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Clinical presentation, imaging characteristics, and short-term outcome of eight cats presented with suspected traumatic atlantoaxial hyperflexion

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Abstract

Traumatic atlantoaxial hyperflexion is considered rare in cats, and only a few case reports have been published. There are other conditions that can result in a peracute onset of neurological signs localized to the cervical spinal cord segments, including acute noncompressive nucleus pulposus extrusion, ischemic myelopathy, or vertebral fractures. Appropriate treatment for these conditions can only be initiated after an accurate diagnosis has been obtained. The aim of this observational, retrospective, single-center, descriptive case series study was to describe the clinical presentation, imaging characteristics, and short-term outcome of eight cats presented with suspected traumatic atlantoaxial hyperflexion. Young male healthy domestic shorthair cats were overrepresented (7/8) and typically presented with a peracute, nonprogressive, nonpainful, nonlateralizing C1–C5 myelopathy (tetraplegia or nonambulatory tetraparesis) following a road traffic accident or head trauma. All MRI studies demonstrated a solitary, focal, ill-defined intramedullary lesion immediately dorsal to the dens of the axis, affecting both grey and white matter. All cats were treated medically. In 50% of the cats, the neurological grade improved at discharge or short-term follow-up, 25% of the cats recovered completely, one cat was static at short-term follow-up, and one cat was euthanized due to persistent forebrain signs and lack of neurological improvement.

KEYWORDS
cervical, dens contusion, feline, peracute C1–C5 myelopathy, tetraplegia

1 | INTRODUCTION

Traumatic atlantoaxial hyperflexion or "dens contusion" is considered rare in cats. To date, only a few cases have been reported that shared similar clinical presentations consisting of a peracute onset of neurological signs following a traumatic event.[1–3] Neurological signs can range from borderline ambulatory tetraparesis to tetraplegia. High-rise syndrome, falling from stairs, running into a door, and forelimb collapse have been reported as possible causes of trauma. Diagnostic imaging features can be slightly variable with[1,2] or without[3] signs of atlantoaxial instability or subluxation, but in most cases, MRI revealed a solitary, focal, ill-defined, intramedullary region of increased signal intensity in T2W images, immediately dorsal to the dens and affecting both grey and white matter. Both medical and surgical treatments have been reported. The latter has been only reported in cases of concurrent atlantoaxial instability.[1,2] Prognosis is generally considered good but can vary from rapid neurological improvement with full recovery[1,3] to lack of improvement with failure to become independently ambulatory, leading to euthanasia.[2] It is clear that cats can be affected by different conditions which can result in a peracute onset of neurological signs localized to the cervical spinal cord segments immediately following external trauma, including acute noncompressive nucleus pulposus extrusion (ANNPE) or other types of trauma such as vertebral fractures.[4,5] Ischemic myelopathy is generally not associated with trauma but can share a similar clinical presentation and MRI features.[6,7] These conditions can be managed by a variety of treatment strategies, ranging from intense physiotherapy to complex spinal surgery. Appropriate treatment can only be initiated after an accurate diagnosis has been obtained. The aim of this study was, therefore, to report the clinical presentation, imaging characteristics, and short-term outcome in a cohort of cats presented with suspected traumatic atlantoaxial hyperflexion.

2 | MATERIALS AND METHODS

2.1 | Study design and subject selection

This study was an observational, retrospective, single-center, descriptive case series study. Digital medical records from the Royal Veterinary College (RVC) were searched using the following keywords: "C1", "C2", "atlas", "axis", "atlantoaxial", "dens", "hyperflexion", "cat", "feline", and "contusion". Ethical approval was granted by the Clinical Research Ethical Review Board at the Royal Veterinary College (URN SR2023 - 0038) to obtain long-term follow-up through the referring veterinarian. Inclusion criteria included feline patients that presented to the small animal referral hospital with a confirmed or highly suspected traumatic episode, peracute onset neurological signs compatible with a C1–C5 myelopathy, and a focal, intramedullary spinal cord MRI lesion immediately dorsal to the dens of the axis. Animals with no evidence of trauma and/or peracute neurological signs or MRI features compatible with ANNPE, vertebral fracture, or ischemic myelopathy were excluded. Patients were also excluded if the MRI or CT did not allow a complete evaluation of the cervical region. Decisions for the inclusion or exclusion of cats were based on a consensus between a board-certified veterinary neurologist (S.D.D., European College Veterinary Neurology [ECVN]), a board-certified veterinary radiologist (E.F., European College Veterinary Radiology [ECVDI]), and a third-year diagnostic imaging resident (C.L.). Shapiro–Wilk test was used to evaluate the normality of the data using commercially available statistics software (SPSS Statistics for Macintosh, Version 29.0.; IBMCorp.). Continuous variables with nonnormal distribution are presented as median values and range.

2.2 | Clinicopathological data recorded

The following clinical data was recorded: age, gender, neutering status, breed, weight, suspected or confirmed cause of trauma, and clinical and neurological examination findings. Neuroanatomical localization and lateralization, if present, were recorded. The neurological grade was classified according to Scott et al.,[8] as follows: tetraplegia with absent deep pain sensation (grade 5), tetraplegia with intact nociception (grade 4), nonambulatory tetraparesis (grade 3), ambulatory tetraparesis (grade 2), spinal pain (grade 1), and normal (grade 0). The outcome was classified as improved spinal cord injury grade with or without complete recovery, static spinal cord injury grade, deteriorated spinal cord injury grade, or deceased. Any additional procedures (e.g., surgery) and postmortem examinations were recorded when available. Biochemistry, complete blood count, and results of cerebrospinal fluid (CSF) analysis were recorded. Concurrent systemic diseases were also recorded. A telephone call and/or follow-up email was sent to the referring veterinarian to obtain long-term follow-up.

2.3 | Image acquisition and image review

MRI of the cervical spinal cord was performed in all patients, and MRI of the brain was performed in 7 of 8 patients. The specific anatomical region subjected to MRI in this study was selected by the overseeing board-certified veterinary neurologist. This decision was based on a comprehensive evaluation of the patient's medical history and the findings obtained from the neurological examination. The studies were performed under general anesthesia using a 1.5 Tesla scanner (Intera Achieva; Philips Medical Systems). In each case, a five-element phased-array rigid surface coil was used to image the spinal cord, and a two element phased-array flexible coil was used to image the brain. All cats were positioned in dorsal recumbency. The anesthetic protocol was chosen by the anesthetist responsible for the case. T2-weighted (T2W) turbo spin echo (TSE) sequences in sagittal and transverse planes and T1-weighted (T1W) TSE precontrast sequences in sagittal and transverse planes were acquired in all patients. Other additional sequences acquired included: 2D T2W FLAIR, 3D T2W steady-state free precession balanced gradient echo (GE) in the transverse plane (5/8), T2*W-weighted (T2*W) GE in the transverse plane (6/8), Short Tau Inversion Recovery in the sagittal plane (4/8), and 3D T1W spoiled GE in the transverse plane (1/8). T1W postcontrast studies were acquired in six patients by intravenous administration of gadolinium (0.1 mmol/kg; Gadobutrol, Gadovist, Bayer, Bayer House) both in sagittal and transverse planes. The MRI technical parameters are summarized in Appendix 1 and Appendix 2. CT scan of the vertebral column was performed in dorsal recumbency. CT studies were acquired using a 320-slice helical multidetector CT scanner (Canon Aquilion ONE/GENESIS; Toshiba Medical Systems) or a 16-slice helical multidetector CT scanner (PQ 500, Universal Systems; GE Healthcare). All the studies were retrospectively reviewed on a digital workstation using an online imaging processing computer software (eUnity, v7.1.204, Mach7 Technologies). The studies were reviewed individually, followed by a consensual evaluation by a board-certified veterinary radiologist (E.F., European College Veterinary Radiology [ECVDI]), a third-year diagnostic imaging resident (C.L.), and a board-certified veterinary neurologist (S.D.D., European College Veterinary

Neurology [ECVN]). Reviewers were aware of the history, signalment, clinical, and neurological examination findings.

Images were assessed for a predefined list of MRI and CT features. Findings were evaluated and recorded in a standardized commercially available spreadsheet (Microsoft Excel 2024, Microsoft). The following intramedullary MRI features were recorded: number of lesions, border definition (ill-defined or well-defined), shape (if well-defined), margination (if well-defined), and classified as smooth or irregular, region affected (white matter, grey matter, both), lateralization (right, left, midline), size/extension (including the length of the lesion in sagittal images and the spinal cord cross-sectional area affected in transverse images), and signal intensity changes of the lesion relative to the normal spinal cord on T1W and T2W images. Intramedullary enhancement on T1W sequences was classified as present (mild, moderate, or severe) or absent. Signal void/susceptibility artifact in T2*W sequences was recorded if present. Swelling of the spinal cord and/or meningeal enhancement was subjectively assessed and recorded as present or absent. The osseous and soft tissue structures of the cranial neck were assessed for signs of occipito-atlantoaxial joint effusion (classified as present or absent) and signal intensity changes and/or contrast enhancement of the adjacent subcutaneous tissues and/or cervical muscles. Dens anatomy was evaluated, and any abnormalities were recorded (size, shape, and dens position relative to the atlas). Finally, atlantoaxial anatomy was assessed for widening of the interspinous or intervertebral space. The transverse, apical, alar, and dorsal atlantoaxial ligaments were assessed when identified for integrity and signal intensity changes. CT was available in 2 of 8 patients (1/2 dynamic) and radiographs in 3 of 8 patients (0/3 dynamic). Any additional findings on any of those modalities were also recorded.

2.4 | Postmortem examination and histopathology

A complete necropsy procedure was conducted on case 4 per standard protocol followed in the Diagnostic Laboratories of the RVC.

Brain and spinal cord tissue sections for histopathological evaluation were fixed in 10% neutral buffered formalin, routinely processed, sectioned at 4 µm, stained with hematoxylin and eosin, and examined with a light microscope by a board-certified veterinary pathologist (B.M.G., European College of Veterinary Pathologists [ECVP]). Masson's Trichrome and Luxol Fast Blue special stains were also performed.

3 | RESULTS

3.1 | Signalment, clinical, and neurological findings

Eight cats met the inclusion criteria. The median age was 6.5 years (range 1–15 years), and the median weight was 3.5 kg (range 2–5.3 kg). Seven males (five neutered and two entire) and one female neutered. All cats were domestic short hair (DSH) with the exception of one British Blue. Most of the cats (5/8) were thought to be involved in a road traffic accident, and 2 of 8 cats had a history of head trauma witnessed by the owner (case 4 was chased by a dog and ran into a pole, and case 7 ran into a door). The remaining cat (case 8) had a forelimb collapse in the kennel after a dental procedure. All cats presented with a peracute, nonprogressive, nonlateralizing (7/8), and nonpainful cervical myelopathy. Four cats presented as tetraplegic (grade 4) and four cats as nonambulatory tetraparetic (grade 3). Postural reactions were absent in all four limbs in all cats. Spinal reflexes were normal in seven cats and one cat (case 6) had a reduced patellar reflex bilaterally. Cranial nerves were normal in 7 of 8 cats. Case 3 had reduced oculovestibular reflex bilaterally and reduced menace response bilaterally, with present pupillary light reflex. Additionally, 4 of 8 cats were localized to diffuse forebrain and presented obtunded (3/4) or stuporous (1/4). A summary of the suspected/confirmed cause of trauma, neurological grade, and presence or absence of an underlying medical condition is outlined in Table 1.

3.2 | Diagnostic imaging findings

All MRI studies demonstrated a solitary, focal, ill-defined intramedullary lesion immediately dorsal to the dens of the axis, affecting both grey and white matter (Figures 1–5). The lesion was lateralized in three cases (always to the right) and involved 40% to 100% of the spinal cord cross-sectional area, extending from 3 to 8 mm in length. In 5 of 8 cats, the lesions were T2W hyperintense and T1W isointense (Figures 1, 2, and 5). The remaining lesions (3/8) were T2W hypointense and T1W iso to hypointense (Figures 3, 4). In two of these cases, the focal T2W hypointense lesion was surrounded by a T2W hyperintense rim (cases 3 and 5). In case 4, the focal hypointense lesion was surrounded by diffuse T2W hyperintense signal affecting the cranial cervical spinal cord (extending from the medulla oblongata to the cranial endplate of C5). T1W postcontrast series were acquired in 6 of 8 patients. Intramedullary enhancement was present in 5 of 6 cases; mild in 3 of 5, moderate in 1 of 5, and marked in 1 of 5 of the cases. Meningeal enhancement was not identified. T2*W was acquired in 6 of 8 patients. No signal void was identified in the T2*W gradient echo sequence in any patient. Spinal cord swelling was noted in 7 of 8 patients (Figures 1, 2). MRI of the brain was performed in 7 of 8 cases and was considered normal in all cases.

The shape of the dens was normal in 6 of 8 cases. In cases 4 and 5 (Figure 4), the dens was fractured at the apex. The position of the dens relative to the atlas was normal in 6 of 8 cases. In two cases (cases 1 and 5), the dens was slightly caudally located relative to the ventral arch of C1, with resultant widening of the atlantoaxial articulation. The transverse ligament was identified in most cases (6/8) but only clearly delineated in cases where a 3D T2W GE sequence was acquired. This ligament was ruptured in 2 of 8 cases (cases 1 and 2). A clear defect was identified in case 1 (Figure 1). In case 2 the ligament had a pendulous appearance. The contour of the lateral mass of the atlas at the attachment of the transverse ligament was asymmetric; a small separate bone fragment was noted within the vertebral

TABLE 1 Signalment, cause of trauma, neurological examination, underlying diseases, and outcome of eight cats with suspected atlantoaxial hyperflexion.

Signalment						Neurological examination			Outcome (follow-up; complete recovery = 1, improved = 2, static = 3, deteriorated = 4, deceased = 5
Case	Age (years)	Gender	Breed	Weight (kg)	Cause of trauma	Neurological grade	Hyperaesthesia	Underlying diseases	
1	8	MN	DSH	3.2	RTA	Tetraplegic[4]	No	No	1 (2 months)
2	5	MN	British Blue	5.3	RTA	Nonambulatory tetraparetic[3]	No	No	2 (grade 2 at 1 month)
3	9	ME	DSH	4.5	RTA	Nonambulatory tetraparetic[3]	No	No	2 (grade 2 at follow-up email >1 year)
4	4	MN	DSH	5	Head trauma	Tetraplegic[4]	No	No	5 (euthanized in hospital due to lack of clinical improvement)
5	1	MN	DSH	3.1	RTA	Tetraplegic[4]	No	No	2 (grade 2 at discharge)
6	1	ME	DSH	2	RTA	Nonambulatory tetraparetic[3]	No	No	3 (static at 2 weeks follow-up)
7	15	MN	DSH	3.3	Head trauma	Nonambulatory tetraparetic[3]	No	Hyperthyroidism Hypertension	1 (6 months)
8	9	FN	DSH	3.7	Forelimb collapse	Tetraplegic[4]	No	No	2 (grade 2 at discharge)

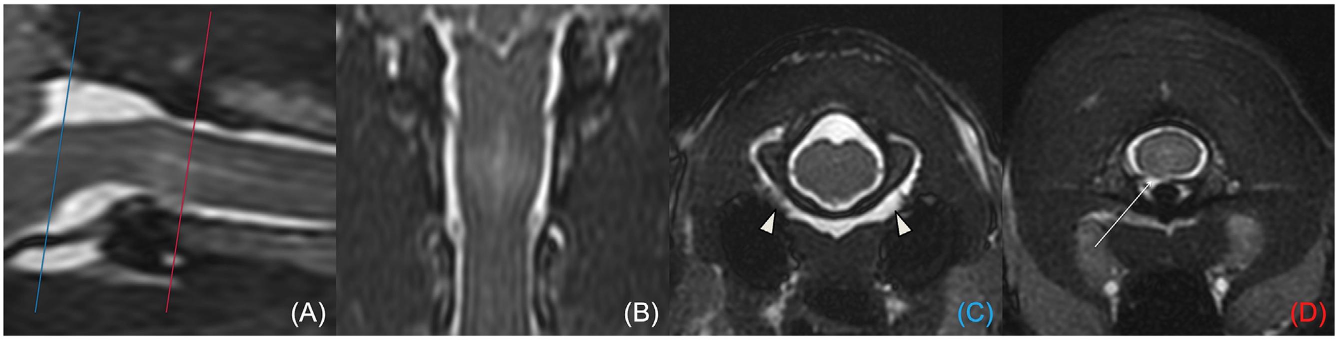

FIGURE 1 Case 1. 3D T2W steady-state free precession balanced GE sequence MPR in sagittal (A), dorsal (B), and transverse planes at two different levels (C and D). A, B, Solitary, ill-defined, T2W hyperintense intramedullary lesion affecting both grey and white matter immediately dorsal to the dens of the axis. B, Spinal cord swelling which is best appreciated in the dorsal MPR reconstruction. C, Moderate occipito-atlantoaxial joint effusion (arrowheads). D, Defect in the transverse ligament of the atlas (arrow). This was not clearly depicted in TSE sequences.

canal located immediately cranial to the attachment. These changes were only identified in the 3D T1W GE sequence and CT images (Figure 2D, F). A presumptive diagnosis of right-sided transverse ligament avulsion was made. The alar ligaments were identified in 7 of 8 cases but only clearly defined in cases where 3D T2W GE sequences were acquired. Occipito-atlantoaxial joint effusion was identified in 5 of 8 cats (Figure 1), and most of the cats (6/8) had regional paravertebral muscular signal intensity changes and contrast enhancement (Figure 5).

Radiographs of the neck were performed in an additional 3 of 8 cases and were all deemed normal. A dynamic study was only performed in case 4 (dynamic CT) with no signs of instability. No other dynamic radiographic or CT studies were performed.

3.3 | CSF, biochemistry, and hematology findings

CSF analysis was performed in 3 of 8 cases. In 2 of 3 cases, the sample was performed at the cerebellomedullary cistern, and in 1 of 3 cases, lumbar puncture. In case 3, the sample was considered nondiagnostic due to blood contamination. In case 4, an elevated white blood cell count was observed (30 TNCC, 1.68 g/L protein, 300 RBC/mm^3). In case 6, an increased protein concentration was observed (2 TNCC, 0.47 g/L protein, 200RBC/mm^3).

Biochemistry with or without hematology was performed in 6 of 8 cases. In three cases, CK was elevated. In case 1, CK was 1697 U/L (ref 52–506); in case 6, CK was 3438 U/L; and in case 7, it was 671 U/L. Two cats had mild anemia, both 23% PCV (ref 25–45%).

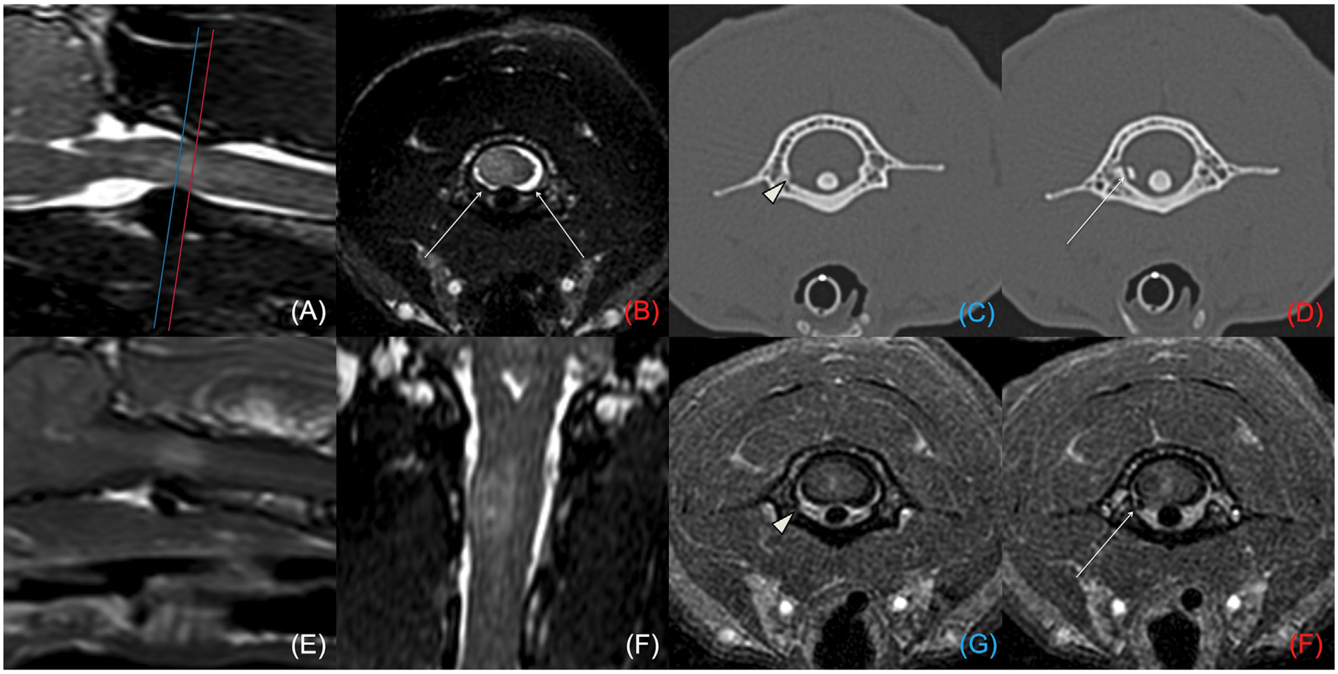

FIGURE 2 Case 2. 3D T2W steady-state free precession balanced GE sequence MPR in sagittal (A), transverse (B), and dorsal (F) planes, T1W TSE postcontrast sagittal image (E) and transverse CT bone reconstruction and 3D T1W spoiled GE sequences at two different levels (C, G and D, F). A solitary, ill-defined, T2W hyperintense, T1W isointense contrast-enhancing intramedullary lesion (lateralized to the right) affecting both grey and white matter is identified immediately dorsal to the dens of the axis (A, B, E, F). Note the pendulous appearance of the transverse ligament identified in (B, arrows). A well-defined, small (2.5 mm) mineral bone fragment within the right side of the vertebral canal is identified lateral to the dens of the axis in (D, F, arrow). An asymmetry at the level of the right lateral mass of the atlas in the region of the attachment of the transverse ligament of the dens is identified in (E, arrowhead). A presumptive diagnosis of right-sided avulsion fracture of the lateral attachment of the transverse ligament of the atlas was made.

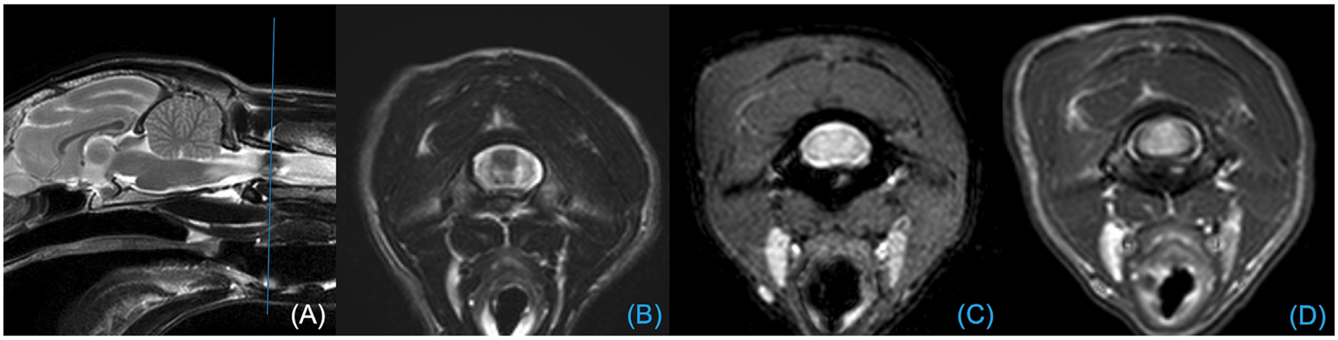

FIGURE 3 Case 4. T2W TSE in sagittal (A) and transverse (B) planes, T2*W GE in the transverse plane (C), and T1W TSE postcontrast transverse image. Focal T2W hypointense intramedullary lesion (A, B) with no signal void on T2*W (C) and marked contrast enhancement (D). The lesion was surrounded by a diffuse intramedullary T2W hyperintense signal affecting the cranial cervical spinal cord (A, B). Histopathology was compatible with spinal cord fibrosis.

3.4 | Outcome

All cases were treated medically. The outcome is outlined in Table 1. Only one referring veterinarian provided long-term follow-up (case 3). Two cats (cases 1 and 7) made a complete recovery at 2 and 6 months, respectively. In four cases the neurological grade improved. Cases 5 and 8 were initially tetraplegic and became ambulatory tetraparetic on discharge with no further follow-up. Cases 2 and 3 were initially nonambulatory tetraparetic and became ambulatory tetraparetic at 1-month follow-up for case 2 and at a long-term follow-up email with the referring veterinarian for case 3. Case 6 was static at 2 weeks follow-up, and case 4 was euthanized 6 days after the initial trauma (3 days after admission to the RVC) due to lack of clinical improvement.

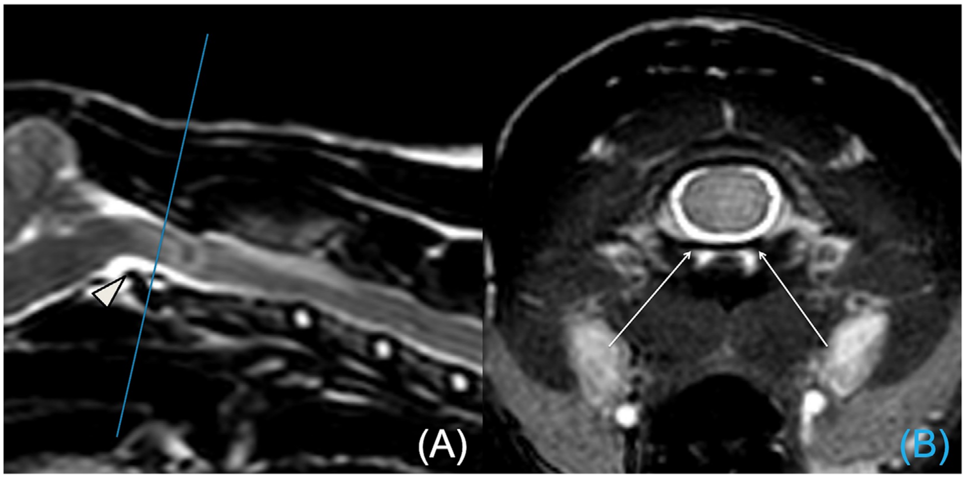

FIGURE 4 Case 5. T2W TSE in sagittal (A) and 3D T2W steady-state free precession balanced GE sequence in transverse (B) planes. Focal lesion similar to case 3 and presumably compatible with spinal cord hemorrhage (A). Note the normal shape of the transverse ligament compared with cases 1 and 2 (B, arrows). The dens is caudally positioned and a small mineral fragment compatible with a chip fracture of the dens is identified (arrowhead).

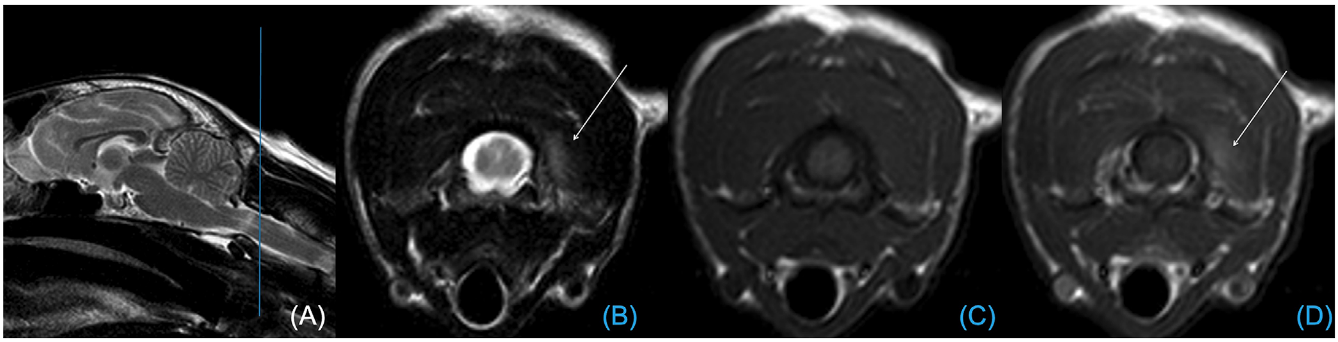

FIGURE 5 Case 8. T2W TSE in sagittal (A) and transverse (B) planes and T1W TSE pre (C) and postcontrast (D) showing a similar T2W hyperintense intramedullary lesion immediately dorsal to the dens (A). There is an increased T2W signal with moderate contrast enhancement of the left obliquus capitis caudalis muscle (B, D arrows).

3.5 | Postmortem examination and histopathologic findings

A gross examination performed on case 4 revealed extensive bruising over the cranium and dorsal cervical region. In the ventral aspect of the brain, at the level of the optic chiasm, there was a blood clot associated with extensive leptomeningeal hemorrhage. Serial slicing of the formalin-fixed brain did not reveal any other abnormalities, whereas serial sectioning of the formalin-fixed cervical spinal cord confirmed a focal area of discoloration of the second cervical spinal cord segment. Microscopically, bilateral, marked disruption of the grey and white matter by an ill-defined and insidious mass was observed (Figure 6B, D), which consisted of fibrosis and neovascularisation extending inwards from the meninges (Figure 6F). Masson's Trichrome special stain confirmed and highlighted the replacement of the parenchyma by mature fibrous tissue (i.e., collagenous fibers; Figure 6F). Leukomalacia, axonal swelling, and spheroids were also prominent features (Figure 6B), and demyelination of dorsal and ventral spinal tracts was better characterized by Luxol Fast Blue special stain (Figure 6D).

4 | DISCUSSION

In this case series, we report eight feline patients with suspected traumatic atlantoaxial hyperflexion. In our cohort, this condition more commonly affects young male healthy cats and presents with a peracute, nonpainful, nonlateralized C1–C5 myelopathy following a road traffic accident or head trauma. Thus, this condition should be considered an important differential diagnosis in cats that present with nonambulatory tetraparesis or tetraplegia after a traumatic incident. The present study emphasizes the importance of diagnostic imaging to differentiate this condition from other peracute cervical myelopathies such as ANNPE, ischemic myelopathy, or vertebral fractures. MRI features are relatively consistent and in agreement with previous case reports[1–3]

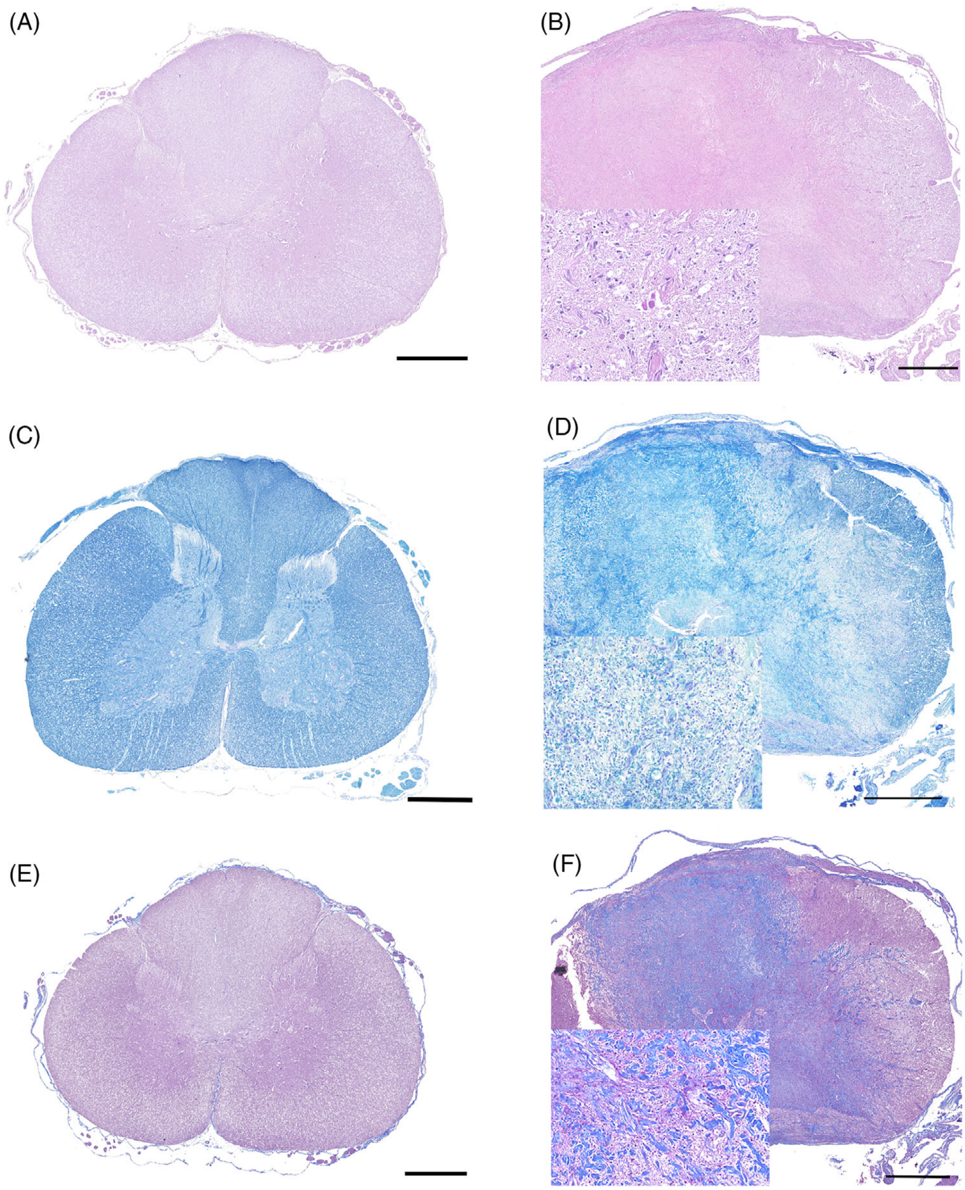

FIGURE 6 Case 4. Histopathology. A and B (hematoxylin and eosin), C and D (Luxol Fast Blue), and E and F (Masson's Trichrome). A, C, E, Sagittal sections of the normal cervical spinal cord. Note the characteristic central "butterfly" shape of the grey matter, the intensely blue myelinated white matter (C), and the blue-stained leptomeninges (E). B, D, F, Sagittal sections of the affected C2 spinal cord segment. B, D, Bilateral, marked disruption of the grey and white matter by an ill-defined and insidious mass, consistent with fibrosis and neovascularisation extending inwards from the meninges (B and F). There is a prominent replacement of the parenchyma by collagenous fibers (inset F). Notably, leukomalacia, axonal swelling, and spheroids are observed (inset B), as well as demyelination of dorsal and ventral spinal tracts (inset D).

and characterized by a solitary, focal, ill-defined intramedullary lesion immediately dorsal to the dens of the axis, which affects both grey and white matter. Also, in agreement with previous literature, these patients can have a good prognosis despite the severity of the initial neurological signs.[1–3] This is especially important when considering the noninvasive and relatively inexpensive nature of treatment.

Most of the patients were young male domestic shorthair cats with a median age of 6.5 years. Previous studies have reported that young males and crossbreed cats were 1.3 and 1.9 times more likely to be involved in road traffic accidents, respectively.[9] Similarly in humans, traumatic brain injury is more common in children and three times more common in males than in females.[10] Case 7 (15 years) was the only patient over 9 years of age and was the only patient with concurrent comorbidities (hyperthyroidism and hypertension). Based on the witnessed trauma (running into a door) and spinal cord changes dorsal to the dens affecting both grey and white matter, this patient was included in the study. The clinical presentation of this cat shares several characteristics with ischemic myelopathy. Ischemic myelopathy commonly affects older cats with concurrent comorbidities and has a predilection for the cranial cervical spinal cord, particularly at C2, due to the narrowing of the ventral spinal artery.[6] Diffusion weighting imaging is the gold standard imaging technique for the diagnosis of ischemic lesions and has been shown to increase the sensitivity of spinal cord infarction in humans.[11] It appears to be technically feasible and useful in cats in the diagnosis of ischemic myelopathy and could be implemented in the protocol when clinically suspected.[12]

All cats presented peracutely with either tetraplegia or nonambulatory tetraparesis. In contrast, two out of the five previously reported cats presented with ambulatory tetraparesis.[1,2] Although a relatively wide spectrum of clinical signs can occur, most affected cats will present with severe neurological deficits. Additionally, four cats in our study were localized to diffuse forebrain. This additional neurolocalization has not been previously reported. One of the cats (case 4) who ran into a door presented stuporous and, due to lack of clinical improvement, was euthanized 6 days after trauma. The remaining cats with forebrain localization were considered obtunded. One of them also had a head trauma, and the other two were thought to be involved in a road traffic accident. Despite all these cats having normal brain MRI studies, it is not surprising that cats involved in head/neck trauma (particularly head trauma) may have exhibited at least transient forebrain neurological signs. Contusions, hematomas, or diffuse axonal injury (DAI) are considered the main causes of primary brain injury in humans and can result in a wide spectrum of neurological signs.[10] More importantly, the absence of MRI findings does not exclude the presence of small contusions or DAI.[13] Conventional MRI has a low sensitivity for DAI but diffusion tensor imaging has been shown to increase the sensitivity for detecting these lesions.[14] Case 4 underwent gross postmortem examination, which confirmed bruising over the cranium and a blood clot on the ventral aspect of the brain around the pituitary gland. Serial slicing of the formalin-fixed brain did not reveal any abnormalities further to the ventral meningeal hemorrhage noted at removal. That lesion was examined histologically and confirmed as a recent dissecting leptomeningeal hemorrhage in the region of the optic chiasm. This lesion was not identified in the MRI performed 3 days prior to euthanasia. The authors hypothesized that the lesion occurred either after the MRI study or during postmortem or the MRI was not sensitive enough to detect those lesions.

Concurrent atlantoaxial instability has been reported in 3 of 5 cats of the previously published case reports.[1,2] Two of these cases underwent surgical stabilization, with one cat making a complete recovery and the second being euthanized 6 months postoperatively due to failure to become independently ambulatory.[2] The third cat was treated medically and made a complete recovery.[1] None of our cases were thought to have instability. However, a dynamic study was only performed in one case. Hence, it is possible that some of these patients suffered concurrent atlantoaxial instability, which remained undiagnosed. Nevertheless, the majority of cats in this study improved with medical management, suggesting nonsurgical management is a reasonable consideration for atlantoaxial hyperflexion in patients with confirmed or suspected exogenous trauma. To the author's knowledge, no research has been published on cats to objectively diagnose atlantoaxial instability, making its diagnosis even more challenging compared with dogs.[15,16]

The reported spinal cord MRI changes are similar compared with previous studies[1–3] and were characterized by a solitary, focal, ill-defined intramedullary lesion immediately dorsal to the dens of the axis, affecting both grey and white matter. In humans with acute spinal cord injury, three types of patterns have been described: type I is compatible with spinal cord hemorrhage and characterized by heterogeneous T1W signal and a T2W hypointense lesion surrounded by a thin high signal peripheral rim, type II represents spinal cord edema and shows a T2W hyperintense, T1W isointense lesion and type III is referred as contusion or mixed pattern with features of both of the previous types.[17] Based on this, we classified our cases as having either spinal cord edema or hemorrhage. Interestingly, case 4 which underwent postmortem evaluation 6 days after trauma, did not fit into the above classification. Histopathologically, the lesion was characterized by marked disruption of the grey and white matter with fibrosis and neovascularization. Masson's Trichrome confirmed the replacement of the parenchyma by mature fibrous tissue. In the spinal cord hemisection injury model, fibroblast proliferation has been reported to occur as quickly as 3 days after the initial injury.[18,19] Considering this, it is possible that additional cases may have undetected fibrotic lesions. Spinal cord swelling (7/8) and contrast enhancement (5/6) were common findings. Spinal cord swelling and edema after spinal cord injury is one of the first observations after injury and can last for days following trauma.[20] Disruption of the blood–spinal cord barrier after spinal cord injury allows extravasation of contrast and has been suggested to have higher sensitivity for the detection of spinal cord edema in humans.[21,22]

In addition to the above-reported spinal cord changes, a variety of osseous, ligamentous, and soft tissue changes were identified. These include occipito-atlantoaxial joint effusion, which was seen in 5 of 8 cases, transverse ligament rupture or avulsion seen in three cats, and fracture of the dens identified in two cases. These changes are not commonly seen with other acute cervical myelopathies and may aid the diagnosis of this condition. The authors recommend including a T2W 3D sequence to assess the ligamentous structures and CT (or T1W or PDW 3D sequences) to assess bony structures. In 2 of 2 cases, CT provided additional information or increased the conspicuity of the MRI lesions. Adjacent muscular signal intensity changes were identified in 6 of 8 patients. Abnormal epaxial muscular signal intensity, both unilateral and bilateral, has been found in 23% of dogs diagnosed with presumptive fibrocartilaginous embolism.[23] Although this feature has not been described in cats with ischemic myelopathy, abnormal muscle hyperintensity should not be used as a sole feature to differentiate both conditions.

All the patients in this study were treated medically and the overall outcome was considered good. Two cats made a complete recovery; in four, the neurological grade improved, one cat was static at 2 weeks follow-up, and one cat was euthanized. The latter is due to ongoing tetraplegia, stuporous mentation, and lack of neurological improvement.

This study is limited by its retrospective nature, which includes nonstandardized MRI sequences and record-keeping. Small sample size, limited CT, and dynamic studies performed and lack of histopathology in most cases are further limitations. However, all these patients had similar clinical presentations with peracute neurological signs following a traumatic event, presented either tetraplegic or nonambulatory tetraparetic, and were all neurolocalized at C1–C5 spinal cord segments. Thus, diagnostic imaging was invaluable for reaching the correct diagnosis. Despite the initial severity of neurological signs, medical management provided a good outcome in the majority of the cases.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA ACCESSIBILITY STATEMENT

Data supporting the results in this paper are available from the corresponding author upon a reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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