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Case Report

Conjoined Lumbosacral (L7-S1) Nerve Roots in a Dog

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Abstract: Vertebral and spinal cord anomalies are well known in veterinary medicine. However, nerve root anomalies are seldomly reported. In human patients, nerve root anomalies can cause back pain and radicular pain. In human medicine, nerve root anomalies are more often found in cadaveric studies than in imaging studies, representing the lack of advanced imaging in the past and the unawareness about these pathologies. Additionally, nerve root anomalies can mimic other pathologies in imaging studies. It is important to know about the anatomy of the individual patient not only for correctly localizing the pathology but also for surgical planning and to prevent iatrogenic trauma to the patient. Conjoined nerve roots are a type of nerve root anomaly described in human medicine and are defined as two nerve roots that either share a common dural envelope at some point during their course from the dural sac or that have their origin very close together in the dural sac. In humans, lumbosacral nerve roots are most commonly conjoined, and signs of pain may be associated with this anomaly. We report the magnetic resonance imaging finding of right-sided conjoined L7 and S1 nerve roots in a dog that presented with lumbosacral hyperesthesia. We postulate that it is possible that the conjoined nerve roots played a role in the clinical signs of this dog. This is an anomaly that has not been reported before in veterinary medicine.

Keywords: conjoined nerve roots; anatomical variant; cauda equina; canine

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1. Introduction

The spinal cord of the dog is an elongated structure of nervous tissue that plays a crucial role in processing and transmitting signals between the brain and the rest of the body. The spinal cord is divided into spinal cord segments. In the dog, there are 8 cervical, 13 thoracic, 7 lumbar, 3 sacral, and 5 caudal spinal cord segments. Each spinal cord segment has a pair of spinal nerves [1].

A spinal nerve is formed by the union of either the left or right dorsal and ventral nerve roots. The dorsal and ventral nerve roots consist of a variable number of rootlets. The dorsal rootlets that together form the dorsal nerve root are almost exclusively formed by afferent neurons. The cell bodies of the afferent neurons accumulate to form the spinal ganglion (also known as the dorsal root ganglion), which is strategically situated just outside the spinal cord, where the dorsal root exits the spinal column. The dorsal nerve root conducts stimuli from intero-, extero-, and proprioceptors. The ventral nerve root consists of efferent fibers that originate from visceral and somatic efferent (i.e., motor) neurons in the spinal cord. A spinal nerve is formed at the merger of the dorsal and ventral nerve roots and thus contains afferent and efferent neurons [1,2].

The proximal portion of the dorsal and ventral roots is covered by a common envelope of arachnoid and dura mater. More distal, before the dorsal and ventral nerve roots merge, each nerve root is situated in an independent envelope. The merged dorsal and ventral nerves leave the spinal canal as a spinal nerve. The spinal nerves leave the spinal canal through the lateral vertebral foramen (the first cervical spinal nerve), the intervertebral foramina (the second cervical spinal nerve until the seventh lumbar spinal nerve), or the dorsal and ventral sacral foramina (the sacral spinal nerves). After the spinal nerves have left the spinal canal, they branch into a dorsal branch, ventral branch, ramus communicans, and (recurrent) meningeal branch [1,2].

The vertebral column and the spinal cord grow at different rates after birth. The length of the spinal cord is less than the length of the vertebral column. The spinal cord ends approximately at the level of the sixth or seventh lumbar vertebra in dogs. The nerve roots that arise from the last spinal cord segments run a long way within the spinal canal to exit through their assigned intervertebral or sacral foramen. These caudally running, extended nerve roots together are called the cauda equina. The spinal nerves from the spinal segments L4 to S3 form the lumbosacral plexus after they leave the spinal canal. Spinal nerves anastomose to form the named 'peripheral' nerves [1,2].

For a veterinarian, it is important to know the normal anatomy of a dog to come to the right localization of the pathology and a correct diagnosis. Also, if surgical therapy is an option, knowing the anatomy is a prerequisite for optimal surgical planning and for the prevention of iatrogenic trauma to the patient. However, anomalies exist, and the spinal cord or vertebral column of an individual patient can differ from what is described in textbooks. Abnormally shaped vertebrae such as hemivertebrae, butterfly-shaped vertebrae, and, more recently, vertebral vascular canal dysplasia, or spinal malformations such as spinal dysraphism or arachnoid diverticula, are frequently diagnosed [3–5].

Diagnostic imaging capabilities in veterinary medicine have become more advanced over the years. Computed tomography (CT) and magnetic resonance imaging (MRI) are becoming more and more accessible for veterinary patients. With these imaging techniques, the anatomy of the vertebrae, spinal cord, and nerves can be studied in a living patient with minimal harm to the patient [6]. Now the anatomy of each individual animal can be visualized, and such information can be used to the benefit of diagnosis and clinical management.

We report the MRI finding of right-sided conjoined L7 and S1 nerve roots in a dog. An anomaly that has been reported in human medicine but has not been reported before in dogs. It is an anomaly that, in human medicine, might be related to back pain or radicular pain [7,8]. With this veterinary case report, we hope to create awareness in veterinary medicine for nerve root anomalies, and especially conjoined nerve roots, as they might be the cause of back pain in dogs.

2. Case Description

A 2-year-old female Australian Labradoodle was presented with a history of exercise intolerance and suspected hyperesthesia of the lumbosacral region. Treatment with 16 mg/kg gabapentin twice a day had resulted in some improvement in owner-reported signs of pain.

A general physical examination revealed no abnormalities. Neurological examination was normal aside from equivocal mild hyperesthesia upon palpation of the lumbosacral region.

An MRI study (1.5 Tesla, Canon Vantage Elan) of the lumbosacral region was performed (Figure 1). The study revealed mild degeneration and protrusion of the lumbosacral intervertebral disc. The right S1 spinal nerve showed an abnormal course. The right S1 spinal nerve followed the right L7 spinal nerve in a common dural sleeve up to the level of the right L7 spinal ganglion. The right L7 spinal ganglion appears to be larger than the left one. Whether there was a connection between the L7 spinal ganglion and the S1 spinal nerve could not be stated accurately based on the imaging study. From here, the right S1 spinal nerve followed the contour of the vertebral body to exit through the right S1 ventral sacral foramen (Figure 1).

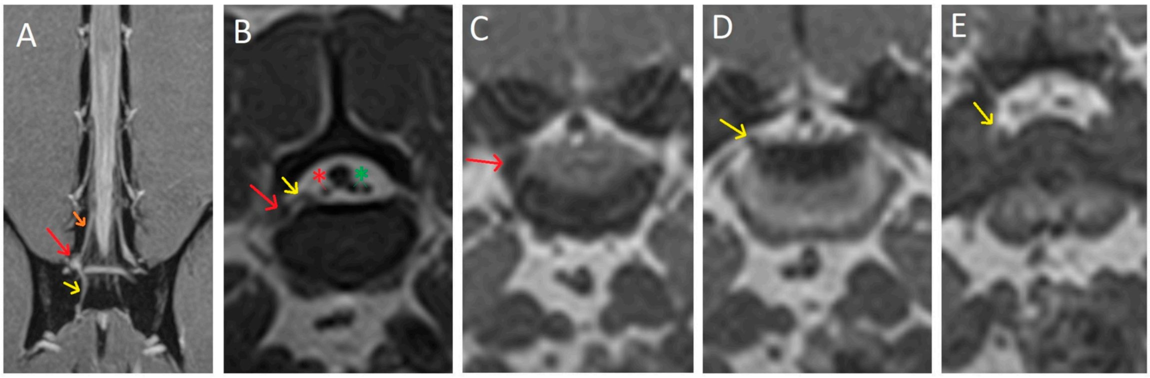

Figure 1. (**A**): 3D fast gradient echo combined with water excitation technique—dorsal plane. (**B**): T1-weighted transverse image at the level of the lumbosacral foramina. (**C**): 3D T1-weighted transverse reconstruction at the level of the L7 spinal ganglion. (**D**): 3D T1-weighted transverse reconstruction is slightly more caudal than C. (**E**): 3D T1-weighted transverse reconstruction at the level of the S1 ventral sacral foramina. Red arrow: right L7 spinal ganglion. Orange arrow: right L7 and S1 conjoined nerve roots. Yellow arrow: right S1 spinal nerve. Red asterisk: right S2 spinal nerve. Green asterisk: left S1 (lateral) and S2 (medial) spinal nerves.

A diagnosis of conjoined L7 and S1 nerve roots was formulated with unclear clinical relevance. It was deemed the most likely to represent a benign anatomical variant. Figure 2 depicts a schematic and simplified representation of the anomaly found in the presented case.

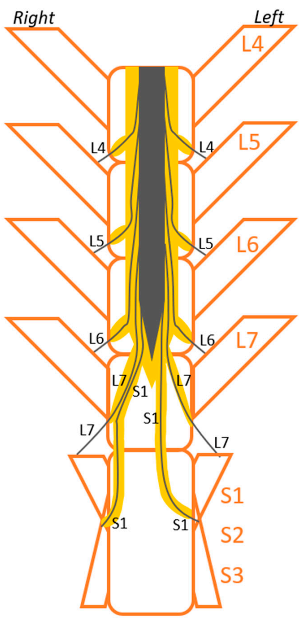

Figure 2. A schematic and simplified representation of the abnormal course of the S1 spinal nerve. The spinal cord and the spinal nerves are depicted in black, the dura in yellow, and the vertebrae in orange. The left spinal nerves L4 until S1 show their normal course. They exit from their spinal segment and course within the spinal canal, embedded in a dural sleeve, to their assigned intervertebral foramen, where they leave the spinal canal. The anomaly encountered in the presented case is shown by the right L7 and S1 nerve roots, which are conjoined. They leave the spinal cord in a common dural sleeve. The S1 spinal nerve initially follows the course of the L7 spinal nerve. At the level of the L7 spinal ganglion, the S1 spinal nerve continues its course within the vertebral canal in its own dural sleeve. It follows the inner contour of the vertebral body, and exits through the S1 ventral sacral foramen. The rest of the sacral spinal nerves (S2 and S3), or caudal spinal nerves, are not shown in this figure.

It was hypothesized that the conjoined nerve root could account for the lumbosacral hyperesthesia; however, it did not explain the exercise intolerance.

Treatment was continued with 16 mg/kg of gabapentin twice a day, and further workup of the exercise intolerance was advised. Based on the assessments of the owner of the dog, the medical treatment with gabapentin did not lead to a sufficient reduction in signs of pain. After two months, the owner discontinued the gabapentin and initiated alternative therapy (acupuncture). The dog was lost to follow-up thereafter.

3. Discussion

Unlike in veterinary medicine, nerve root anomalies have been reported in human medicine. A prevalence of 14–30% has been reported in cadaveric studies [7,9]. A classification of the different nerve root anomalies was made and adjusted over the years [8,10,11]. Nerve root anomalies are divided into conjoined (type 1), redundant (type 2), anastomotic (type 3), and confluent (type 4) nerve root anomalies [8].

Conjoined nerve roots are the most commonly reported nerve root anomaly in humans. Conjoined nerve roots are defined as two nerve roots that either share a common dural envelope at some point during their course from the dural sac (type 1A) or that have their origin very close together in the dural sac (type 1B). They usually occur unilaterally. The nerve roots that are most frequently involved are the L5 and S1 nerve roots (reported prevalence of up to 75% in human cadaver studies [7]), which are analogous to the L7 and S1 nerve roots in dogs [12]. The true cause of this anomaly is unknown, but it is hypothesized that aberrant migration of the involved nerve roots during embryonic development causes the conjoined nerve roots [13]. The nerve root anomaly in the patient presented in this case report is likely to be a Type 1A anomaly: conjoined nerve roots that arise from a common dural envelope. However, this can only be confirmed with surgical or post-mortem visualization.

It is known that anatomical variations in the origin of the nerves of the lumbosacral plexus and the connectivity of the lumbosacral ganglia in dogs exist. The nerves of the lumbosacral plexus are formed by multiple spinal nerves from different spinal cord segments, but how many spinal nerves and which spinal nerves contribute to a nerve of the lumbosacral plexus differ [14]. In 1970, a classification scheme was made of the different origins of the nerves of the lumbosacral plexus [15]. The classification was based on which spinal nerve contributed to a nerve, but more recent research has shown that there are more anatomical variations than in the classification scheme [14,15]. Also, lumbosacral sympathetic ganglia showed connectivity between the left- and right-ganglia from the same spinal cord segment, between adjacent ganglia on the same side, and between ganglia of more than two segments [14]. These studies show that (spinal) nerve and ganglionic variations or anomalies exist in dogs, but to the authors' knowledge, there are no previous reports about conjoined nerve roots or other nerve root anomalies in dogs.

Nerve root anomalies might be underreported in humans and dogs not only because of unawareness but also because imaging modalities have only relatively recently become advanced enough to accurately identify them. In human imaging studies, the incidence of nerve root anomalies is much lower than reported in cadaveric studies, namely 1.9–4% [7,16]. At the time of these imaging studies, the 1980′s, MRI was just invented, and imaging techniques were not as advanced as they are nowadays. At that time, CT scans were the modality of choice for diagnosing conjoined nerve roots, and a prevalence of 2% was found in 8000 scans [17]. Shortly after, opacification of nerve roots with metrizamide myelography and metrizamide CT has been shown to be helpful in diagnosing conjoined nerve roots [18]. Currently, MRI is deemed the superior imaging modality to visualize nerve roots, and this technique is more frequently available to veterinary patients. Dorsal (or coronal in human medicine) plane imaging allows for visualization of the course of several nerve roots simultaneously and is therefore most appropriate to screen for nerve root anomalies [12,19]. However, even with advanced imaging techniques, it remains difficult to diagnose nerve root anomalies since they can mimic signs of disc herniation or other extradural lesions [20]. There are several features of conjoined nerve roots that can help to distinguish disc herniations from nerve root anomalies with MRI. The density of the nerve root anomaly is less than that of disc material. Also, the location of the nerve root anomaly is at the level of the pedicle and not at the level of the intervertebral disc space, as is usually the case with herniated disc material. The presence of conjoined nerve roots should be considered with an asymmetrical subarachnoid space in the transverse (axial) plane [12].

Knowledge of the presence of nerve root anomalies before going into spinal surgery aids in surgical planning and increases the chances of a positive surgical outcome. However, since nerve root anomalies are difficult to diagnose with diagnostic imaging, nerve root anomalies are frequently identified for the first time in the operating room [12]. This increases the risk for iatrogenic trauma to the spinal nerves or even surgery at the wrong anatomic location [12,21,22]. Conjoined nerve roots are less mobile than normal nerve roots, and excessive traction to the conjoined nerve roots could potentially damage the nerve roots [12]. It has been shown that nerve root anomalies are one of the causes of failed spinal surgery, and additional surgical measures are sometimes needed to address the pathology completely [23]. Traditional discectomies in the presence of a conjoined nerve root have been shown to have a less satisfactory outcome [17,24–26]. One study showed that only 30% of the patients with lumbar disc disease and a conjoined nerve root that had been treated with a standard discectomy had a satisfactory outcome. With the addition of a pediculectomy, the success rate of the surgery increased to 87.5% [26].

In human patients, some authors believe that nerve root anomalies can cause signs of back pain or radicular pain, even in the absence of associated disc or bone pathology [7,8], but most authors only report clinical signs in patients where the malformed nerve roots were compressed or entrapped [10,16,27–29]. Because the abnormal nerve roots are less mobile, they are more easily affected by minor compressions such as disc herniations or protrusions [27]. Therefore, it is of utmost importance to diagnose nerve root anomalies in patients, because a nerve root anomaly with or without an otherwise insignificant other pathology could account for the pain the patient presented with.

In the presented case, the mild protrusion of the lumbosacral intervertebral disc alone is unlikely to be the cause of the hyperesthesia in the lumbosacral region. Therefore, we postulate that, as in human patients, dogs can experience back pain or radicular pain with conjoined nerve roots. The conjoined nerve roots found in the presented case may account for the signs of pain exhibited by this dog, and possibly the mild protrusion of the lumbosacral intervertebral disc adds to this pain.

4. Conclusions

Little is known about nerve root anomalies in dogs, and conjoined nerve roots have not been reported before in veterinary medicine. The case report above describes the finding of conjoined nerve roots on MRI in a dog that presented with signs of pain and the clinical finding of hyperesthesia in the lumbosacral area. In humans, it is thought that nerve root anomalies may be the cause of pain. It is important to diagnose nerve root anomalies before operating on the patient for proper surgical planning and to prevent iatrogenic trauma to the patient. However, it can be challenging to diagnose nerve root anomalies pre-operatively with diagnostic imaging because of the unawareness of the anomaly and because nerve root anomalies can mimic other pathologies with diagnostic imaging.

With this case report, we hope to create awareness for nerve root anomalies, especially conjoined nerve roots in dogs. Hopefully, this will result in nerve root anomalies being diagnosed more often with diagnostic imaging instead of intra-operatively or post-mortem. With the imaging diagnosis, a thorough surgical plan can be made, if necessary. In general, this will lead to a better overall outcome for our patients.

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Informed Consent Statement: The owners of the dog consented to the use of diagnostic imaging results for publication.

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