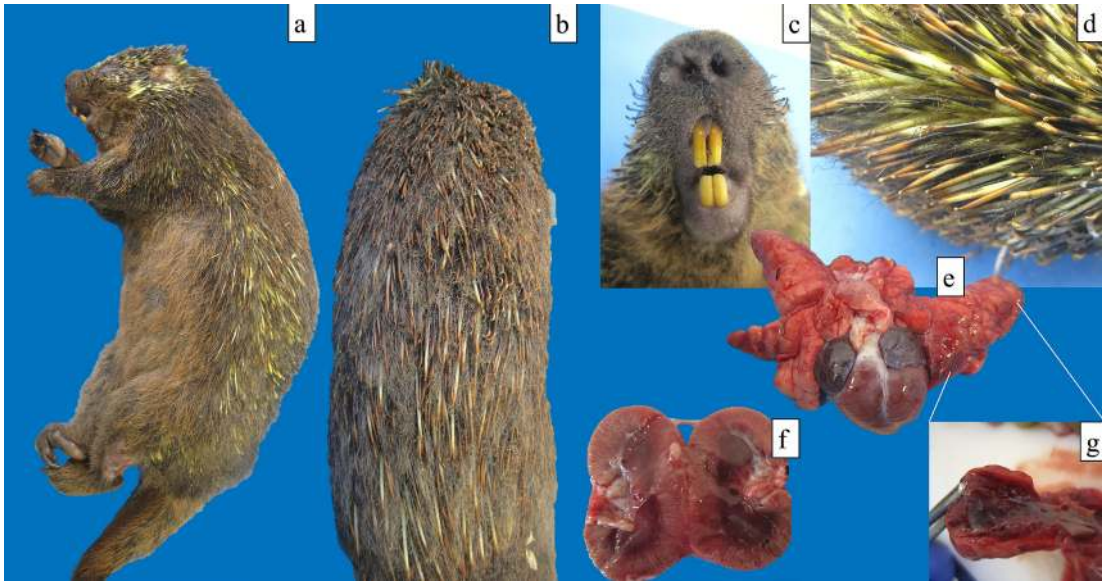

Figure 2. Macroscopic lesion of a male adult Paraguayan Hairy Dwarf Porcupine (*Coendou spinosus*) that was the victim of a fire. Images are not proportionally scaled. A) Lateral body surface with singed hairs. B) Dorsal body surface with singed hairs. C) Region of the nasal plane, showing the singed hairs. D) Hairs modified into spines in the dorsal region, twisted, brownish and broken at the ends. E) Heart and lung; lung with an edematous appearance. F) Kidney, medullary congestion. G) Lung, draining foam when cut.

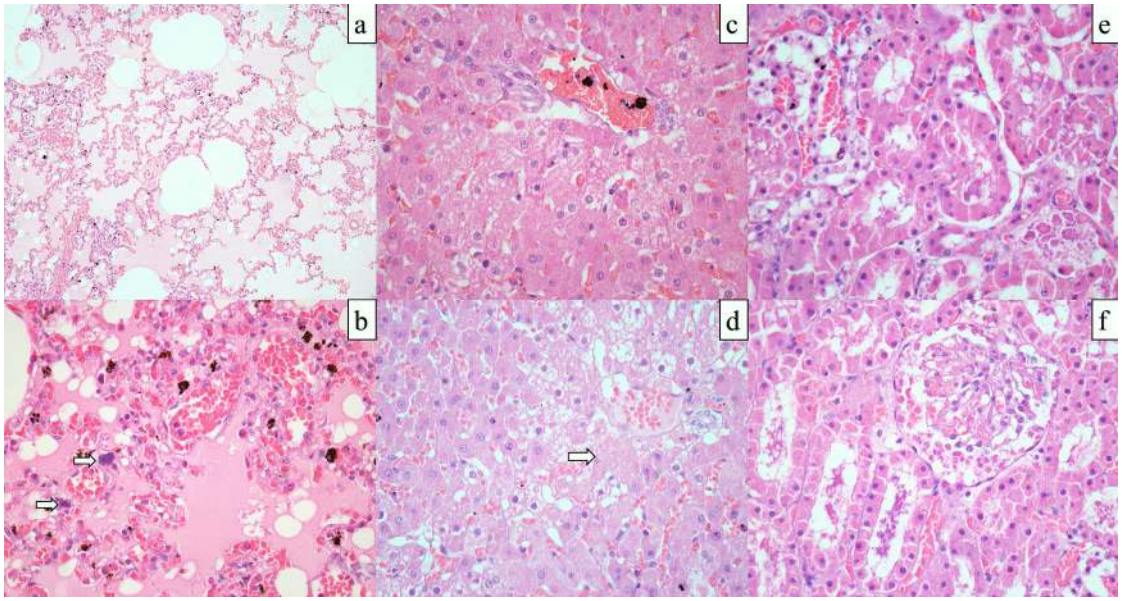

Figure 3. Histopathological examination of a porcupine victimized in a forest fire. A) Lung, acute pulmonary edema and black particulate material in alveoli, HE, 100x. B) Lung, diffuse carbon pigment deposition in several macrophages of alveoli and bronchi; hemorrhage and congestion. Pulmonary edema. Presence of mast cells (arrow), HE, 400x. C) Liver, microgoticular vacuolar degeneration (arrow), closer to zones 1 and 2, and an increased volume of hepatocytes, HE, 400x. D) Liver, individual necrosis of hepatocytes (arrow) and microgoticular vacuolar degeneration, HE, 400x. E) Kidney, degeneration and acute tubular necrosis, HE, 400x. F) Kidney, degeneration and protein loss in tubules and glomeruli, HE, 400x.

vulnerable to the inhalation of airborne toxins in the smoke [e.g., carbon monoxide (CO), hydrogen cyanide (HCN), and delicate particulate matter (PM)]. Many animals die from smoke-induced asphyxiation (18). Noncardiogenic pulmonary edema, which occurs in these cases, is a consequence of primary damage to the alveolar membrane (high permeability edema) and is associated with the inhalation of toxic gases and smoke (19). Inhaled hot particles may also cause thermal injury to deeper airways (32). Microscopic examination of the lungs often reveals the presence of carbon particles (soot) on the mucosal surfaces of the conducting system (33). Lung´s morphological findings in human patients who died of acute burning disease include edema (alveolar, interstitial, intramural vascular), small hemorrhagic infarctions, desquamation of alveolar epithelial cells and capillary thrombi (32). These changes were seen in the present case and were responsible for the death of the animal.

In dogs, early acute kidney injury (AKI) is seen during the initial resuscitation phase after severe burn and it is thought to be due to hypovolemia, increased inflammatory mediators, mechanical tissue destruction, release of denatured proteins, and cardiac dysfunction (1). Substantial fluid loss from the burn wound and fluid shift from the intravascular space to the interstitial space cause hypovolemia and a decrease in cardiac output. This results in a decrease in renal blood flow leading to ischemia and cellular injury and death (1). Kidney's morphological findings in human patients who died of acute burning disease include microthrombi in mesangial capillaries, vacuolar degeneration and necrosis of tubular epithelial cells with tubular dilatation, hyaline casts, red blood cells, and cellular debris and interstitial edema (32). These events have not been studied in porcupines, however our microscopic findings of protein loss in glomeruli and tubules and tubular epithelial degeneration and necrosis, indicating acute tubular injury, are consistent with findings in dogs and humans (1, 32).

The accumulation of intra-abdominal fluid has also been observed in cases of burn injuries in cats (27), as well as in the present case. Cats progressed to congestive heart failure as defined by atrial enlargement with evidence of cavitary effusion (ascites, pleural and/or pericardial effusion) or pulmonary edema (27).

Furthermore, hepatic changes have also been described. Liver´s morphological findings in human patients who died of acute burning include degeneration of hepatocytes, centrolobular necrosis of single/small clusters of hepatocytes and dilatation of sinusoids (32). Here, we diagnosed vacuolar degeneration of hepatocytes in zones 1 and 2, an increase in the volume of hepatocytes, different from what is described for humans, but there was individual hepatocyte necrosis.

This case study found that cardiorespiratory changes were the most significant and responsible for the animal's death. These findings are a warning sign, since rescue veterinarians are often concerned primarily with providing support for burns visible on physical external examination, neglecting cardiorespiratory function and metabolic changes that may be present. Necropsy of an animal killed by a forest fire should always be encouraged, as it can help clarify the events that occurred, allows comparative pathology and develop intensive care protocols, reducing the loss of life.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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