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Review

Intervertebral disc degeneration in the dog. Part 1: Anatomy and physiology of the intervertebral disc and characteristics of intervertebral disc degeneration

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ABSTRACT

Intervertebral disc (IVD) degeneration is common in dogs and can give rise to a number of diseases, such as IVD herniation, cervical spondylomyelopathy, and degenerative lumbosacral stenosis. Although there have been many reports and reviews on the clinical aspects of canine IVD disease, few reports have discussed and reviewed the process of IVD degeneration. In this first part of a two-part review, the anatomy, physiology, histopathology, and biochemical and biomechanical characteristics of the healthy and degenerated IVD are described. In Part 2, the aspects of IVD degeneration in chondrodystrophic and non-chondrodystrophic dog breeds are discussed in depth.

Introduction

The canine spine consists of 7 cervical, 13 thoracic, 7 lumbar, 3 (fused) sacral, and a variable number of coccygeal vertebrae (Hansen, 1952; Dyce et al., 2010). The vertebral bodies of C2-S1 and all coccygeal vertebrae are interconnected by an intervertebral disc (IVD) (Dyce et al., 2010). The IVD is composed of a central nucleus pulposus (NP), an outer annulus fibrosus (AF), the transition zone (TZ), and cartilaginous endplates (EPs) (Fig. 1).

Degeneration of the IVD is a common phenomenon in dogs and can lead to disease (Brisson, 2010; da Costa et al., 2006; Meij and Bergknut, 2010). IVD degeneration is known to predispose dogs to Hansen type I cervical and thoracolumbar disc herniation (Hansen, 1952) and Hansen type II disc herniation diseases, such as degenerative lumbosacral stenosis (DLSS) (Meij and Bergknut, 2010) and cervical spondylomyelopathy (CSM) (da Costa et al., 2006). However, IVD degeneration is also a common incidental finding in dogs without clinical signs of disease (Hansen, 1952; da Costa et al., 2006; De Decker et al., 2010).

The first case report of IVD degenerative disease in a dog was published in 1881 and involved a Dachshund with sudden onset of hind limb paralysis (Janson, 1881, cited by Hansen, 1952); the mass that compressed the spinal cord was described as a '*chondroma located only to the epidural space*'. Shortly afterwards, in 1896, a more comprehensive study was published on 'enchondrosis intervertebralis' (Dexler, 1896, cited by Hansen, 1952), a reactive inflammation in the epidural space, but it would take another 40 years before that disease was correctly described in the veterinary literature as the herniation of NP material into the spinal canal, causing compression of the spinal cord (Tillmanns, 1939).

Pioneering studies of IVD degeneration in dogs were performed during the 1950s by the Swedish veterinarians Hansen and Olsson, in particular the study that led to the thesis by Hans-Jörgen Hansen in 1952 (Fig. 2) (Hansen, 1951, 1952, 1959; Olsson, 1951; Olsson and Hansen, 1952). Since their studies, numerous publications have described the clinical aspects of IVD degenerative diseases, but few have revisited the fundamental aspects of IVD degeneration (Braund et al., 1975, 1976; Ghosh et al., 1975, 1976a,b, 1977a,b; Cole et al., 1985, 1986; Gillett et al., 1988; Royal et al., 2009; Johnson et al., 2010). The aim of this two-part review was to summarize current literature on canine IVD degeneration. In this first part, the anatomy, physiology, histopathology, and biochemical and biomechanical characteristics of the healthy and degenerated IVD are described. In Part 2, aspects of IVD degeneration in chondrodystrophic and non-chondrodystrophic dog breeds are discussed (Smolders et al., 2013).

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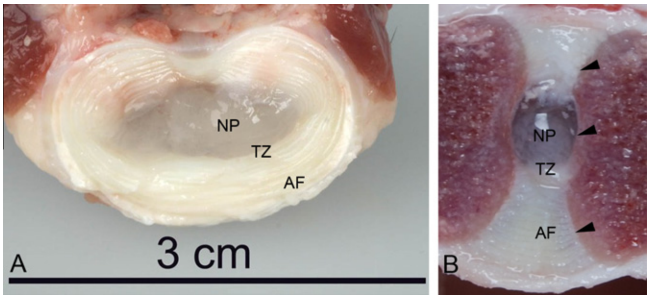


Fig. 1. Transverse (A) and sagittal (B) sections through a L5–L6 intervertebral disc of a mature non-chondrodystrophic dog, showing the nucleus pulposus (NP), transition zone (TZ), annulus fibrosus (AF), and endplates (arrowheads).

Embryology of the canine spine and intervertebral disc (IVD)

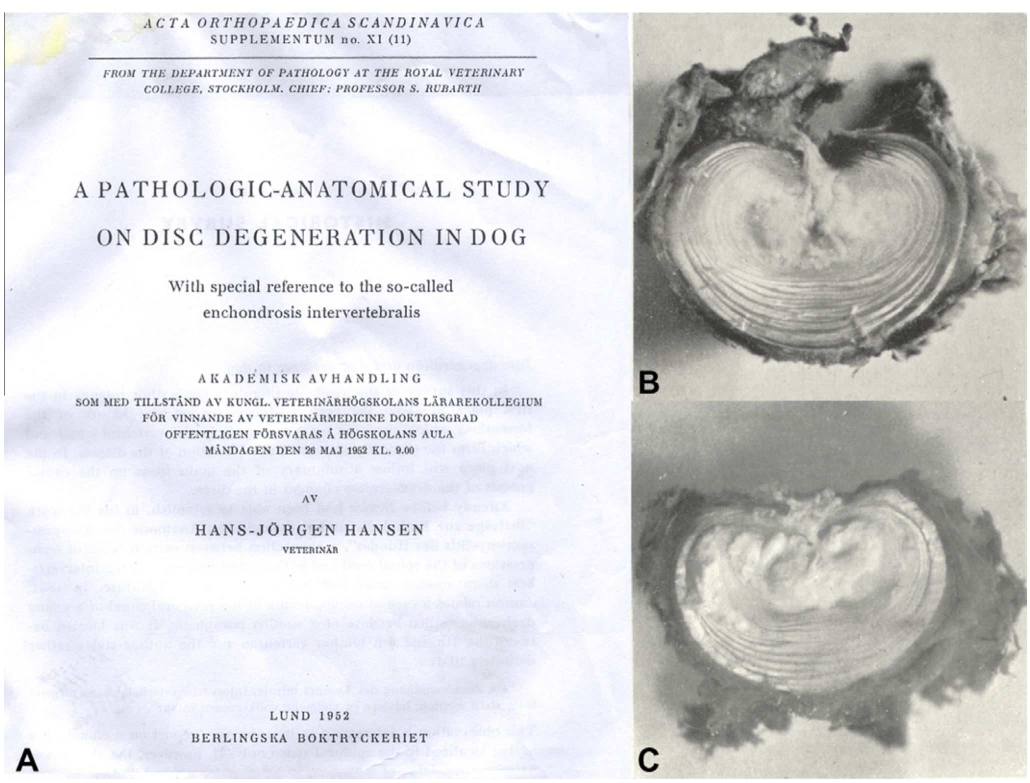
Three somatic germ layers are formed early in mammalian embryogenesis: an outer ectodermal layer, a middle mesodermal layer, and an inner endodermal layer (Vejlsted, 2010). A longitudinal column of mesoderm, the notochord, establishes the cranial/caudal and posterior/anterior axes of the developing embryo (Fig. 3) (Vejlsted, 2010). Ectoderm directly posterior to the notochord gives rise to the neural plate, which is composed of so-called neuroectoderm. The neural tube and neural crest cells (positioned dorsolateral to the neural tube) are formed from the neuroectoderm and give rise to the central nervous system and peripheral nervous system, respectively (Vejlsted, 2010).

During the development of the neural tube, mesoderm adjacent to the developing neural tube forms a thickened column of cells, the paraxial mesoderm. The paraxial mesoderm ultimately develops into discrete blocks, the somites, which form the axial skeleton, the associated musculature, and the overlying dermis. Each somite is divided into: (1) a dermatome, which gives rise to dermis; (2) a myotome, which gives rise to epaxial musculature; and (3) a sclerotome, which gives rise to vertebral structures (Vejlsted, 2010). Sclerotomal cells form a continuous tube of mesenchymal cells, the perichordal tube, which completely surrounds the notochord. An alternating series of dense and less dense accumulations of cells form along the perichordal tube, a process called resegmentation (Sinowatz, 2010). While the bodies of the vertebrae develop from the less dense accumulations, the dense accumulations form the AF and TZ of the IVD, intervertebral ligaments, vertebral arches, and vertebral processes, of which the latter two eventually fuse with their corresponding vertebral body (Sinowatz, 2010). The formation of the vertebral bodies results in segmentation of the notochord, which persists as separate portions in each intervertebral space. These separate portions of notochord expand, forming the NP of the individual IVDs (Sinowatz, 2010; McCann et al., 2011).

The healthy canine intervertebral disc

Anatomy and physiology of the intervertebral disc

The healthy IVD is composed of four distinct components, namely, the NP, AF, EP and TZ. The NP is a mucoid, translucent, bean-shaped structure, mainly composed of water, located slightly



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FROM THE DEPARTMENT OF PATHOLOGY AT THE ROYAL VETERINARY COLLEGE, STOCKHOLM. CHIEF: PROFESSOR S. RUBARTH

A PATHOLOGIC-ANATOMICAL STUDY ON DISC DEGENERATION IN DOG

With special reference to the so-called enchondrosis intervertebralis

AKADEMISK AVHANDLING

SOM MED TILLSTÅND AV KUNGL. VETERINÄRHÖGSKOLANS LÄRAREKOLLEGIUM FÖR VINNANDE AV VETERINÄRMEDICINE DOKTORSGRAD OFFENTLIGEN FÖRSVARAS Å HÖGSKOLANS AULA MÅNDAGEN DEN 26 MAJ 1952 KL. 9.00

AV

HANS-JÖRGEN HANSEN
VETERINÄR

LUND 1952
BERLINGSKA BOKTRYCKERIET

Fig. 2. (A) Title page of the thesis written by Hans-Jörgen Hansen in 1952, providing the first clear description of intervertebral disc degeneration and herniation in dogs, and the distinction between chondrodystrophic and non-chondrodystrophic breeds with regard to this process (discussed in Smolders et al. (2013)). (B) Reproduction from Hansen's thesis (1952). The original figure legend reads as follows: 'Dachshund, 6 years old. Disc 21 (L2–L3). Protrusion of type I. the picture shows the large dimensions of the protrusion and demonstrates clearly its origin from nucleus. The annulus fibrosus rupture is situated close to the right side of the dorsal longitudinal ligament. Nucleus is the site of a calcified necrosis and has lost its normal shape'. (C) Reproduction from Hansen's thesis (1952). The original figure legend reads as follows: 'Dachshund, 4 years old. Disc 22 (L3–L4) with a calcified centre and a dorsomedian rupture of the a.f. the protrusion is of type I with loose consistency and rough, uneven surface. An interlamellar dissection of calcified material is seen to the left o nucleus, emanating from a ventral rupture of the inner layer of the a.f. this rupture, however, is not seen in this picture' (a.f., annulus fibrosus).