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Stabilization of a vertebral fracture by a monolateral external fixator placed percutaneously with fluoroscopy guidance in a rabbit (*Oryctolagus cuniculus*)

José Rosas-Navarro, DVM[1*]; Carlo Paoletti, DVM[1], Jean-François Quinton, DVM, DECZM (SM)[1], Diego Rossetti, DVM, DECVS[2]

[1]Exotics Surgery and Medicine Service, Centre Hospitalier Vétérinaire Advetia, Vélizy-Villacoublay, France
[2]Surgery Service, Centre Hospitalier Vétérinaire Advetia, Vélizy-Villacoublay, France

*Corresponding author: Dr. Rosas-Navarro (rosas.navarro@advetia.fr)

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CASE DESCRIPTION
A 2-year-old intact male Mini Lop rabbit (*Oryctolagus cuniculus*) exhibited acute paraplegia and was suspected of having a traumatic spinal injury after leaping from the owner's arms.

CLINICAL FINDINGS
In the physical examination, the patient was conscious and responsive and presented a loss of hind-limb motor function. The results of the neurologic examination indicated a T3-L3 spinal cord lesion. Vertebral column radiography and CT showed a fracture of the dorsal arch in the right caudal part of vertebra L1 and a fracture of the caudal end plate of vertebra L1 without displacement.

TREATMENT AND OUTCOME
The vertebral fracture was stabilized by a monolateral external fixator placed percutaneously with fluoroscopy guidance. The rabbit was discharged 48 hours after surgery. Three days later, the rabbit was able to walk with mild paraparesis, and 2 weeks after surgery, the rabbit showed full recovery of neurologic function. The follow-up performed 6 weeks after surgery showed normal gait, good alignment and complete consolidation of the fracture. The external fixator was then removed. The follow-up examination and radiographic findings showed complete recovery at 2 and 6 months after surgery.

CLINICAL RELEVANCE
The most common cause of traumatic posterior paralysis in rabbits is vertebral fracture. This article describes the possibility and successful outcome of stabilizing a vertebral fracture in a rabbit with an external fixator using a minimally invasive fluoroscopic technique. This technique, described to the authors' knowledge for the first time in a rabbit, allows a fracture to be stabilized accurately without any incisions while minimizing complications and postoperative pain.

A 2-year-old 2-kg intact male Mini Lop rabbit (*Oryctolagus cuniculus*) was presented 2 hours after leaping from the owner's arms without having previously been examined at a veterinary center and without having received any previous treatment. The patient exhibited loss of hind-limb motor function.

The results of the initial physical examination were unremarkable except for the presence of paraplegia. The complete neurologic examination revealed appropriate mentation, and the rabbit had a bright and alert demeanor. The results of the cranial nerve examination were normal. Normal postural reactions of the forelimbs were present; however, postural reactions of the pelvic limbs were absent. The patellar and withdrawal reflexes in the pelvic limbs were normal. Deep pain sensation was preserved in the pelvic limbs. On the basis of these findings, the neuroanatomic diagnosis was a lesion affecting the T3-L3 spinal cord segment. No urinary or fecal incontinence was observed during the clinical examination. The CBC and serum biochemical profile were within the laboratory's reference values for this species.

After premedication with midazolam (0.5 mg/kg, IM),[1] a 24-gauge, 3-quarter-inch intravenous catheter was placed in the left marginal auricular vein after the application of lidocaine gel (Xylocaine 2% topical).

The primary differential diagnosis related to trauma included vertebral luxation, hematoma, spinal cord contusion, intervertebral disk protrusion, ischemic myelopathy, or pathological vertebral fracture.[2] Less likely differential diagnoses included paraspinal abscess formation, congenital malformation (synovial cyst, subarachnoid diverticulum, and hemivertebrae), degenerative changes and metabolic bone disease.[3]

Radiography of the vertebral column showed a nondisplaced transverse fracture of the caudal end plate of L1 **(Figure 1)**. Kyphosis, lordosis and scoliosis, which are frequent incidental factors in pet rabbits and may fragilize the spinal column,[4] were not observed in the animal. To further evaluate the extent and nature of the lesions and to help with surgical planning, 1 hour after receiving the patient, a vertebral column pre- and postcontrast CT scan (Revolution ACT 16 slice; GE Healthcare) was performed. For the postcontrast images, iohexol (Omnipaque 300; GE Healthcare; 2 mL/kg, IV) was used. General anesthesia was induced with alfaxalone (3 mg/kg)[1] administered intravenously, and tracheal intubation was performed with a 2.5-mm uncuffed endotracheal tube. Anesthesia was maintained with sevoflurane in 100% oxygen. During anesthesia, the oxygen flow was maintained at 1.5 L/min, and the dose of sevoflurane was adjusted to achieve an end-tidal value between 2% and 2.5%. The results confirmed a fracture of the vertebral arch in the right caudal part of vertebra L1 and a fracture of the caudal end plate of vertebra L1 without displacement (Figure 1). No fracture fragments within the vertebral canal were found, and misalignment or stenosis of the vertebral canal was not found, even at the fracture site. The fracture involved the dorsal and ventral compartments and the articulation processes. Therefore, the fracture was considered unstable and conservative management was not an option. A surgical intervention was planned.

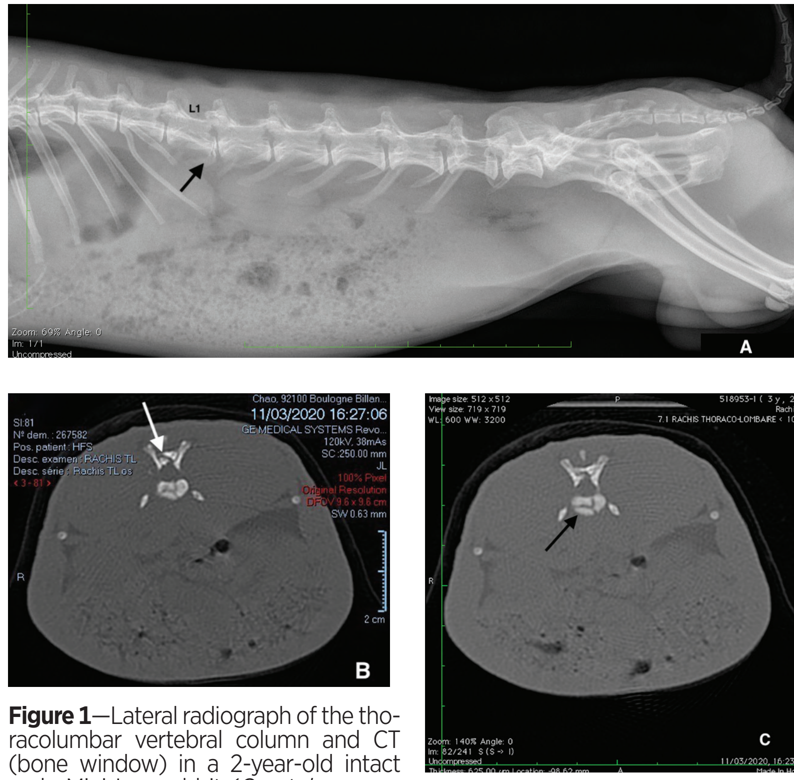

Figure 1—Lateral radiograph of the thoracolumbar vertebral column and CT (bone window) in a 2-year-old intact male Mini Lop rabbit (*Oryctolagus cuniculus*) showing a fracture of the caudal end plate of the first lumbar vertebra without displacement (A through C; black arrow) and a fracture of the right side of vertebral arch of the first lumbar vertebra (B; white arrow).

Immediately following the CT scan, a minimally invasive technique involving fluoroscopy (OEC 9000 stenoscope; GE Healthcare) was used to stabilize the vertebral fracture with an external fixator. Intraoperative analgesia was provided with intravenous constant rate infusion (CRI) of fentanyl-lidocaine-ketamine (1 mL/kg/h throughout the anesthetic procedure) consisting of fentanyl (3 µg/kg/h), lidocaine (4 mg/kg/h), and ketamine (0.4 mg/kg/h).[1] Standard saline (0.9% NaCl) solution (10 mL/kg/h) were administered as fluid therapy during surgery.

The rabbit was positioned in sternal recumbency, and the spine regions from the scapula to the cranial aspect of the iliac wings were prepared aseptically. The surgical site was visualized using fluoroscopy. Large needles (18 gauge; 40 X 1.1 mm) were used to guide the insertion of the percutaneous pin. Five 1-mm Kirschner wires were unilaterally placed with a battery-driven drill (Colibri II; DePuy-Synthes) in the vertebral body by a percutaneous small-stab approach using a low drill speed (under 300 rpm). Kirschner wires were inserted in 3 adjacent vertebral bodies, T13, L1, and L2 **(Figure 2)**. The pins were cut such that they could be bent backward on themselves and externally connected and stabilized using epoxy resin placed at the distal ends (Technovit 6091; Kulzer Technique International). During modeling of the epoxy resin frame, the reduction of the fracture site was carefully observed by intraoperative fluoroscopy **(Figure 3)**. The duration of the surgery was 40 minutes.

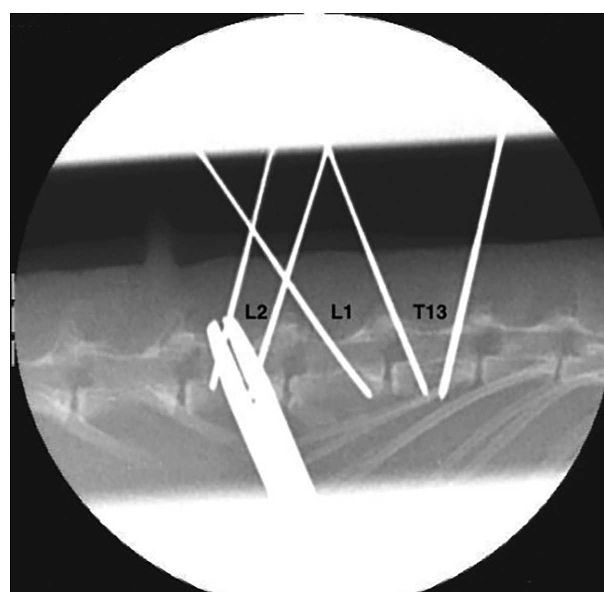

Figure 2—Intraoperative fluoroscopy image of the rabbit of this report showing five 1-mm Kirschner wires in the vertebral body unilaterally. Kirschner wires were inserted in 3 adjacent vertebral bodies: T13, L1, and L2.

The constant rate infusion of fentanyl-lidocaine-ketamine was maintained for 24 hours after surgery. The rabbit had a good appetite after surgery and urinated and defecated normally. Twenty-four hours after surgery, the rabbit received buprenorphine (0.05 mg/kg, SC, q 6 h for 2 days), meloxicam (1 mg/kg, SC, once), and fluid therapy

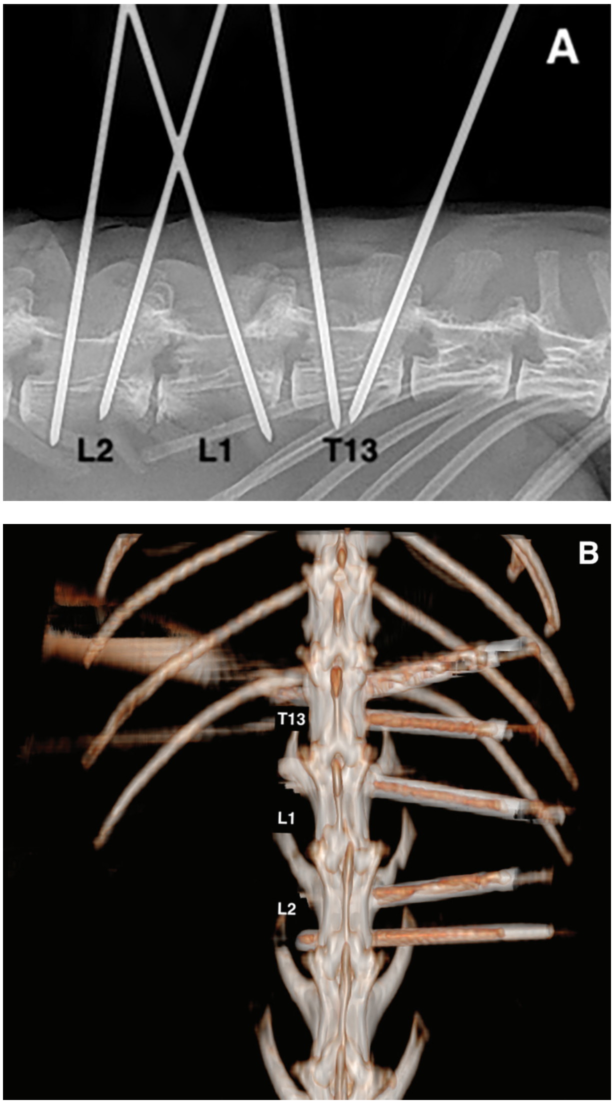

Figure 3—Postsurgical lateral radiograph view (A) and 3D computed tomography (B) of the thoracolumbar vertebral column of the rabbit of this report showing five 1-mm Kirschner wires inserted in 3 adjacent vertebral bodies: T13, L1, and L2.

with standard saline solution (90 mL/kg/24 h, IV). Antibiotherapy using trimethoprim-sulfamethoxazole (30 mg/kg, PO, q 12 h)[1] was initiated. A protective cohesive bandage was attached to the external fixator. An Elizabethan collar was not used because the animal remained calm while hospitalized after surgery, and these devices can cause additional anxiety for patients. At discharge 72 hours after surgery, the rabbit was able to walk with mild paraparesis **(Figure 4)**. Meloxicam and trimethoprim-sulfamethoxazole were prescribed PO at the same dosage during hospitalization for 7 days and 21 days, respectively. Cage rest for 4 weeks was recommended for the patient.

Guidelines for postoperative external skeletal fixation care were given to the owner. The external frame was to be examined, and the pin skin interface was to be cleaned daily to minimize the risk of infection. Home physiotherapy was recommended, with gentle massage of the pelvic limbs to promote blood flow.

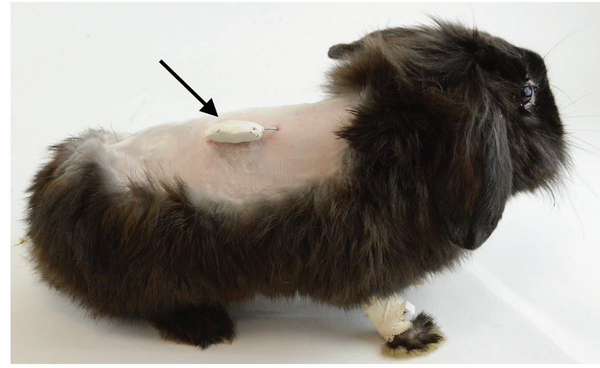

Figure 4—Photograph of a 2-year-old at 72 hours after stabilization of a vertebral fracture by a monolateral external fixator (arrow) placed percutaneously with fluoroscopy guidance.

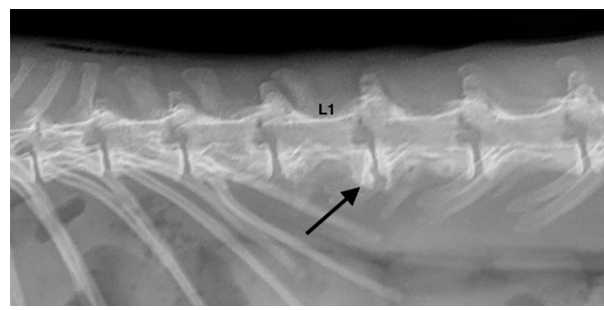

Figure 5—Lateral radiographic view of the thoracolumbar vertebral column 3 months after surgery showing complete healing of the fracture (arrow).

At follow-up 10 days after surgery, the clinical examination findings of the animal were normal. According to the owners, the rabbit had a good appetite and normal control over voluntary urination and defecation. Six weeks after surgery, the neurologic examination results were within normal limits, and the radiographs showed complete healing of the fracture; the external fixator was then removed. At the 3-month follow-up, neurologic examination findings were unremarkable, and radiographs showed complete healing of the fracture **(Figure 5)**.

Discussion

To the authors' knowledge, this is the first report describing the feasibility and successful outcome of a surgical repair of a vertebral fracture in a rabbit.

The surgical repair of any orthopedic injury is considered more difficult in rabbits than in dogs or cats due to the size and relatively brittle nature of rabbit bones.[5] Although rabbits have a haversian bone structure,[6] cortical bone is thinner in rabbits than in dogs or cats.[7] These findings have led to the conclusion that the prognosis for the successful surgical treatment of vertebral fractures and luxation in rabbits is poor.[2,4,8]

If prognosis of appendicular fracture is usually good,[9,10] there is a lack of published information on the treatment of rabbit spinal injuries. The majority of rabbit patients with these injuries are euthanized either before or after attempting medical therapy.[11,12] However, successful conservative treatment and medical management, including cage rest for 6 weeks, has been reported in a rabbit presenting with severe multifocal spinal trauma.[5] In dogs, evidence of minor compression and minimal to no neurologic dysfunction is an indication for conservative management, including strict confinement, generally for 4 weeks. In the present case, conservative management was not indicated due to the instability of the fracture and the risk of additional displacement and trauma of the spinal cord.

Decision criteria for surgery for vertebral fractures in rabbits needs to be further determined, but they should follow the same guidelines as those established for dogs and cats.[13]

The lack of bone strength in rabbits combined with their muscular hind limbs makes these animals susceptible to self-injury.[5] Self-injuries can occur when rabbits are frightened or handled inappropriately or when the muscular hindquarters are hyperextended, leading to hyperextension of the spine. When rabbits attempt to escape, their heavily muscled hindquarters twist at the lumbosacral junction. This movement can lead to disc damage, dislocations, and compression fractures that, in turn, may result in pelvic limb paresis or paralysis.[4,5,8,14] In addition, the presence of other neurologic signs may arise, such as urinary and fecal incontinence, depending on the severity of the spinal cord lesion.[15]

Neurologic examination is fundamental for the assessment and diagnosis of vertebral trauma in rabbits.[14,16] However, the findings of these exams in rabbits are more difficult to interpret than those in dogs and cats due to the propensity of this prey species to “freeze” when frightened. The patient must be carefully handled to avoid additional injury. Postural abnormalities do not indicate the precise location of the injury since they can be caused by injuries in different areas of the nervous system. Paresis and plegia are often caused by injury to the voluntary motor pathway, which runs from the cerebral cortex to the peripheral nerves.[14] Sedatives or opioids should not be administered before examination. Moreover, it is important that the rabbit is as relaxed as possible.[14,16]

The loss of deep pain perception, which involves severe and extensive damage to the most resistant nerve fibers, is an extremely important clinical sign related to poor prognosis. It is essential to be able to assess the perception of pain in an animal and to be able to differentiate between the unconscious reflex withdrawal of an extremity and the conscious perception of pain.[14] In dogs and cats, thoracic or lumbar vertebral column injuries have a good prognosis when nociception is intact.[13] In this case, the patient exhibited a normal deep pain sensation. This finding was crucial, as it motivated the owners to pursue treatment instead of euthanasia.

Although radiographs can allow the visualization of spinal fractures, they do not always provide complete identification and precise location of the fractures. In dogs, radiography has been reported to have only moderate sensitivity for fractures (72%) and luxation (77.5%).[17] Radiography appears to be particularly poor at detecting fractures in the middle and dorsal vertebral compartments, and thus may overestimate the stability of some fractures.[7,9,13] In addition, it is not sensitive for detecting the presence of fracture fragments within the vertebral canal, or spinal cord compression.[13,18] Moreover, the lack of displacement at the moment when radiographs are obtained does not eliminate the possibility that severe displacement has occurred at the time of injury and that the lesion is unstable.[13] Therefore, additional imaging is indicated to explore such injuries, as precise determination of the nature and the extent of the lesions will help to determine which surgical procedure will be chosen and the prognosis.

Myelography can be used to evaluate cord compression; however, this technique provides little information about spinal cord hemorrhage or the potential for future insult from unstable lesions.[17] In addition, in positioning a patient with an unstable spine for cervical or lumbar injection of contrast medium, myelography poses risks to the patient. Due to the potential risks to small species such as rabbits (including death, seizures, and the exacerbation of clinical signs),[17,19] myelography was not considered in this case.

CT scans are the imaging modality of choice for the diagnosis of osseous lesions in patients with spinal cord injury.[2,14,17,20,21] In addition, compared with traditional radiograph techniques and myelography, this modality offers the advantage of reduced patient manipulation.[5]

Although CT myelography is a sensitive technique for the identification of compression,[20] it is technically challenging and potentially damaging to rabbits because of their small size.[2]

MRI is preferred over CT for evaluating soft tissue injuries such as spinal cord injuries (spinal cord edema and myelomalacia), but as osseous details are poorly displayed on MR images compared with CT scans,[21] some osseous lesions may not be detected.[2,14,21] For these reasons, the selected imaging modality in this case was CT.

In dogs and cats, the indications for surgical intervention include compressive or unstable lesions.[13,18,22] Surgery has been performed for 2 cases of spinal disease in rabbits,[2,3] but these cases did not involve fractures.

The minimally invasive fluoroscopic technique we used on this rabbit is a technique which has revolutionized surgery in human patients, resulting in significantly less severe postoperative morbidities and fewer days of hospitalization.[23,24] The fluoroscopically guided percutaneous placement of pins for spinal stabilization is currently performed in human patients and has been reported in dogs for vertebral fractures, with excellent results.[25,26] This technique provides accurate visualization of vertebral bodies, allowing precise control over pin placement and better reduction. Furthermore, compared with open surgical approaches, fluoroscopically guided placement decreases the amount of tissue dissection needed and lessens the degree of uncertainty involved in placing pins near the spinal cord, spinal nerves and vessels.[25] Therefore, this technique decreases the occurrence of postoperative complications and morbidities and allows for an earlier recovery of function than similar open surgery approaches.[27,28]

The surgical time for other vertebral surgery cases in rabbits has not been reported; in our case, it was 40 minutes. Therefore, it is not possible to compare this critical aspect (surgical time) of the treatment with respect to our closed procedure and that of open techniques. If the fluoroscopically guided technique requires a shorter surgical time, it could contribute to increasing the overall prognosis of the injury. A large-scale prospective study reported a general perianesthetic mortality rate of healthy pet rabbits of 1.39%, which is 5 times higher than that found in dogs and cats.[29-31] Given the multiple perianesthetic changes in biological functions, it is possible that a shorter surgical duration increases the chance of improving the patient's condition and decreases the morbidity and/or mortality risk.

In dogs, the main pitfalls of external fixation are implant breakage, pin tract inflammation/infection and the need for specialized postoperative care.[18,25] None of these complications were observed in the patient in this report.

In conclusion, rabbits with paraparesis or paraplegia with deep pain sensation following a spinal fracture may regain full neurologic recovery after surgical stabilization. Surgically repairing an unstable vertebral fracture in a rabbit is challenging, but it may have a better prognosis than previously thought. The results of neurologic examination and adapted imaging testing should be initially considered to determine the best option among surgery, conservative treatment and euthanasia. Intraoperative fluoroscopy is feasible for the placement of external fixators, does not require access to the fracture site, and is effective in rabbits. This technique allows accurate fracture stabilization without incisions and therefore minimizes the occurrence of complications and postoperative pain. Utilizing this technique may yield better outcomes than other open technique to produce a better prognosis in this fragile species.

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