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Retrospective analysis of fractures in crab-eating foxes (*Cerdocyon thous*)

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Abstract

This study assessed axial and appendicular fractures in crab-eating foxes (*Cerdocyon thous*; Linnaeus, 1766) admitted to the Reference Center for Wildlife. Medical records and plain radiographs of *C. thous* were retrospectively evaluated. Seventy-four free-ranging *C. thous* were admitted over 10 years, of which 21 had fractures in the appendicular and/or axial skeleton. Appendicular skeleton fracture was verified in 42.86 % of the animals, five of whom had long bone involvement and four the hip bones. More than one fracture in the appendicular skeleton occurred in 14.28 % of the animals, with the most common being a long bone fracture with a hip fracture. Axial skeleton fractures were observed in 9.52 % of the cases, with one fracture located in the vertebral column and the other in the head. Five animals died and nine were euthanized due to injury severity, prognosis and/or poor outcome after treatment. Seven animals showed good evolution after treatment, and four animals were released. In conclusion, hip bone fractures, isolated or combined with injuries to other bones of the axial and/or appendicular skeleton, were the most common injuries in *C. thous*. The characteristics of multiple trauma were associated with high mortality and complications.

Keywords: Bone; Roadkill; Trauma; Wild; Skeleton.

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Study contribution

Fractures in *Cerdocyon thous* have been under-reported despite the severity of the lesions, which contribute to the high mortality of the species. Understanding the most common fracture types may help in the first aid and can improve the treatment. Thus, the results of this research highlight the importance of the problem and risks to species conservation. The high number of traumatized animals is associated with the degradation of natural habitats and shows that may occur impact the loss of biodiversity.

Introduction

The crab-eating fox (*Cerdocyon thous*) is a medium-sized wild canid (5–7 kg) with opportunistic eating habits and a generalist omnivorous diet.[1–3] The species has wide geographic distribution and is considered endemic in South America.[2] There are records of preference for forest habitats, but the animal is also found in open pastures.[4] Although the *C. thous* is categorized as Least Concern by the International Union for Conservation of Nature (IUCN),[5] the species has been subjected to several threats, including a high rate of road kills, retaliation due to predation and transmission of diseases by domestic animals.[3, 6, 7] These threats are more evident in highly anthropic environments, such as those currently occupied by the species.[8]

More than 475 million wild animals have been estimated to die due to roadkill, of which 90 % are small vertebrates, 9 % are medium-sized animals, and 1 % are large animals.[9] Studies have shown that *C. thous* is one of the most afflicted species in death by being run over on several roads and highways in different regions of Brazil.[10, 11] Despite this high prevalence of animal-vehicle collisions, there are still few studies on fractures in the species, such as necropsy findings of long bone fractures and some reports of specific treatments.[12–14] Thus, this study aimed to retrospectively assess the fractures of the axial and appendicular skeletons in *C. thous* admitted at a Reference Center for Wild Animals to better understand the processes involved.

Materials and methods

Ethical statement

The protocol for this study was approved by the Institutional Ethics Committee on Animal Use (CEUA 0156/2021). Medical records and plain radiographs of crab-eating foxes admitted to the Center for Medicine and Research in Wildlife (CEMPAS) were retrospectively evaluated for 10 years (2013–2022).

Assessment and treatment protocol

All *C. thous* admitted to CEMPAS after obtaining the history are evaluated as follows: distance examination to identify visible injuries; restraint and handling to perform a physical examination, most of the time after dissociative anesthesia; complemen-

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tary exams, including complete blood count and biochemical tests; imaging studies (x-rays, ultrasound); and treatment (conservative or surgical).

Data regarding animal signalment (age classified as puppy, juvenile, or adult, based on body mass and growth plate closure in the radiographic exams sex; body mass), fracture cause, and involvement of one or more bones according to skeleton were assessed. Appendicular skeleton fractures were classified based on previously described,[15] such as involved bones, fracture site, closed or open, complete or incomplete, simple (transverse, oblique, spiral), or multifragmentary (more than two fracture fragments). Axial skeleton fractures were evaluated in terms of site and features. The presence of one or more fractured bones in the same animal, fracture treatment, follow-up and other lesions was also verified.

Results

Seventy-four free-ranging *C. thous* were admitted over 10 years, of which 21 had fractures in the appendicular and/or axial skeleton, representing 28.38 % of the patients. Animals with fractures were individually rescued by environmental police officers, firefighters, and citizens. Most of these fractures were related to road traffic accidents. A total of 61.9 % (n = 13) of the animals were males, and 38.1 % (n = 8) were females. The age distribution was 57.14 % (n = 12) adults, 28.57 % (n = 6) young, and 14.28 % (n = 3) puppies, with mean body masses of 6.09 kg (± 1.09 kg), 2.88 kg (± 1.38 kg), 0.39 kg (± 0.14 kg), respectively.

Appendicular skeleton fracture was verified in 42.86 % (n = 9) of the *C. thous*, five of whom had long bone involvement and four hip bones (Table 1; Figure 1). More than one fracture in the appendicular skeleton occurred in 14.28 % (n = 3) of the animals, with the most common fracture being the long bones with hip bone fracture (Table 2). Axial skeleton fractures were observed in 9.52 % (n = 2) of the cases, one located in the vertebral column and the other in the head (Table 3, Figures 2a and 2b). A total of 33.33 % (n = 7) of the animals had injuries that included both skeletons, most commonly vertebral column injuries with hip bone

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Table 1. *Cerdocyon thous* with single fractures in one location in the appendicular skeleton

	Age	Sex	Body mass (kg)	Cause	Fracture site and classification/Observation	Treatment/Follow-up
1	Puppy	F	0.35	Unknown (found in a sugarcane plantation)	Left humerus (middle third): complete, transverse	Death due to infectious disease (distemper)
2	Juvenile	M	5.5	Unknown	Left radius/ulna (middle third): complete, short oblique (signs of malunion)	External coaptation/ Released back to nature (functional malunion) Fig. 1 (a-d)
3	Juvenile	M	2.64	Unknown	Left femur (distal third): complete transverse Right tibia (proximal third): greenstick (thin cortical bone)	Tibia - external coaptation Femur – intramedullary pin/ malunion Fig. 1 (e-g)
4	Puppy	M	0.58	Unknown	Left tibia (middle third): complete, long oblique Left fibula (middle third): complete, transverse	Euthanasia (clinical signs of brain injury)
5	Adult	M	7.4	Hit by a vehicle	Left femur (middle third): complete, short oblique	Surgery (plate and screws) Euthanasia-inadequate outcome
6	Adult	F	6.5	Unknown	Hip bone: Left: oblique of the ilial body (caudal fragment displaced medially and cranially); pubis (moderate pelvic canal narrowing) Right: pubis; caudal acetabulum (Hip luxation)	Euthanasia (spastic paralysis, fluid in peritoneal cavity)
7	Adult	M	6	Hit by a vehicle	Hip bone: Left: oblique of the ilial body(caudal fragment displaced medially and cranially); pubis; caudal acetabulum (moderate pelvic canal narrowing)	Conservative
8	Adult	M	7	Hit by a vehicle	Hip bone: Left: oblique of the ilial body (caudal fragment displaced medially and cranially); ischial body (slight pelvic canal narrowing)	Conservative/Released back to nature
9	Adult	F	6.13	Hit by a vehicle	Hip bone: Left: oblique of the ilial body (caudal fragment displaced medially and cranially); pubis; caudal acetabulum (radiographic signs of an old fracture)	Death two days after admission

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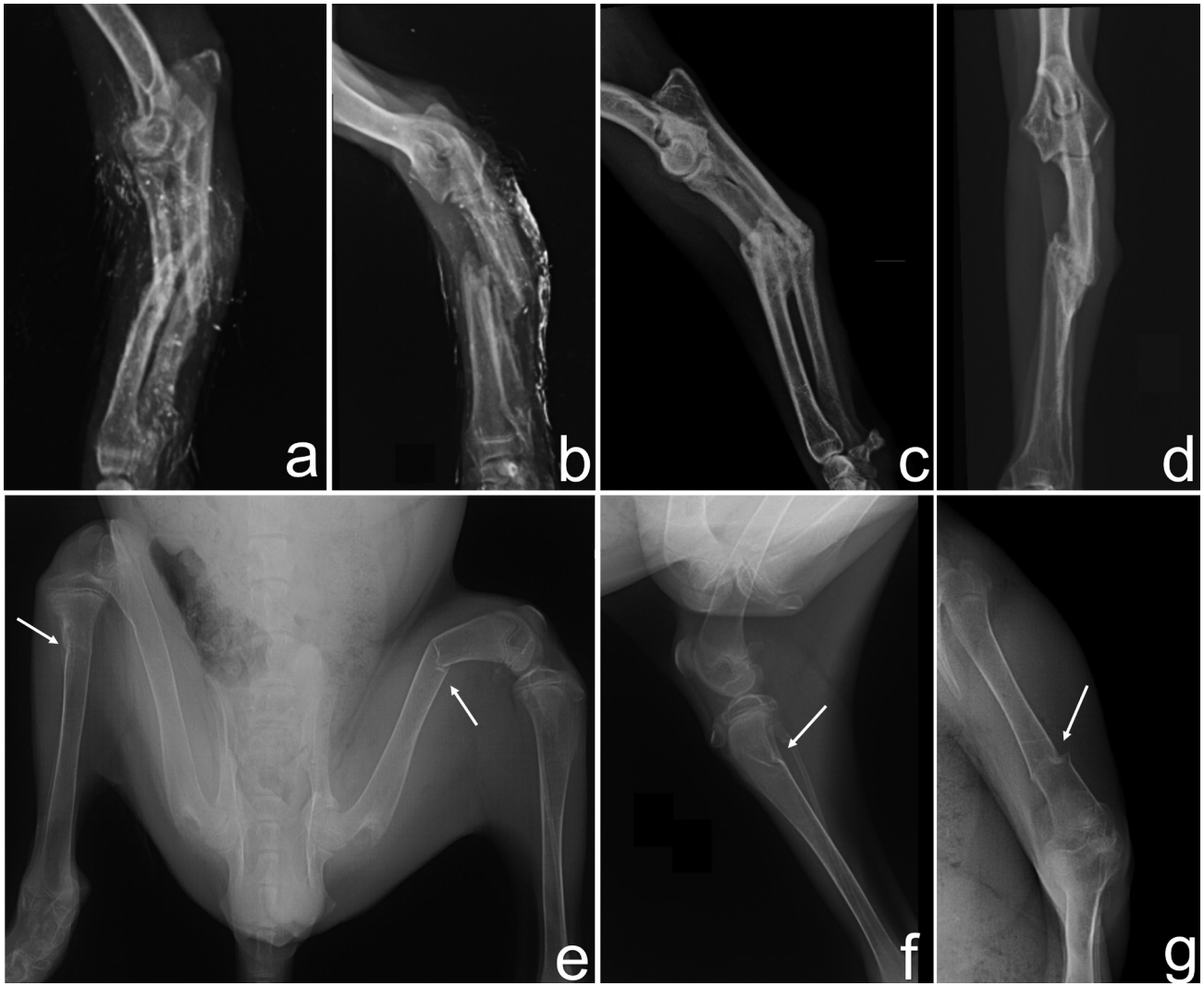

Figure 1. (a-d) Mediolateral and craniocaudal radiographic views of the left radius/ulna of a juvenile (no. 2) *Cerdocyon thous*. Note the short oblique fracture with signs of malunion (a, b), and diaphyseal malunion after external coaptation treatment (c, d). (e-g) Radiographic views of a juvenile *Cerdocyon thous* (no. 3). Observe the thin cortical tissues of the bones, greenstick fracture of the proximal third of the right tibia (e, f), and complete transverse fracture of the distal third of the left femur (e, g).

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Table 2. *Cerdocyon thous* with multiple appendicular fractures

	Age	Sex	Body mass (kg)	Cause	Forelimbs and/or hind limbs bones Fracture site and classification/ Observation	Hip bone Fracture site and classification/ Observation	Treatment/ Follow-up
10	Juvenile	F	1.27	Unknown (found in a sugarcane plantation)	Right humerus: distal physis (Salter-Harris type 2) Right metacarpals II through V (middle third): complete, transverse Right tibia (proximal third): complete, short oblique Right fibula (proximal third): incomplete, transverse	Right: transverse of the ilial body (caudal fragment displaced medially and cranially) Left: oblique of the ilial body; ischium (incomplete)	Death
11	Adult	M	5.6	Hit by a vehicle	Right femur (proximal third): complete, short oblique (open) (Stifle luxation)	Left: pubis; caudal acetabulum Right: pubis (Hip joint luxation)	Euthanasia (severe cachexia)
12	Adult	F	5.87	Hit by a vehicle	Left femur (distal third): multifragmentary Right femur (middle third): complete, short oblique	Right: pubis	Surgery (plate and screws in femur) Euthanasia-inadequate outcome

Table 3. *Cerdocyon thous* with axial fractures

	Age	Sex	Body mass (kg)	Cause	Fracture site and classification	Treatment/Follow-up
13	Adult	F	3.39	Hit by a vehicle	L7 vertebral body: complete (cranio-ventral displacement of the sacrum)	Euthanasia (Fig. 2a)
14	Adult	M	7	Hit by a vehicle	Zygomatic process of the temporal bone: complete	Conservative (Fig. 2b)

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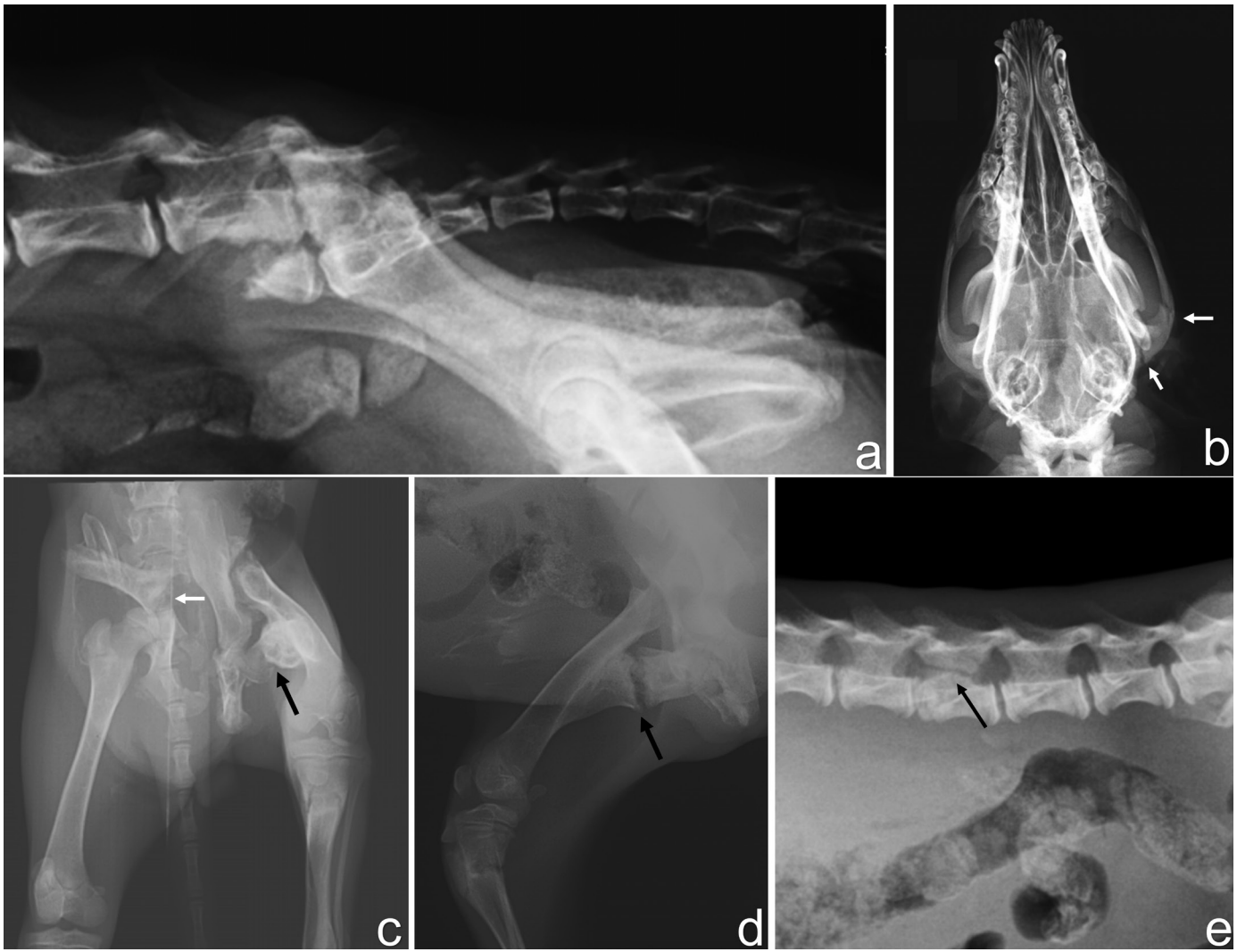

Figure 2. (a-b) Radiographic views of two adults (nos. 13 and 14). Note the fracture of the L7 vertebral body with a cranioventral displacement of the sacrum (no. 13), and fracture of the zygomatic process of the temporal bone (arrows) (no. 14). (c-d) Radiographic views of a juvenile (no. 21). New fractures were observed in the hip bone (white arrow) (c), and L4 (e) (cranial endplate and vertebral arch-black arrow), and old fractures located in the proximal third of the left femur with severe deformity (black arrow) (c, d), left acetabulum (c), and left tibia (c, d).

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Table 4. *Cerdocyon thous* with fractures in both the appendicular and axial skeletons

	Age	Sex	Body mass (kg)	Cause	Vertebral column Fracture site and classification	Fracture site and classification/Observation	Treatment/Follow-up
15	Juvenile	M	2	Hit by a vehicle	L1 – compressive	Left radius (proximal middle third): complete, transverse Right and left distal tibia and fibula: distal physis (Salter-Harris type 1)	Surgery (cross pins-tibia) Released back to nature
16	Adult	M	7	Hit by a vehicle	S3–Cd1 luxation/ fracture	Hip bone Left: oblique of the ilial body (fragment displaced medially and cranially); pubis; ischium Right: pubis and sacroiliac luxation (severe pelvic canal narrowing) (Right stifle luxation)	Death
17	Adult	F	4.65	Hit by a vehicle	S3 - complete	Hip bone Right: pubis; caudal acetabulum Left: pubis; ischium (moderate pelvic canal narrowing)	Death (pregnancy)
18	Adult	F	6.65	Hit by a vehicle	Left sacral wing – complete	Hip bone Right: pubis, ischium	Conservative/ Released back to nature
19	Juvenile	M	3.69	Unknown (found in a sewer)	Right sacral wing – complete	Hip bone Right: transverse of the ilial body (sacroiliac luxation); central acetabulum Left: transverse of the ilial body (sacroiliac luxation) (severe pelvic canal narrowing; pelvic symphysis separation)	Surgery (plate and screws in ilium). Euthanasia-inadequate outcome
20	Puppy	M	0.25	Hit by a vehicle	Left sacral wing – complete	Right femur (proximal): complete of the femoral neck Hip bone Left: central acetabulum (sacroiliac luxation) (severe pelvic canal narrowing)	Euthanasia (pelvic limb paralysis)
21	Juvenile	M	2.20	Hit by a vehicle	L4 – cranial endplate (decreased disc space at L3 - L4 level), vertebral arch	Left femur (proximal third): severe deformity with abnormal alignment of shaft – old lesion Left tibia (proximal third): complete, transverse (old lesion) Hip bone Right: transverse of the ilial body (fragment displaced laterally), central acetabulum, pubis Left: malunion acetabular (deformed femoral head) (severe pelvic canal narrowing)	Euthanasia (pneumothorax and intra-abdominal bleeding Fig. 2 (c-e)

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fractures (Table 4, Figures 2c-e), except for one animal (no. 11) that presented with an open fracture of the femur.

Of the long bones, the femur (n = 7) and tibia (n = 6) were the most affected, followed by the humerus (n = 2) and radius/ulna (n = 2). Among the fractures in the femoral diaphysis (n = 6), three were short oblique, one transverse, one multifragmentary, and one involved severe deformity. A femoral neck fracture was also detected. The tibial diaphysis had spiral (n = 1), oblique (n = 1), transverse (n = 1), and greenstick (n = 1) fractures. Two fractures occurred in the distal tibial growth plate. A diaphyseal transverse fracture and another fracture was observed in the distal growth plate of the humerus. Moreover, a short oblique fracture and another transverse fracture were observed in the radial diaphysis. Luxation of the hip joint (n = 2) and stifle joint (n = 2) were also seen.

Of the 13 animals that presented with hip bone fractures, eight involved the ilium body, and six also had pubis fractures. Considering the hemipelvis, six ilium fractures were oblique and three transverse. Pelvic narrowing was noted in eight animals: four severe, three moderate, and one mild. Regarding the fractures in the acetabulum (n = 9), five were in the caudal portion, three in the central portion, and one was a malunion. Five animals (23.80 %) died and nine (42.86 %) were euthanized due to injury severity, prognosis, and/or poor outcome after treatment. Seven animals (38.33 %) showed good evolution after treatment, including four with conservative, one with external coaptation, one with surgical, and one with surgical and external coaptation. Four animals were released back into nature after treatment.

Discussion

The present study showed that most fractures were due to trauma, with the appendicular skeleton being the most affected (42.86 %), followed by injuries in the bones of both appendicular and axial skeletons (33.33 %). Although *C. thous* may be active during the day, they prefer crepuscular and nocturnal habits,[2] in addition to choosing edges and open environments,[3] which may have favored the high number of motor vehicle trauma (66.67 %) found in the current study.

The animals rescued were always found alone. The fact may relate to the behavior of traveling in pairs and hunting individually, especially in adults.[6] On the other hand, as the animals start hunting with their parents around six weeks of age[1] and between 90 days and five months of age, they are in a post-weaning dependency stage,[6] probably puppies and some of the juveniles get lost from their parents and are exposed to traumatic processes, which culminate in fractures. In addition, two animals (specimens 9 and 21) had both old and new fractures, indicating that they had been previously exposed to trauma. The reported *C. thous* body mass ranges from 5 to 7 kg,[1] which is compatible with the 6.09 kg mean body mass of adult animals observed in this study. On the other hand, 61.9 % of the animals were males and 38.1 % were females, which differed from a study of 18 *C. thous* cadavers, in which 66.67 % were females and 33.33 % males.[14]

Numerous hip bone fractures (n = 13, 61.9 %) were verified in this study, either as a single injury or combined with fractures of long bones or vertebral column, which denotes the intensity and severity of the trauma. In domestic dogs

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and cats, pelvis fractures represent between 20 % and 30 % of all fractures, and are associated with major traumas, such as car accidents.[15, 16] In the presence of imminent trauma caused by a motor vehicle, these animals expose the hindquarter in an attempt to escape, thus favoring pelvic limb fractures,[17] which would also justify what was observed in *C. thous*.

Of the 13 animals with hip bone fractures, eight had involvement of the ilium body, and six had concomitant pubis fractures. Bone displacement occurs when the hemipelvis is fractured at three different sites.[18] The fractures of the ilium (hemipelvis) were oblique (n = 6) and transverse (n = 3) in *C. thous*. Oblique fracture of the ilium body is also the most common in dogs and cats, although transverse or comminuted fractures can be observed.[15, 18] Displacement of the caudal fragment usually occurs in iliac fractures, which favors pelvic canal narrowing,[15] as verified in eight animals in the present study. The lesions were classified as severe in four *C. thous*, of which three were sacrificed due to comorbidities and/or unsatisfactory outcomes and one died. To avoid complications, surgical intervention is recommended when the pelvic canal is narrowed by more than one-third .[16]

Of the 20 fractured hemipelvis, 45 % had acetabulum involvement (n = 9), five of which were located in the caudal portion, three in the central portion, and one was a malunion. In domestic dogs, 12 % of pelvic fractures involve the acetabulum.[16] Generally, fractures located outside the cranial two-thirds of the acetabulum can be treated conservatively,[16] as performed in the current study, although a degenerative process can still occur.[16, 18] Surgery is indicated for fractures located in the cranial and central portions of the acetabulum because they are weight-bearing areas.[18] The *C. thous* with fractures in the central portion were those that died or underwent euthanasia.

Regarding the long bones, the femur (n = 7) and tibia (n = 6) were the most affected. On the other hand, in a study in which eight *C. thous* cadavers were presented with fractures (n = 12), the humerus, femur, and tibia were equally injured, with 61.54 % having diaphyseal fractures.[14] Generally, in domestic dogs, the femur is the long bone most susceptible to fracture, with transverse or oblique diaphyseal fractures more frequent than comminuted ones.[17] However, there are studies in which the tibia was more affected when only the pelvic limb was evaluated.[19] Other studies have referred to the tibia as the second most affected bone in dogs, of which 62 % had transverse or oblique diaphyseal fractures and 38 % comminuted.[20] In the current study, oblique and transverse fractures were the most seen in the tibial and femoral diaphysis.

Forelimb fractures were less frequent in the current study, with two in the radius/ulna and two in the humerus. In dogs, radius/ulna fractures are more common in the distal third, mainly related to falls.[20] This finding differed from the present study in which the fractures were in the middle third of the radius/ulna. Physeal fractures were detected in the humerus (n = 1) and tibia (n = 2). These fractures are characteristic of immature animals, such as those in this study. The younger the animal, the greater the effects on the physis, with the possibility of growth retardation or interruption and consequent shortening or deformity of the limb.[15, 18]

Vertebral column fractures represented 4.76 % (n = 1) of the cases as single lesions and 33.33 % (n = 7) when associated with the appendicular skeleton. In domestic dogs, 41–63 % of vertebral fractures and luxations are due to traffic accidents.[21] Four *C. thous* that had a sacral fracture had a concomitant hip bone

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fracture, but only one had an ilium fracture. The finding differed from a study on domestic dogs in which 32 % of those with a sacral fracture had an ilium fracture.[22]

The outcome was poor for 66.66 % of the animals, with five deaths and nine euthanasias, despite the active participation of authorities in the rescue of animals hit by cars in the region. However, the severity of the fractures and the complications resulting from them contributed to a reduced chance of survival. Other studies of roadkill mammals have also shown a high mortality rate in this species.[23] Based on the most frequent findings in the present study, the pelvic girdle must always be evaluated in *C. thous* due to its high risk of fractures. The treatment choice for fractures should include the recovery prognosis and likelihood of reintegration into the wild population.

Conclusions

In conclusion, hip bone fractures, isolated or combined with injuries in other bones of the axial and/or appendicular skeleton, were the most common injuries in *C. thous*. The characteristics of multiple traumas are associated with mortality and complications. However, in addition to fracture treatment, other strategies must be established. For instance, enforcement of policies aimed at preventing road traffic injuries is imperative, such as the implementation of wildlife passages and equipment to help wildlife cross, driver warnings, and fences, among others. In addition, environmental education campaigns are fundamental to encourage people to protect these animals.

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Data availability

The original datasets used in this study (and, if applicable, supporting information files) are available at the SciELO Dataverse repository doi:10.48331/scielodata.SEYKXM.

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Conflicts of interest

The authors declare no conflicts of interest in regard to this publication.

Author contributions

Conceptualization: SC Rahal.
Data curation: MJ Mamprim.
Formal analysis: SC Rahal.
Funding acquisition: SC Rahal.
Investigation: MVLSG Marques.
Methodology: JP da Silva.
Project administration: GC Camargo.
Resources: JIS Silva.
Software: RS Ichikawa.
Supervision: SC Rahal.
Validation: RS Ichikawa
Visualization: GC Camargo, RS Ichikawa.
Writing-original draft: MVLSG Marques.
Writing-review and editing: MVLSG Marques,GC Camargo, RS Ichikawa, JP da Silva.

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