10.22059/IJVM.2022.336985.1005225

Iranian Journal of Veterinary Medicine
Volume 16- Issue 4

Original Article

Online ISSN: 2252-0554

Characteristics of Fractures of the Appendicular and Axial Skeletons in Rabbits and Hares: A Retrospective Study

Rodrigues, C.S.M.P.[1], Rahal, S.C.[1]*, Silva Júnior, J.I.S.[1], Silva, J.P.[1], Mamprim. M.J.[1], Figueroa, J.G.[1], Tokashiki. E.Y.[1], Melchert, A.[2]

1. *Department of Veterinary Surgery and Animal Reproduction, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu - São Paulo, Brazil*
2. *Department of Veterinary Clinics, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu - São Paulo, Brazil*

Abstract

BACKGROUND: The frequency and characteristics of fractures may vary according to the environment.

OBJECTIVES: The present study aimed to assess the fractures of the appendicular and axial skeletons in rabbits (*Oryctolagus cuniculus*) and hares (*Lepus sp.*) presented at a veterinary teaching hospital.

METHODS: Medical records and radiographs were retrospectively analyzed over eight years.

RESULTS: Twenty-six pet rabbits and five free-ranging hares were enrolled in this study. Twenty-one of them had fractures in the appendicular skeleton, nine in the axial skeleton, and one in both. The fractures were related to traumatic events, such as being hit by a vehicle (22.58%), falling (12.9%), being attacked by another animal (12.9%), and having a paw stuck in a hole (3.22%); 48.38% had an unknown cause. Long bone fractures were found in the humerus (n=2), radius/ulna (n=1), femur (n=5), and tibia (n=12). Fractures involving the distal aspects of the limbs included the tarsus (n=1) and metatarsus (n=2) bones. Except for one rabbit, all of the others had unilateral fractures. Fourteen presented closed fractures, and nine were open fractures. All these fractures were complete, 56.52%% simple, and 43.47% multifragmental. The procedures used included osteosynthesis (42.85%), external coaptation (28.57%), amputation (14.28%), euthanasia (4.76%), and two animals died (9.52%). The fractures of the axial skeleton included the vertebral column (n=6), mandible (n=3), and pelvis (n=2). Five fractures were treated conservatively, and the rabbits were euthanized in four cases.

CONCLUSIONS: The fractures resulted from a traumatic episode, which had an unknown origin in most of the cases, involving mainly the appendicular skeleton, being the tibia the bone most affected.

KEYWORDS: Bone, Lagomorphs, Radiography, Trauma

Correspondence

Sheila Canevese Rahal, Department of Veterinary Surgery and Animal Reproduction, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu - São Paulo, Brazil. Tel: +55 (14) 38802041, Email: sheila.canevese-rahal@unesp.br

Received: 2022-03-08

Accepted: 2022-06-13

How to Cite This Article
Rodrigues, C.S.M.P., Rahal, S.C., Silva Júnior, J.I.S., Silva, J.P, et al. (2022). Characteristics of Fractures of the Appendicular and Axial Skeletons in Rabbits and Hares: A Retrospective Study. *Iranian Journal of Veterinary Medicine,* 16(4), 338-347.

Introduction

Rabbits and hares belong to the Leporidae family, order Lagomorpha; however, the term hare is reserved for Lepus genera (Graham, 2015). Rabbits are a popular pet for adults and children in a substantial number of countries throughout the world (Hillyer, 1994; Miwa and Carrasco, 2011). Pet rabbits' life expectancy is more than seven years, reaching 11-12 years or longer (Hillyer, 1994; Harcourt-Brown, 2002; Meredith, 2016). On the other hand, wild rabbits may not survive beyond their first year (Meredith, 2016). The small breeds of rabbits are sexually mature at approximately 4-5 months, and larger breeds at 5-8 months of age (Harcourt-Brown, 2002).

The skeleton is equivalent to 7% to 8% of the body mass and is considered somewhat fragile in rabbits (Cruise and Brewer, 1994; Brewer, 2006; Miwa and Carrasco, 2011). The bones are brittle, with thin cortices (ratio of the thickness cortex/bone of 12%), and have lower density and higher mineral composition than dog bones (Miwa and Carrasco, 2011; Guzman and Kapatkin, 2021). In addition, the muscles of the hind limbs are strong, and the locomotion is particularly based on jumping (Miwa and Carrasco, 2011; Meredith, 2016).

The cause of fracture in pet rabbits and hares is usually associated with a traumatic event (Fettinger *et al.*, 2010; Miwa and Carrasco, 2011; Pećin *et al.*, 2015; Sasai *et al.*, 2015). Improper handling can induce fractures or luxation of the lumbar vertebrae or hind limbs (Brown, 1997), even in animals with normal bone density (Brown, 1997; Meredith, 2016). Fractures in rabbits are often complex with multiple fragments, but bone healing may occur quickly (Harcourt-Brown, 2002).

The principles of surgical treatment and techniques used in small animals have been used in clinical cases of fractures in rabbits and hares (Harcourt-Brown, 2002; Pećin *et al.*, 2015; Kawamoto *et al.*, 2018; Sasai *et al.*, 2018; Miwa and Carrasco, 2011; Garcia-Pertierra, 2020), but there are challenges associated with the anatomy and composition of the bone tissue (Barron *et al.*, 2010; Miwa and Carrasco, 2011; Guzman and Kapatkin, 2021). In addition, because rabbits are natural prey for many carnivores (Meredith, 2016), the stress and pain reactions are different from those in dogs and cats (Hillyer, 1994; Miwa and Carrasco, 2011; Guzman and Kapatkin, 2021).

Since the frequency and characteristics of fractures may vary according to the environment, this study aimed to retrospectively assess fractures of the appendicular and axial skeletons in rabbits (*Oryctolagus cuniculus*) and hares (*Lepus sp.*) presented at a veterinary teaching hospital.

Materials and Methods

This study was approved by the Institutional Ethics Committee on Animal Use (CEUA: 074/2020). Medical records and complementary diagnostic exams (based on radiographs) of rabbits and hares with fractures, evaluated at the Center for Medicine and Research in Wild Animals (CEMPAS) from a veterinary teaching hospital, were retrospectively analyzed over eight years (2013-2020). The inclusion criteria included cases with described management, and plain radiographs confirmed the fracture. The exclusion criteria were descriptive cases without images.

The following information was taken into account: patient signalment (sex; body mass; age, in case of age not provided, the animal was classified as young or adult according to opened or closed physis on x-ray); cause of the fracture; involvement of one or more bones of the appendicular and/or axial skeleton; management of the case. The fractures of the appendicular skeleton bones were classified as follows: affected bone; closed or open; complete (both cortices disrupted) or incomplete (only one cortex disrupted); simple (transverse, oblique, spiral) or multifragmentary fracture (more than two fractured fragments, which can be a reducible wedge, nonreducible wedge, or segmental); location (proximal third, middle third, or distal third (epiphysis, physis, and metaphysis). If the animal presented one or multiple fractures were also verified. Those of the axial skeleton were classified to the location and characteristics of the fracture.

The association between fracture site (appendicular or axial skeletons) and sex, and also the age (≤ 8 months age and young; > 8 months of age and adult) of the animals were compared using Fisher's exact test (two-sided). The significance level was set at 5%. The statistical analysis was performed with commercial statistical software (GraphPad Prism 8.3.1®, San Diego, CA, USA).

Results

A total of 26 pet rabbits and five free-ranging hares met the inclusion criteria and were enrolled in the study. Twenty-one (67.74%) of them had fractures in the appendicular skeleton (Table 1), nine (29.03%) in the axial skeleton (Table 2), and one (3.22%) in both skeletons, which represented 5.75% of all rabbit admissions in the period. One hare showed fractures that included bones in both skeletons; therefore, it was not included in the Tables.

Table 1. Fractures of the appendicular skeleton in rabbits and hares

No.	Body mass (kg)	Age (years)	Sex	Fracture site	Cause	Fracture classification	Treatment
1	-	adult	-	left humerus (middle third)	attack by a dog	closed, multifragmental, reducible wedge	plate-rod construction
2	1.5	3,0	M	left humerus (distal third)	fall from owner's arms	closed, multifragmental, reducible wedge	one intramedullary pin and two cerclage wires
3	-	0,8	M	right radius/ulna (middle third)	unknown	radius: closed, complete, transverse ulna: closed, complete, long oblique	conservative - external coaptation
4	2.7	6	M	left femur (proximal third)	unknown	closed, multifragmental, reducible	one intramedullary pin and two cerclage wires
5	1.7	0,4	F	left femur (Salter-Harris type I)	unknown	closed, complete	two Kirschner wires
6	3.0	1,0	M	left femur (Salter-Harris type I)	unknown	closed, complete	death
7	2.5	6	M	left femur (proximal third)	unknown	closed, multifragmental, nonreducible	two intramedullary pins
8	0.6	0,5	M	left tibia (middle third)	unknown	closed, complete, long oblique	conservative - external coaptation
9*		young	0	right tibia (middle third)	unknown	open, complete, transverse	euthanasia
10	-	young	0	left tibia (distal third)	unknown	open, complete, short oblique	amputation
11	3.8	adult	M	left tibia (distal third)	fall from owner's arms	closed, complete, spiral	one intramedullary pin and three cerclage wires
12	-	0,7	F	left tíbia (distal third)	attack by a dog	open, multifragmental, nonreducible	amputation
13	0.8	0,8	M	left tibia (distal epiphysis)	unknown	open, multifragmental, nonreducible	amputation
14	1.8	young	F	right tibia (distal third)	attack by a dog	right: open, multifragmental segmental	intramedullary pin bilateral

No.	Body mass (kg)	Age (years)	Sex	Fracture site	Cause	Fracture classification	Treatment
				left tibia (distal third)		left: closed, complete, short oblique	
15	1.9	2	0	right tibia (distal third)	hit by a vehicle	open, multifragmental, reducible wedge	external fixator and two cerclage wires
16	3.1	2	M	right tibia (distal third)	hit by a vehicle	open, multifragmental, nonreducible	external fixator
17		young	-	right tibia (distal third)	unknown	open, complete, short oblique	death
18	2.0	0,7	M	right tibia (epífise distal)	hit by a vehicle	closed, complete, spiral	conservative - external coaptation
19	1.3	0,2	M	right tarsus	foot stuck in a hole	closed, multifragmental, reducible	conservative - external coaptation
20	2.9	1,5	M	right 3rd metatarsal bone (proximal third)	unknown	closed, complete, transverse	conservative - external coaptation
21	10	young	M	right 1st, 2nd, 3rd metatarsal bone (proximal third)	unknown	open, complete, short oblique	conservative - external coaptation

*hare; M: Male; F: Female.

Table 2. Fractures of the axial skeleton in rabbits and hares

No.	Body mass (kg)	Age (Years)	Sex	Cause	Fracture site	Fracture classification	Treatment
1	1,3	young	M	fall from a height of 5 m	left mandible body	complete, transverse	conservative
2	-	3	M	unknown	right and left mandibular rami	complete, transverse	conservative
3*		adult	-	hit by a vehicle	iliac wing	multifragmental, reducible	conservative – cage rest
4	-	0.5	F	attack by another rabbit	vertebral column (L6)	vertebral body compression	euthanasia
5	2.6	adult	F	unknown	vertebral column (L4)	vertebral body compression	euthanasia
6	0.9	2	M	fall from cage	vertebral column (caudal epiphysis of L6)	complete, transverse	conservative – cage rest
7	1.7	adult	M	unknown	vertebral column (L7)	vertebral body compression	conservative – cage rest
8*	-	young	F	hit by a vehicle	vertebral column (L3, L4, L5)	L3: caudal articular process L4: vertebral body and transverse process	euthanasia

No.	Body mass (kg)	Age (Years)	Sex	Cause	Fracture site	Fracture classification	Treatment
						L5: transverse process Luxation between L3 and L4	
9*	3.3	adult	M	hit by a vehicle	vertebral column (T8, T10, T11)	T11: vertebral arch T8 and T10: spinous processes Luxation between T11 and T12	euthanasia

*hare; M: Male; F: Female

The body mass ranged from 0.6 to 3.8 kg (mean 2.1 kg ± 0.97). The average age was 1.83 years (± 1.79), calculated from rabbits whose age was known. Seven of the animals whose age was not provided were classified as young and six as adults. All rabbits were entire (unclear), being 58.06% (n=18) males, 22.58% (n=7) females and 19.35% (n=6) there was no identification. Fischer's exact test showed no significant association between fracture site and sex (*P*=0.3618). Likewise, no association was observed between fracture site and age (*P*=0.427).

Including only the appendicular skeleton, the causes of fractures were hit by a vehicle (14.28%; n=3), falling from the owner's arms (9.52%; n=2), being attacked by a dog (14.28%; n=3), having the paw stuck in a hole (4.76%; n=1), and 57.14% (n=12) having an unknown cause. Including only the axial skeleton, the causes of fractures were being hit by a vehicle (33.33%; n=3), falling from a height or cage (22.22%; n=2), being attacked by another rabbit (11.11%; n=1), and 33.33% (n=3) having an unknown cause. Including both skeletons, one hare was hit by a vehicle.

Fracture classifications in appendicular and axial skeletons are given in Tables 1 and 2, respectively. The exception was the hare that had fractures in the axial skeleton (right mandible body - closed, complete, transverse; right pelvic floor and ischium) and appendicular skeleton (right femur –closed, transverse, complete). Long bone fractures were found in the humerus (n=2), radius/ulna (n=1), femur (n=5), and tibia (n=12). Fractures involving the distal aspects of the limbs included the tarsus (n=1) and metatarsus (n=2) bones. Except for one rabbit that showed right and left tibia fractures, all the others had unilateral fractures. A total of 14 fractures were closed (60.86%) and nine open (39.13%). All these fractures were complete, being 56.52%% (n=13) simple and 43.47% (n=10) multifragmentary fracture. The procedures used in the fractures of the appendicular skeleton included osteosynthesis (42.85%; n=9), external coaptation (n=6; 28.57%), amputation (14.28%; n=3), euthanasia (n=1; 4.76%), and two animals died (n=2; 9.52%) (Figures 1 and 2).

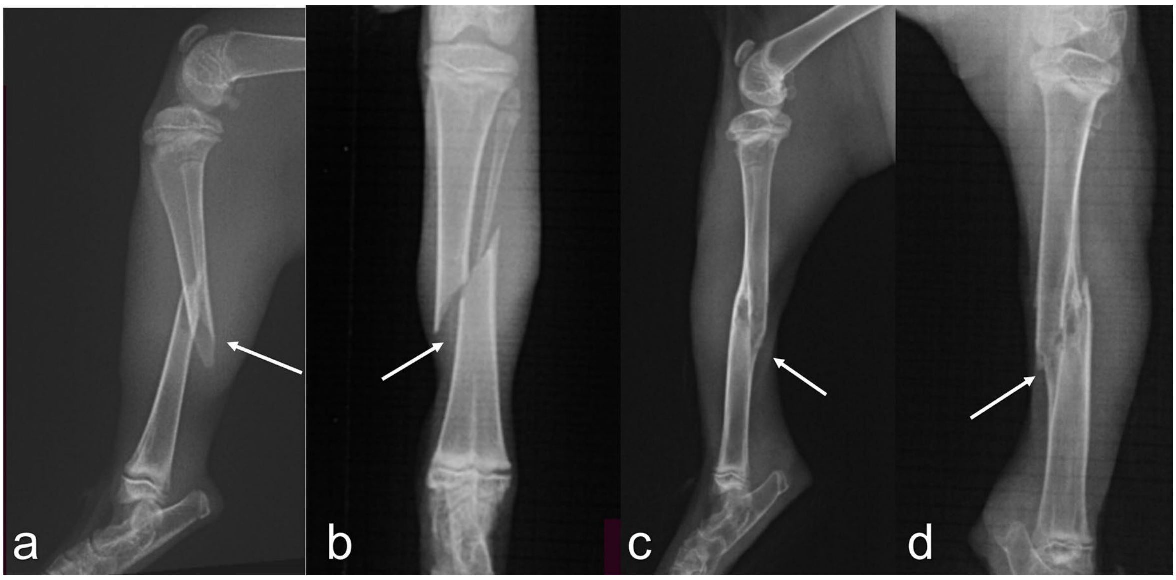

Figure 1. Mediolateral (a, c) and craniocaudal (d, e) radiographic views of the left tibia of a rabbit (no. 8). Long oblique fracture (a, b) treated with external coaptation due to financial constraint, showing malunion in part compensated for by remodeling of the bone (c, d) 35 days after surgery

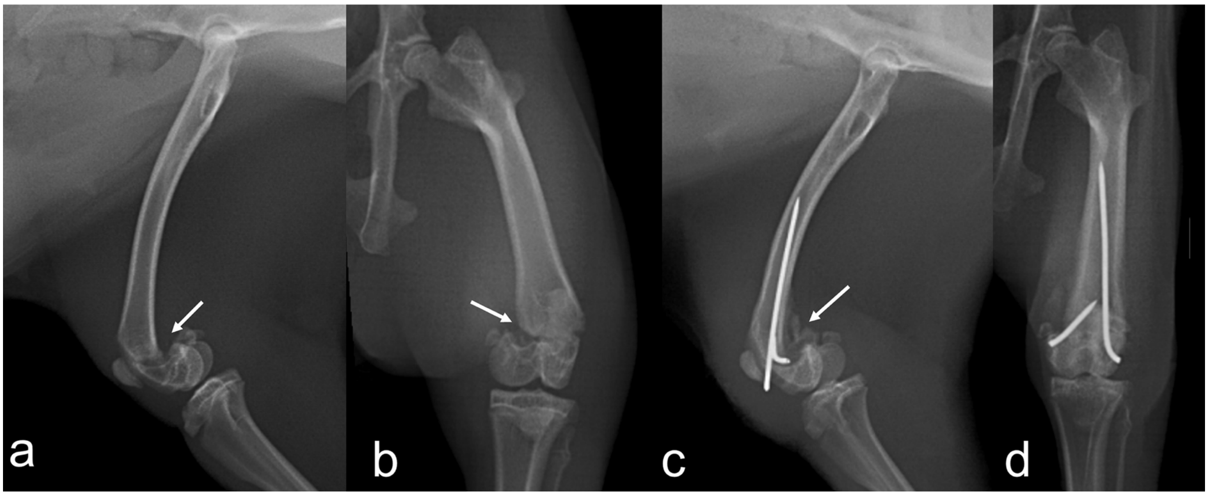

Figure 2. Mediolateral (a, c) and craniocaudal (d, e) radiographic views of the left femur of a rabbit (no. 5). Salter-Harris (type I) distal femur fracture stabilized with two Kirschner wires, showing advanced bone healing on the 15th day after surgery

The fractures of the axial skeleton (n=11) included vertebral column (54.54%; n=6), mandible (27.27%; n=3) and pelvis (18.18%; n=2). All of them were closed fractures. Five fractures of the axial skeleton were treated conservatively, and in four cases, the rabbits were euthanized due to poor prognosis at presentation (Figure 3).

The hare, whose fractures included bones of both skeletons, was euthanized.

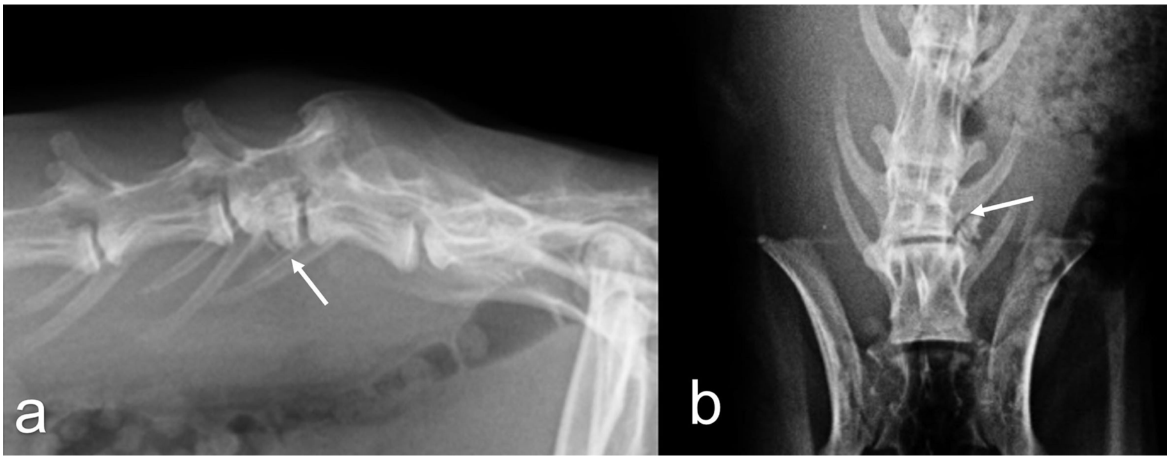

Figure 3. Lateral (a) and ventrodorsal (b) radiographic views of the vertebral column of a rabbit (no. 4). Observe the vertebral compression fracture of L6

Discussion

Fractures accounted for 5.75% of the total rabbit admissions over the eight years, being 67.74% in the appendicular skeleton, 29.03% in the axial skeleton, and 3.22% in both skeletons. The fractures in this study were non-neoplastic and related to traumatic events, mainly due to being hit by a vehicle (22.58%), falling (12.9%), being attacked by another animal (12.9%), having a paw stuck in a hole (3.22%), and 48.38% had an unknown cause. On the other hand, in a retrospective study with 210 pet rabbits, 24.8% of the fractures were due to accidental falls as a result of human error, 22.9% were related to other causes, and 16.7% the cause was unknown (Sasai *et al.*, 2015). In another retrospective study with 28 pet rabbits, 70% had unknown causes, and 17% were related to a known trauma (Garcia-Pertierra, 2020). All hares in the present study were free-ranging, and most of them had been hit by a vehicle. However, the hares are game species in some countries, and femur fractures have been related to shots (Fettinger *et al.*, 2010).

The mean age of the rabbits was 1.83 years. A study verified that one year was the age that most fractures happened, supposedly due to the sexual maturity of the rabbits (Sasai *et al.*, 2015). Also, in another study that evaluated long-bone fractures in rabbits, 75% had aged less than two years, and the others were under six months (Garcia-Pertierra, 2020). The present study did not detect fractures related to neoplasia in the clinical and radiographic exams, probably because most were young rabbits. Fractures due to metastasis of uterine adenocarcinoma, osteosarcoma, and rhabdomyosarcoma have been observed in rabbits (Sasai *et al.*, 2015).

The percentage of males (58.06%) was higher than females (22.58%), but 19.35% were unknown. Another study found 54.8% males and 45.2% females; however, in fractures associated with neoplasms, female rabbits were considered more likely to have a fracture (Sasai *et al.*, 2015).

Including all fractures, the three fracture sites more frequent were the tibia (35.29%), vertebral column (17.64%), and femur (14.70%). On the other hand, the vertebral column (23.2%), tibia (22.7%), and femur (13.1%) were the most affected, considering non-neoplastic fractures in a study with 198 rabbits (Sasai *et al.*, 2015). Different types of traumatic events may influence the differences in findings. Considering only the appendicular skeleton, the tibia followed by the femur was the most fractured, as observed in other pet rabbit studies (Sasai *et al.*, 2015; Sasai *et al.*, 2018). On the opposite, in a retrospective study with 28 pet rabbits, the femur followed by the tibia was the most fractured (Garcia-Pertierra, 2020). The highest proportion of fractures in the hind limbs verified in this study and the others (Sasai *et al.*, 2015; Garcia-Pertierra, 2020) has been attributed to a considerable force exerted by the rabbits on the hind limbs (Sasai *et al.*, 2015).

The tibia fractures comprised 58.33% simples and 41.66% multifragmental, being 66.66% open fractures. A study on the rabbit's tibia showed that an oblique loading induced diaphyseal fracture and short duration loading induced comminuted fracture (Hirsch *et al.*, 1954). The simple fractures in the present study included short oblique (n=3), long oblique (n=1), transverse (n=2) and spiral (n=2) fractures. In mature rabbits, angulatory forces in the tibia caused transverse and oblique fractures with more damage to soft tissues than the spiral forces, which caused spiral fractures (Oni *et al.*, 1988). This fact probably justifies two short oblique fractures and one transverse that had been open in the present study.

All femur fractures were closed, being two Salter-Harris Type 1, two multifragmental, and one transverse. A study showed that the force required to induce femoral fracture in rabbits was smaller than tibia fracture, which was attributed to the femoral shape (Hirsch *et al.*, 1954). Comminuted fractures may occur in rabbits due to traumatic events of high energy and low energy impacts (Miwa and Carrasco, 2011). Just one animal had a tarsal fracture, which is generally associated with the category of low-energy fractures; closed, slight soft tissue trauma, and preservation of the blood supply (Harcourt-Brown and Chitty, 2013).

In the axial skeleton, vertebral fractures were the most frequent (54.54%), being the lumbar region the most affected. The lumbosacral region (L6–L7) is a common site of fracture or luxation in rabbits; the force applied by hind limbs during the escape can over-flex the vertebral column inducing the lesion (Fisher *et al.*, 2021). However, another study found L5, the site most affected by fractures (Sasai *et al.*, 2015). These patterns were not verified in the current study since the fractures occurred at different sites from L4 onwards. However, most rabbits and hares were euthanized due to injury severity. Regarding the mandible fractures, one was caused by falling, and the other had an unknown cause in rabbits. One hare had a fracture due to being hit by a vehicle. In general, mandibular fractures in rabbits have been more frequently associated with dropping or leaping from the owner's arms (Harcourt-Brown, 2002).

Although this study was not focused on fracture treatments, surgical treatment was used only in long bone fractures. Internal fixation methods, such as those used in the current study, have been used in rabbits and hares, but species-specific guidelines for fracture treatment are still lacking (Harcourt-Brown and Chitty, 2013; Poćin *et al.*, 2015; Garcia-Pertierra, 2020). A study has successfully used sheep xenograft and low-level laser therapy to treat segmental bone defects induced in rabbits (Nazht *et al.*, 2021). Because of the financial constraints, conservative methods or even euthanasia were sometimes used. Additionally, the amputation was done in three pet rabbits with severe open tibia fractures. Limb amputation has been cited as an economical solution for complex fractures, being well-tolerated more frequently when performed on the thoracic limb (Harcourt-Brown, 2002). However, a study (n= 32) detected nineteen chronic complications and six deaths after limb amputation in client-owned rabbits (Northrup *et al.*, 2014).

The primary limitation of this study was the incomplete data in medical records, which reduced the number of animals in the inclusion criteria. Another limitation was that the breed was not provided. However, the findings in the study helped to understand the species'.

Conclusion

the fractures resulted from a traumatic episode, which had an unknown origin, involving mainly the appendicular skeleton, the tibia the most affected bone.

Acknowledgments

The authors are grateful to CNPq (National Council for Scientific and Technological Development - PIBIC and PQ no.301585/2017-2), and Finep (Financiadora de Estudos e Projetos), no. 01.12.0530.00).

Conflict of Interest

The authors declared no conflict of interest.

References

Barron, HW; McBride, M; Martinez-Jimenez, D; Foutz, T; Divers, S and Budsberg, S (2010). Comparison of two methods of long bone fracture repair in rabbits. *Journal of Exotic Pet Medicine, 19*: 183-188. [DOI:10.1053/j.jepm.2010.06.004]

Brewer, NR (2006). Biology of the rabbit. Journal of the American Association for Laboratory Animal. 45: 8-24.

Brown, S. A. (1997, April). Clinical techniques in rabbits. In *Seminars in Avian and Exotic Pet Medicine* (Vol. 6, No. 2, pp. 86-95). WB Saunders. [DOI:10.1016/S1055-937X(97)80015-1]

Cruise, LJ and Brewer, NR (1994). Anatomy. In: Manning, PJ; Ringler, DH and Newcomer, CE (Eds.), *The biology of the laboratory rabbit*. (2nd Edn.), Orlando, Academic Press. PP: 47-61. [DOI:10.1016/B978-0-12-469235-0.50009-9]

Fettinger, V; Smulders, FJM; Lazar, P; Omurtag, I and Paulsen, P (2010). Lesions in thighs from hunted Brown Hares (Lepus europaeus) and microflora under vacuum-packaging storage. *European Journal of Wildlife Research, 56*: 943-947. [DOI:10.1007/s10344-010-0427-4]

Fisher, PG; Künzel, F and Rylander, H (2021). *Neurologic and musculoskeletal diseases*. In: Quesenberry, KE; Orcutt, CJ; Mans, C and Carpenter, JW (Eds.), Ferrets, rabbits, and rodents: clinical medicine and surgery. (4th Edn.), St. Louis, Elsevier. PP: 233-249. [DOI:10.1016/B978-0-323-48435-0.00018-6] [PMID] [PMCID]

Garcia-Pertierra, S; Ryan, J; Richardson, J; Koterwas, B; Keeble, E; Eatwell, K and Clements, DN (2020). Presentation, treatment and outcome of long-bone fractures in pet rabbits (Oryctolagus cuniculus). *Journal of Small Animal Practice, 61*: 46-50. [DOI:10.1111/jsap.13087] [PMID]

Graham, JE (2015). *Lagomorpha (Pikas, Rabbits, and Hares)*. In: Miller, RE and Fowler, ME (Eds.), Fowler's zoo and wild animal medicine current therapy. (8th Edn.), St. Louis, Elsevier Saunders. PP: 375-384. [DOI:10.1016/B978-1-4557-7397-8.00041-4]

Guzman, D.S-M and Kapatkin, AS (2021). *Orthopedics in small mammals*. In: Quesenberry, KE; Orcutt, CJ; Mans, C and Carpenter, JW (Eds.), Ferrets, rabbits, and rodents: clinical medicine and surgery. (4th Edn.), St. Louis, Elsevier. PP: 483-497. [DOI:10.1016/B978-0-323-48435-0.00034-4]

Harcourt-Brown, F. (2002). *Textbook of rabbit medicine. Butterworth-Heinemann*: Oxford. 410p.

Harcourt-Brown, F and Chitty, J (2013). *BSAVA manual of rabbit surgery, dentistry and imaging*. Gloucester, British Small Animal Veterinary Association. 440p.

Hirsch, C; Cavadias, A and Nachemson, A (1954). An attempt to explain fracture types; experimental studies on rabbit bones. *Acta Orthopaedica Scandinavica, 24*: 8-29. [DOI:10.3109/17453675408988549] [PMID]

Hillyer, EV (1994). Pet rabbits. The Veterinary Clinics of North America. Small Animal Practice, 24: 25-65. [DOI:10.1016/S0195-5616(94)50002-0]

Kawamoto, FYK; Perles, L; Santos, LO; Simionato, GC; Gonçalves Dias, LGG; Minto, BW and Werther, K (2018). Association of Rush pin and intramedular pin techniques for the stabilization of Salter Harris type I fracture in rabbit (Oryctolagus cuniculus). *Acta Scientiae Veterinariae, 46*: 1-4. [DOI:10.22456/1679-9216.86894]

Meredith, A (2016). *Biology, anatomy and physiology*. In: Meredith, A and Lord, B (Eds.), BSAVA manual of rabbit medicine. Gloucester, British Small Animal Veterinary Association. PP: 1-12. [DOI:10.22233/9781910443217.1]

Miwa, Y and Calvo Carrasco, D (2019). Exotic mammal orthopedics. The Veterinary Clinics of North America. *Exotic Animal Practice, 22*: 175-210. [DOI:10.1016/j.cvex.2019.02.001] [PMID]

Nazht, HH; Abduljabbar, IH and Omar RA (2021). Physical, chemical, and mechanical evaluation of irradiated xeno-sheep bony implantation by low-level laser therapy of long bones fractures in rabbits. *Archives of Razi Institute. 76*: 1445-1451.

Northrup, NC; Barron, GH; Aldridge, CF; Powers, LV; Greenacre, CB; Hutcheson, JD and Morrisey JK (2014). Outcome for client-owned domestic rabbits undergoing limb amputation: 34 cases (2000-2009). *Journal of the American Veterinary Medical Association, 244*: 950-955. [DOI:10.2460/javma.244.8.950] [PMID]

Oni, OO; Gregg, PJ; Morrison, C and Ponter AR (1988). An investigation of the fracture characteristics of the tibia of mature rabbits. *Injury, 19*: 172-176. [DOI:10.1016/0020-1383(88)90009-5.]

Pećin, M; Kos, J; Kreszinger, M; Vnuk, D; Stejskal, M; Radisic, B; Smolec, O and Lipar, M (2015). Osteosynthesis of the radius and ulna in a brown hare lepus europeu. *Journal of Dairy, Veterinary & Animal Research, 2*: 225-227. [DOI:10.15406/jdvar.2015.02.00059]

Sasai, H., Fujita, D., Tagami, Y., Seto, E., Denda, Y., Hamakita, H., ... & Yamate, J. (2015). Characteristics of bone fractures and usefulness of micro–computed tomography for fracture detection in rabbits: 210 cases (2007–2013). *Journal of the American Veterinary Medical Association*, *246*(12), 1339-1344. [DOI:10.2460/javma.246.12.1339] [PMID]

Sasai, H., Fujita, D., Seto, E., Denda, Y., Imai, Y., Okamoto, K., ... & Sasai, K. (2018). Outcome of limb fracture repair in rabbits: 139 cases (2007–2015). *Journal of the American Veterinary Medical Association*, *252*(4), 457-463. [DOI:10.2460/javma.252.4.457] [PMID].