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Foraminal and paraspinal extraforaminal attachments of the sixth and seventh lumbar spinal nerves in large breed dogs

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ABSTRACT

Fresh cadaveric lumbar spines of 20 adult large breed dogs were used to study the sixth and seventh lumbar spinal nerves along their course through their respective intervertebral foramen. The relationship between the periosteum lining the vertebral canal (endorhachis; peridural membrane) and the vessels inside the vertebral canal, and the relationship between the nerves and the wall of the intervertebral foramen and the extraspinal suspensory apparatus were investigated.

Each intervertebral foramen contained a fibrous septum that divided it into two sub-compartments by connecting the fibrous capsule of the facet joints with the intervertebral disc and the adjoining vertebral body. The lumbar nerves and the main artery passed through the cranial sub-compartment and the main vein passed through the caudal sub-compartment. In all cases, there was a circumneural sleeve that connected the ventral branches of the lumbar nerves extraspinally with the fibrous capsule of the facet joints dorsally, the fibrous septum caudally, and the caudal vertebral notch and accessory process cranioventrally. The deep layer of the circumneural sleeve was formed by the periosteum lining the vertebral canal pouching laterally through the intervertebral foramen; the superficial (lateral) layer was formed by the deep sheet of the thoracolumbar fascia. The deep sheet of the thoracolumbar fascia continued cranially and caudally to the circumneural sleeve to attach it to the vertebral body and the intervertebral disc. Regional and individual differences were noted in the composition and length of the circumneural sleeve. The potential biomechanical and clinical roles of these variations are discussed.

Introduction

Lumbar spinal stenosis is a common cause of pain and neurological dysfunction and is diagnosed mainly in large dog breeds (Tarvin and Prata, 1980; Linn et al., 2003; Wood et al., 2004; Gödde and Steffen, 2007; Carozzo et al., 2008; Jones et al., 2008; Meij and Bergknut, 2010). The most common sites of involvement are the L6/7 and L7/S1 segments (Tarvin and Prata, 1980). Clinical signs can be related to stenosis of the central spinal canal causing impingement of the cauda equina and/or the associated vasculature, but might also be related to stenosis of the intervertebral foramina (Tarvin and Prata, 1980; Linn et al., 2003; Wood et al., 2004; Gödde and Steffen, 2007; Carozzo et al., 2008). In an earlier report, foraminal stenosis was considered rare in dogs (Tarvin and Prata, 1980). However, with the widespread availability of cross-sectional imaging modalities, recognition of foraminal stenosis and compressive radiculopathy of lumbar nerve roots has increased considerably (Linn et al., 2003; Wood et al., 2004; Gödde and Steffen, 2007).

Surgical procedures that address foraminal stenosis include extension of the dorsal laminectomy (Linn et al., 2003), an intraspinal endoscopic approach (Wood et al., 2004), and the lateral foraminal approach (Gödde and Steffen, 2007; Carozzo et al., 2008). However, the anatomy of the intervertebral foramen is poorly described in the published veterinary literature.

In contrast, numerous descriptions of the anatomy of the intervertebral foramen are available in human medicine. These suggest that, within the boundaries of the lumbar and lumbosacral intervertebral foramina, there is an intricate network of foraminal and/or extraforaminal ligaments that divide the foramen into multiple sub-compartments (Golub and Silverman, 1969; Amonoo-Kuofi et al., 1988; Transfeldt et al., 1993; Grimes et al., 2000; Wiltse, 2000; Gilchrist et al., 2002; Kraan et al., 2005; Min et al., 2005; Kraan et al., 2010). Additionally, foraminal attachments (Grimes et al., 2000; Wiltse, 2000) or suspensory ligaments (Transfeldt et al., 1993) are reported to tether the lumbar spinal nerves to the adjoining pedicles, vertebral body and/or intervertebral disc in humans. These ligaments are thought to be normal anatomical

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structures within the intervertebral foramen, which play a role in the protection of the nerve (Spencer et al., 1983; Amonoo-Kuofi et al., 1988; Grimes et al., 2000; Caglar et al., 2004; Kraan et al., 2005, 2010). However, some authors have postulated that foraminal and extraforaminal ligaments are a potential source of nerve root entrapment in some pathological conditions (Golub and Silverman, 1969; Amonoo-Kuofi et al., 1988; Hogan, 1991; Transfeldt et al., 1993; Grimes et al., 2000; Min et al., 2005).

The aim of the present study was to identify and describe the existence of ligamentous structures at lumbar levels L6/7 and L7/S1 that attach the lumbar spinal nerves to the tissues at the foraminal region in large breed dogs, to provide an anatomical basis for diagnostic imaging and surgery in the canine intervertebral foraminal region.

Materials and methods

Twenty fresh-frozen cadaveric lumbar spines of adult large breed dogs obtained within 48 h of death were examined. The dogs had been obtained from the Department of Pathology and Forensic Veterinary Medicine of the University of Veterinary Medicine, Vienna, and had been euthanased for medical reasons unrelated to this study. The sample was unselected to exclude pathological specimens and included four mixed breed dogs, three Great Danes, two each of German shepherd dogs, Golden retrievers and Dalmatians, and one each of Bernese mountain dog, Boxer, Bullmastiff, Doberman Pinscher, Hovawart, Newfoundland, and Rottweiler. Twelve dogs were male and eight were female. The dogs had a mean age of 8.3 ± 4.2 years (range 1–15 years) and a mean bodyweight of 39.0 ± 18.6 kg (range 17.5–89.0 kg).

While frozen, all spines were cut with a band saw in the mid-sagittal line (n = 40 specimens). Additionally, six specimens were cut horizontally through the centre of the vertebral canal so that laminectomy and facectomy could be performed, and 26 others were cut in the transverse plane at various levels of the intervertebral foramen L6/7 and L7/S1 ranging between the caudal border of the pedicle of L6 and L7 (next to the caudal vertebral notch), up to the level of the intervertebral disc L6/7 and L7/S1, respectively. In all specimens, the course of the sixth and seventh lumbar nerves through their respective intervertebral foramen and their relation to foraminal membranes and ligamentous, vascular and neural structures were dissected macroscopically and with mesoscopic magnification. If necessary, the transverse processes of lumbar vertebra 6 and/or 7 and/or the wing of the ilium were removed.

Changes recorded at the spinal levels examined included arthritic facet joints, degeneration of the intervertebral discs, osteophyte formation and hypertrophy of the interarcuate ligaments. If at least one of these changes was present, the segment was classified as degenerate and categorised by one person (SB) as follows: 1, subtle change; 2, degeneration clearly evident, or 3, segment severely altered, to assist the interpretation of the nature of any potential neural attachments. Otherwise, the segment was classified as 0, anatomically normal. Category 1 changes included osteophytes not protruding beyond the edge of the vertebral border into the intervertebral space, and/or a nucleus pulposus completely replaced by opaque white mass, and/or dull and slightly uneven articular cartilage of the facet joints. Category 2 lesions comprised osteophytes protruding beyond the edge of the vertebral border into the intervertebral space, and/or lesions of the intervertebral disc affecting annulus fibrosus and nucleus pulposus without disruption of annulus fibres, and/or circumscribed defects of the articular cartilage of the facet joints between normal areas. Category 3 lesions included bridging osteophytes, and/or disruption of fibres of the annulus fibrosus and/or subchondral lesions in the facet joints, and/or an interarcuate ligament at least twice as thick as normal.

Results

The majority of motion segments L6/7 were anatomically normal (category 0, n = 12/20; category 1, n = 4/20; category 2, n = 4/20; category 3, n = 0/20), whereas <50% of the L7/S1 segments were categorised as 0 (category 0, n = 7/20; category 1, n = 4/20; category 2, n = 4/20; category 3, n = 5/20).

Foraminal and paraspinal extraforaminal attachments of the sixth and seventh lumbar nerves were found bilaterally at all levels examined (n = 80 intervertebral foramina). However, the appearance of these attachments was highly variable.

Medial entrance zone of the intervertebral foramen L6/7 and L7/S1

No major differences in the structures attaching the spinal nerve were noted between the levels L6/7 and L7/S1. The foramen was closed by the periosteum lining the vertebral canal (also known as peridural membrane or endorhachis) containing variable amounts of a dense circumneural venous network entering the lumbar intervertebral vein, which passed through the intervertebral foramen caudal to the lumbar nerve (Fig. 1B). These vessels predominately joined the caudodorsal aspect of the dorsal root ganglion (spinal ganglion) and the dorsal and ventral internal vertebral plexus.

The main arterial vessel (the spinal branch of the lumbar artery) was located cranial to the nerve, just between the nerve and the caudal vertebral notch of L6 and L7, respectively. Intraspinally, this vessel travelled along the ventral root of the lumbar nerve. At the intervertebral foramen it separated and the nerve was connected to the arterial vessel by a mesoneurium (Figs. 1A, B and 4E). The diameter of this artery and the length of the mesoneurial fold were variable, but its position and the presence of the mesoneurial fold were constant. The third structure identified at the medial wall was the origin of the dorsal branch of the lumbar nerve. This branch was constantly found originating at the level of the distal pole of the dorsal root ganglion (Figs. 1C and 4C). It originated lat-

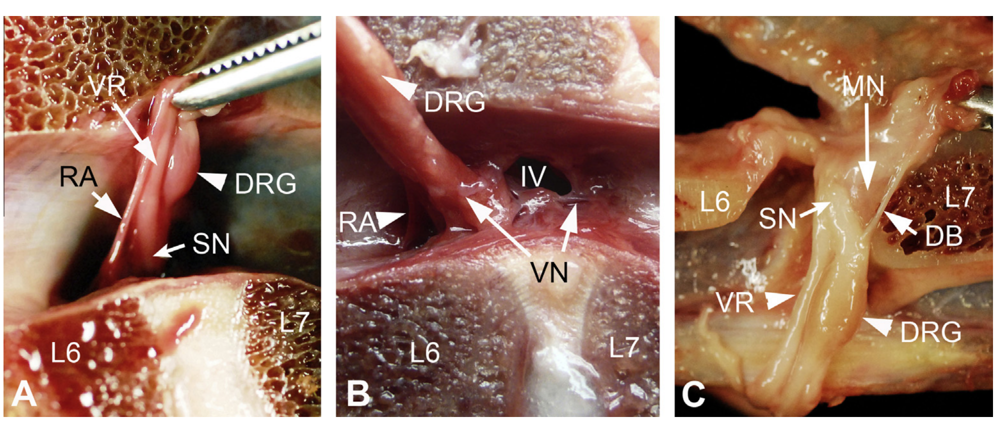

Fig. 1. Medial entrance zone of the right intervertebral foramen L6/7 in (A) an 8 year old male Great Dane and (B) a 1 year old male Great Dane in the medial view (sagittal section of the spine) and dorsal view of the right intervertebral foramen L6/7 (horizontal section) in (C) an 11 year old male mixed-breed dog. Note that the artery next to the ventral root (RA) is the largest arterial vessel and at the intervertebral foramen it is located between the ventral root (VR) of the spinal nerve (SN) and the caudal vertebral notch. A network of venous blood vessels (VN) joins the intervertebral vein (IV), which passes the intervertebral foramen caudal to the spinal nerve. The dorsal branch (DB) of the spinal nerve arises at the distal pole of the dorsal root ganglion (DRG). To allow better visualisation, the DB has been separated from the mesoneurial fold (MN) in which it travels.